Children's Attentional Skills 5 Years Post-TBI

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Objective While a small number of research papers have reported findings on attentional deficits following pediatric traumatic brain injury (TBI), no study to date has reported findings in this area at 5 years post-TBI in very young children. This study examined attentional skills in a group of children who had sustained a mild, moderate, or severe TBI between the ages of 2 and 7 years. **Methods** The sample comprised 70 children, 54 of these had sustained a TBI and 16 the non-injured control group. Children were assessed 5 years post-TBI, with focus on tests of attentional ability. **Results** Attentional and processing speed (PS) deficits do occur and persist up to 5 years post-TBI, particularly following severe TBI in early childhood. Predictors of attentional outcomes varied depending on the component of attention investigated. **Conclusions** Those skills developing or emerging at time of injury (e.g., sustained attention, shifting attention, divided attention, PS) are more compromised and may not develop at a normal rate of post-injury.

Key words attention; children; traumatic brain injury.

Introduction

Owing to the immaturity of the central nervous system (CNS), researchers have proposed poor outcome in attentional and speed of processing skills in pediatric samples following traumatic brain injury (TBI), both acutely and long-term (Anderson & Moore, 1995; Anderson & Pentland, 1998; Catroppa & Anderson, 1999, 2003a; Catroppa, Anderson, & Stargatt, 1999; Dennis, Wilkinson, Koski, & Humphreys, 1995; Ewing-Cobbs, Miner, Fletcher, & Levin, 1989; Kaufmann, Fletcher, Levin, Miner, & Ewing-Cobbs et al., 1993). From a developmental perspective, injury at an early age may impact on cognitive skills that are developing at the time of injury, and on those skills that are yet to develop or reach maturity, but are dependant on an intact nervous system to do so most efficiently (Anderson & Moore, 1995; Dennis, 1989; Dennis et al., 1995; Ewing-Cobbs et al., 1989; Gronwall, Wrightson, & McGinn et al., 1997).

It has been proposed that attention is not a unitary process but an integrated system both cognitively and physiologically (Cooley & Morris, 1990; Halperin, 1991; Mirsky, Anthony, Duncan, Ahearn, & Kellam, 1991; van Zomeron & Brouwer, 1994) involving a number of separate, though not independent components. Although there is ongoing debate, current neuroscience models identify several components of the attentional system: (a) sustained attention, or vigilance, refers to the capacity to maintain arousal and alertness over time; (b) selective attention is the ability to select target information while ignoring irrelevant stimuli and to differentially process simultaneous sources of information; (c) shifting attention involves the ability to change attentive focus in a flexible and adaptive manner; (d) divided attention refers to the ability to divide one's attention between two or more competing sources of information; (e) attentional control which includes the ability to inhibit responses; and (f)

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speed of processing which refers to the rate at which activities may be completed and so is often considered to underpin the efficiency of the system. These skills are thought to be subserved by a diffuse cerebral system, with brain regions attributed to specific skills unclear following childhood injuries in comparison with adult brain injuries (Anderson, 2002; Mirsky et al., 1991; Posner & Petersen, 1990; Stuss, Shallice, Alexander, & Picton, 1995).

While attentional and processing deficits following adult TBI are reasonably well documented, this is not the case following pediatric TBI (Anderson & Moore, 1995; Catroppa & Anderson, 2003a). In the mature brain, the attentional system is thought to be subsumed by a number of cerebral areas, vulnerable to TBI, including the brainstem, midbrain structures, temporal, parietal, and frontal regions (Mirsky et al., 1991; Stuss et al., 1995). It is argued that each area is related to a specific attentional component, suggesting damage or dysfunction to any one of these regions can lead to specific deficits in attentional ability. In the pediatric population where the CNS is in a rapid state of growth, developmental factors may mask such difficulties, as delays or deficits in certain skills may not be evident until that skill is expected to emerge at a certain age, perhaps not until the child has reached upper primary or secondary school levels, leading to cumulative deficits over time (Dennis et al., 1995).

Research investigating attentional and processing skills in young children is scarce, and of that available, only a few researchers have considered developmental implications (Anderson, 2002; Anderson, Anderson, Northam, Jacobs, Catroppa, 2001; Betts, McKay, Maruff & Anderson, in press; Kail, 1986; Manly, Anderson, Robertson, & Nimmo-Smith, 1999; McKay, Halperin, Schwartz, & Sharma, 1994; Rebok et al., 1997). Dennis and associates (1995) found that children and adolescents with a history of head injury performed poorly on both measures of vigilance and selective attention. Alternatively,Timmermans and Christenson (1991) investigated 38 children with a history of TBI, aged 5–16 years, and found evidence for impairments in sustaining attention, with selective attention skills intact. Using a continuous performance task (CPT), Kaufmann et al (1993) also reported significant difficulties sustaining attention when examining 36 children, aged 7–16 years, at 6 months post-TBI. However, while adding to the current knowledge base regarding attentional skills following TBI, developmental aspects were not the focus of the above mentioned studies.

Catroppa and Anderson (2005) investigated the recovery of attentional skills at 2 years post-TBI in a group of children who had sustained their injury between the age of 8 and 12 years. Children who had sustained moderate–severe TBI were found to have difficulties on measures of sustained attention and shifting attention, particularly on more complex tasks, with psychomotor slowness also apparent. Although the severe TBI group showed steepest recovery over time, they often did not perform at the same level as those who had sustained mild or moderate injuries, even 2 years after insult. It was suggested that the widespread difficulties noted may reflect the immature nature of the CNS at time of injury, where attentional skills not yet fully developed may be more vulnerable and less likely to develop normally following TBI.

Investigating a younger sample, Anderson, Catroppa, Morse, Haritou, & Rosenfeld (2005) studied attentional and processing skills at 30 months following TBI between the ages of 2 and 7 years. The main attentional measure used was a CPT task of 6 min duration. After ensuring that the child recognized the target letter, the child was required to press a "yes" button on the keyboard when the letter was flashed and a "no" button for all other stimuli. Results indicated that young children who sustained severe TBI presented with reduced response accuracy, impaired response inhibition, and slowed processing. While a sustained attention deficit was not found, the importance of reviewing this group of children was stressed, as sustained attention shows a developmental spurt at an older age (Betts et al., in press; Manly et al., 1999; McKay et al., 1994), and it is then that such a deficit may become obvious.

Other researchers investigating sustained attention have extended the CPT paradigm. Rather than analyzing end scores alone, tasks were divided into sequential blocks to study performance decrements over time (Anderson & Pentland, 1998; Catroppa & Anderson, 1999, 2003a), likely to be characteristic of impairments in sustained attention (van Zomeron & Brouwer, 1994). Even when using this approach, results were inconsistent, perhaps because of differences in age at injury, for example, Anderson and Pentland (1998) identified impaired speed of processing, with intact sustained attention in an adolescent group. Catroppa and Anderson (2003a) reported, in a younger sample of TBI participants, that when using a sustained attention task of graded difficulty, the more complex tasks requiring speed, accuracy, and decision-making differentiated best between the mild and severe TBI groups. While it is difficult to draw firm conclusions, there was a strong suggestion that the developmental level of the child and the level of mastery of a particular skill at the time of injury, were associated with performance on given tasks.

While injury severity has been considered the key factor for predicting outcome following pediatric TBI

(Anderson & Moore, 1995; Anderson, 2006; Yeates et al., 2002), it fails to fully account for the variability seen in children following TBI. Glasgow coma scale scores (GCS) (Goldstein & Levin, 1992; Hsiang, Yeung, Yu, & Poon, 1997; Levin, Goldstein, High, & Eisenberg, 1988), length of post-traumatic amnesia (PTA) (Gronwall & Wrightson, 1981; Ruijs, Gabreels, & Keyser, 1993), and radiological results including both computed tomography (CT) and magnetic resonance imaging (MRI) (Levin et al., 1993; Ruijs, Gabreels, & Thijssen, 1994; Stein & Spettell, 1995) have been found to be predictive of cognitive outcomes and recovery following TBI. Other factors have also shown to be useful in explaining some of the observed variability in outcome. Pre-morbid levels of functioning and pre- and post-family functioning have also been found, with some consistency, to influence the level of recovery of a child. Researchers have reported poorer outcomes in association with pre-morbid academic problems, impulsivity and distractibility (Haas, Cope, & Hall, 1987), pre-morbid character disturbances (Cattelani, Lombardi, Brianti, & Mazzucchi, 1998), pre-injury psychiatric disorder (Brown, Chadwick, Shaffer, Rutter, & Traub, 1981), and families with little cohesiveness and poor family relationships (Anderson et al., 2006; Max et al., 1998; Rivara et al., 1993, 1994; Taylor et al., 1999; Yeates et al., 1997).

The aim of this study was to investigate residual attention and speed of processing difficulties at 5 years post-TBI and to determine whether any identified attentional deficits were of a generalized nature or were specific to a particular aspect of attention. The study employed the Test of Everyday Attention for Children (TEA-Ch) (Manly et al., 1999), an assessment tool specifically adapted for use with children and designed to separate specific components of attention and speed of processing. It was predicted that more severe TBI would be associated with generalized attention and information processing deficits at 5 years post-TBI. Taking into account a developmental perspective (Anderson et al., 2001; Kail, 1986; McKay et al., 1994; Manly et al., 1999; Rebok et al., 1997), it was expected that early established attentional skills (e.g., selective attention) which were more consolidated at time of injury would be less vulnerable and thus less impaired. In contrast, those skills not yet mastered at time of injury [sustained attention, shifting attention, divided attention, and processing speed (PS)], some of which are thought to be subserved by anterior brain regions, due to the early age of injury in the current sample, would be characterized by impairment, reflecting the interaction between injury characteristics and ongoing development. Additionally, it was expected that injury variables (GCS, localization of lesion), social/environmental factors (SES), general intelligence during the acute stage [full scale IQ (FSIQ)], developmental factors (age at acute assessment), and pre-injury abilities [Vineland Adaptive Behavior Scale (VABS)] would each contribute to level of recovery and outcome at 5 years post-TBI.

Method

Participants

During the recruitment period, 109 children were admitted to the Royal Children's Hospital, Melbourne, Australia, with a diagnosis of TBI. Seven were ineligible for the study because of pre-existing developmental, behavioral, or neurological problems (*n* = 2), previous head injury (*n* = 1), or had sustained injury due to abuse (*n* = 4). One child had sustained such severe injuries that he was unable to participate in the assessment at any time point. Initial approaches were made to 101 children, and families, with 17 declining to participate. Reasons for refusal included inconvenience of time requirements (*n* = 6), residing outside the state (*n* = 6), and lack of interest in the study (*n* = 5). A further 30 children were either unable to be located or were not interested in further involvement in the study at the 5 year follow-up time point. Comparison of the demographic and injury characteristics of participating and non-participating groups identified no significant group differences.

Seventy children participated in the 5-year follow-up. Fifty-four of the children had a diagnosis of closed head injury and had been originally recruited from consecutive admissions to the neurosurgical ward of the Royal Children's Hospital, Melbourne, between June 1993 and June 1997, immediately following their injury. Inclusion criteria were as follows: (a) age at injury 2.0–7.0 years; (b) documented evidence of TBI, including period of altered consciousness; (c) medical records sufficiently detailed to determine severity of injury; (d) able to complete study protocol; (e) completed 5-year evaluations; and (f) English speaking. Exclusion criteria were as follows: (a) head injury as a result of child abuse; (b) penetrating head injury; (c) documented history of previous closed head injury; (d) evidence of pre-existing physical, neurological, psychiatric, or developmental disorder.

The remaining 16 children comprised the non-injured control group. These children were identified 5 years earlier through preschools and childcare centers, during the initial stage of the study, to match the TBI group as closely as possible with respect to age, gender,

Table I. Demographic Information

	Mild TBI	Moderate TBI	Severe TBI	Control
Number of subjects	12	24	18	16
Gender (number of males)	6	17	12	9
Injury age *M* (*SD*)	4.3 (1.5)	4.8 (1.8)	4.6 (2.1)	–
Age at acute assessment *M* (*SD*)	4.7 (1.3)	5.0 (1.8)	4.8 (2.1)	4.7 (1.7)
Age at 5 years post-TBI *M* (*SD*)	9.6 (1.4)	10.4 (2.0)	9.8 (2.3)	10.1 (1.9)
Socio-economic status (Daniel, 1983)				
Pre-injury *M* (*SD*)	3.8 (0.9)	4.1 (0.8)	4.3 (0.9)	3.6 (0.9)
Five years post-TBI *M* (*SD*)a,b,c,d*	3.4 (0.8)	4.2 (0.8)	4.2 (0.8)	3.2 (0.7)
Number of intact families *n* (%)	11 (92)	20 (83)	12 (67)	15 (94)
VABS: pre-injury *M* (*SD*)	109.8 (14.3)	111.4 (15.4)	106.1 (16.6)	112.4 (18.9)

TBI, traumatic brain injury; VABS, Vineland Adaptive Behaviour Scale.

[a] Significant difference between mild and severe TBI groups.

[b] Significant difference between mild and moderate TBI groups.

[c] Significant difference between control and severe TBI groups.

[d] Significant difference between control and moderate TBI groups.

*$p < .001$.

Table II. Injury and Medical Characteristics

	Mild TBI (*n* = 12)	Moderate TBI (*n* = 24)	Severe TBI (*n* = 18)
Cause of injury			
Passenger [*n* (%)]	1 (8)	5 (21)	6 (33)
Pedestrian [*n* (%)]	–	4 (17)	7 (39)
Falls [*n* (%)]	10 (83)	13 (54)	3 (17)
Blows [*n* (%)]	1 (8)	2 (8)	2 (11)
Medical characteristics			
Abnormal CT [*n* (%)]	–	17 (71)	16 (89)
Coma (>1 hr) [*n* (%)]	–	8 (33)	18 (100)
Skull Fracture [*n* (%)]	4 (33 : linear)	11 (46)	11 (61)
Neurological signs [*n* (%)]	–	8 (33)	15 (83)
Surgical intervention [*n* (%)]	–	9 (38)	12 (67)
GCS on admission *M* (*SD*)a*	14.2 (1.3)	10.1 (3.6)	4.7 (1.7)
Frontal [*n* (%)]	1 (8)b	1 (4)	7 (39)
Extrafrontal [*n* (%)]	–	1 (4)	2 (11)
Diffuse [*n* (%)]	–	7 (29)	5 (28)

TBI, traumatic brain injury.

[a] Significant difference between all TBI groups.

[b] Scan indicates a cerebro-vascular event.

*$p < .01$.

SES, and pre-injury characteristics. These children have been reviewed, along with children with TBI, at all time points through the study. Inclusion criteria (a), (d), (e), and (f) and exclusion criteria (c) and (d), described above, also applied to this group. There were no statistical differences across TBI and control groups with respect to age at injury, age at 5-year assessment, gender, initial SES, pre-injury adaptive abilities, or family structure. There were significant group differences in SES at the 5-year assessment stage (Table I).

Children with TBI were divided into severity groups as follows: (a) mild TBI (*n* = 12): GCS on admission 13–15 (glasgow coma score; Teasdale & Jennett, 1974), indicating some alteration of conscious level (e.g., drowsiness, disorientation), with no evidence of mass lesion on CT/MRI, and no neurologic deficits; (a) moderate TBI (*n* = 24): GCS on admission 9–12, indicating significantly altered consciousness, with reduced responsiveness; and/or mass lesion or other evidence of specific injury on CT/MRI and/or neurological impairment; and (c) severe TBI (*n* = 18): GCS on admission 3–8, representing coma and mass lesion or other evidence of specific injury on CT/MRI, and/or neurological impairment. No child was on medication at this time point post-injury. Implementation of this categorization procedure for severity successfully classified most children with TBI, however, where categorization was not clear, further information from the child's medical file (e.g., presence of neurological signs) was taken into account.

GCS scores (on admission) were recorded by the admitting medical officer. Following admission, half-hourly neurosurgical observations were recorded by nursing staff on the neurosurgical ward, and these gradually increased to 4-hourly observations, with recordings continuing until the child had regained consciousness. CT/MRI scans were reported by a pediatric neuroradiologist and neurosurgeon, with classification of pathology (frontal, extrafrontal, and diffuse) conducted on the basis of radiological reports. As can be seen in Table II, most injuries for the mild TBI group occurred as a result of falls (>3 m), with motor car accidents (either passenger or pedestrian) more common in the severe TBI group. Other medical indices were as expected, with more significant injury indicated for the severe TBI group.

Measures

Parent Questionnaires (Pre-Injury)

Families agreeing to participate were required to complete the following questionnaires.

Injury and Demographic Variables. Data were collected on each child's medical and developmental history, parental education and occupation, and family constellation. During in-patient stay, medical records were reviewed daily, and GCS, length of coma, neurological abnormalities, and surgical interventions were recorded. SES was coded using Daniel's Scale of Occupational Prestige (1983) which rates parent occupation on a 7-point scale, where a high score represents low SES.

Adaptive Functioning. The VABS (Sparrow, Bella, & Cicchetti, 1984) was completed by parents on enrolment to the study, based on pre-injury child function, and again at 6 and 30 months and 5 years post-injury. This scale has a questionnaire format, which provides information on a child's level of adaptive function in the following domains: communication, daily living skills, and socialization. A total adaptive behavior score (VABS : TOT) was also derived. For each of these areas, standard scores were calculated (M = 100; SD = 15), as well as percentage impaired at 5 years post-injury, that is, those scoring more than 1 *SD* below the mean (Fig. 1). Pre-injury and 5 year total adaptive scores were used in analyses (Table III).

Behavioral Functioning. The revised format version of the Personality Inventory for Children (PIC; Lachar, 1992) was employed, which included 131 items for which parents respond either true or false. Parents completed this questionnaire based on their child's pre-injury functioning, and again at 6 and 30 months post-injury and again at 5 years. Four factors are derived from the scale: Factor I, undisciplined/poor self-control; Factor II, social incompetence; Factor III, internalization/somatic symptoms; and Factor IV, cognitive development. Factor scores have a mean of 50 and standard deviation of 10 points, with a higher score indicating greater behavioral disturbance, and scores of 70 or more considered to represent behavioral difficulties of clinical significance. Factor 1 comprises items describing undisciplined behavior and poor self-control (e.g., my child cannot sit still) and was used as an estimate of pre-injury attentional behavior, with pre-injury Factor 1 scores used in analyses.

Child Evaluations—Five Years

Initial evaluation for each child occurred within the first 3 months after injury, as soon as the child was able to participate in test procedures. Follow-up evaluations were conducted at 12 and 30 months and 5 years post-injury. For the purposes of this manuscript 5-year data were examined.

Intellectual Abilities

The Wechsler Intelligence Scale for Children–Third Edition (WISC-111; Wechsler, 1991) was administered. FSIQ and index scores such as freedom from distractability (FFD) and PS were used in analyses. These scores are standardized tests with a mean of 100 and a standard deviation of 15. Percentage impaired for FSIQ was also calculated at 5 years post-TBI (Table IV and Fig. 1)

Attentional abilities

Attentional abilities were investigated using the TEA-Ch (Manly et al., 1999). The specific subtests employed in this study and the aspects of attention assessed are described below:

Sustained Attention

Code Transmission. The code transmission (CT) subtest is an auditory vigilance-level measure. The children are asked to monitor a stream of monotonous digits (presented at a rate of one every 2 s) for the occurrence of a particular target sequence (e.g., 5, 5) and then to report the digit that occurred immediately before. Following a practice sequence to ensure comprehension, 40 targets were presented over the 12 min of the task. Total correct and total number of errors were employed in analyses.

Score! The Score! (Sc) subtest is a 10-item tone counting measure. In each item, between 9 and 15 identical tones are presented, separated by silent inter-stimulus intervals of variable duration (between 500 and 5000 msec). Children were asked to silently count the tones (without assistance from fingers) and to give the total at the end—as if they are "keeping the score by counting the scoring sounds in a computer game." If a child was unable to count to 15 or were unable to pass two practice trials (with relatively few tones) the test was not given. The requirement to pass practice items as a way of ensuring task comprehension, checking on possible sensory problems, and improving the reliability of the measures was a feature of each of the tasks. The total number of items in which tones were correctly counted was employed in analyses.

Selective Attention/Speed of Processing

Sky Search. In this measure, children were given a laminated sheet depicting rows of space-craft and instructed to find all targets, indicated by two of the same ships within a pair as quickly as possible. Children were instructed to mark a box in the lower right corner when they felt that they had identified all targets. Before commencing the test trial, children first completed a practice trial. To control for differences that are attributable to motor speed rather than visual selection, the children then completed a motor control version of the task, identical to that of the sky search (SS) test with the exception that all of the distracter items were removed. For each part of the test, total number correct and total time taken were employed in analyses.

Shifting Attention/Inhibitory Control

Opposite Worlds. In this task, the children were presented with a stimulus sheet showing a mixed, quasi-random array of the digits 1 and 2. In the "same world" condition, they were asked to read out the digits as quickly as possible in the conventional manner. In the opposite world (OW) condition, they were asked to say the opposite for each digit ("1" for 2 and "2" for 1) as quickly as possible. Each digit in turn was indicated by the examiner who remained on that digit until a correct response was given. This in effect turned errors into time penalties. Following a practice, two of each condition were run in the order; same, opposite, opposite, same. The time taken to complete each condition was recorded.

Divided Attention

Score Dual Task. The score dual task (score DT) measure was designed to measure divided attention within the auditory–verbal domain. The child is asked to listen to a tape and to count a series of tones while listening to a news broadcast. The tone counting aspect of the task required children to silently count a series of tones (without assistance from fingers), separated by silent inter-stimulus intervals of variable duration (between 500 and 5000 msec), and to give the total at the end. In addition, meaningful, auditory speech—in the form of news bulletins—was simultaneously presented. Children were asked to keep a count of the tones whilst at the same time keeping "an ear out" for the mention of an animal during the news broadcast. Two practice items were given before the 10 items of the test. Scores used in analyses included number of tones correct, number of animals correctly identified, and a score combining accuracy for both measures, that is, where the number of tones and the animal were correct in the same trial.

Procedure

Children were enrolled in the study during their initial hospital admission. Families were given a detailed description of the study and asked to provide written consent, in keeping with hospital ethics procedures. Once they had agreed to participate, parents were requested to complete the demographic questionnaire and the VABS, based on child's pre-injury abilities, and then again during the 5 year review, based on current function at the 5 year assessment.

While Children were Evaluated at Four Data Points

Acute (0–3 months post-injury), 12 months and 30 months and 5 years post-injury for the IQ measure, for the purposes of this study the main focus is on performance at the 5-year assessment, when detailed attentional asessment was conducted. Each assessment occurred over two 1-hr sessions to ensure optimal performance in this age group. Assessments were conducted on an individual basis, by a qualified child psychologist, with IQ measures administered in the first session and attentional measures in the second session. Order of test presentation was fixed within each session.

Statistical Analysis

Initially the four groups (mild, moderate, severe TBI, and controls) were compared on demographic, pre-injury, and psychosocial measures to identify any differences across groups that might influence post-injury performance. Multivariate analysis of covariance (MANCOVA) was then conducted, covarying for SES at the 5-year stage, to examine the association between injury severity and attentional measures at 5 years post-injury. Separate analyses were conducted for each attentional domain. Effect size (ES : Cohen's *d*) was also calculated when statistically significant results were perhaps not obtained because of the small sample size, for measures in the attentional domain. In accordance with Tabachnick & Fidell (2000), an ES of 0.50 was classified as moderate and an ES of 0.67 as "clinically" significant. ESs were only reported where moderate or clinically significant differences were identified.

Hierarchical regression was performed to investigate predictors of outcome at 5 years post-injury. Correlations among independent variables were initially calculated to identify multicollinearity. Not unexpectedly, given the design of the study, age at injury and age at testing correlated highly ($r = 0.93$, $p < .001$). As a result, variables used in these analyses were injury variables (severity and localization of lesion), SES (at acute stage), acute child function (FIQ), developmental factor (age at acute assessment), and pre-injury abilities (VABS : TOT, PIC-Factor 1). The block function was utilized where age at acute assessment and pre-injury PIC-Factor 1 were entered in the first block and then all predictor variables were entered in block 2.

Results

Demographic, Pre-Injury, and Medical Information

Statistical analysis indicated no group differences on demographic variables or on pre-injury adaptive measures, suggesting that any differences between the groups could not be explained in terms of these variables. While no significant difference was evident for SES at the acute stage post-injury, $F(3,69) = 2.65$, $p = .06$, there was a significant difference at 5 years post-injury, $F(3,69) = 7.43$, $p < .001$ (Tables I and II), with an indication of higher SES for both mild and control groups retained at 5 years.

Intellectual Performance and Adaptive Functioning Measures

Table III provides results for the intellectual and adaptive measures 5 years post-injury. MANCOVA revealed a significant difference between the TBI groups for FSIQ, $F(3,65) = 6.17$, $p < .01$. Post hoc analyses indicated a significant difference between the severe TBI group and the mild ($p = .03$), moderate ($p = .02$), and control ($p < .01$) groups. These results were also reflected in the significantly higher number of participants with severe TBI performing more than 1 *SD* below the mean (Fig. 1). In general, results for intellectual measures revealed a dose-response pattern, with the severe TBI group performing the poorest and the control group the best. Similar analyses were undertaken for the FFD and PS factors from the WISC-111. While significant results were not evident for FFD, $F(3,65) = 1.81$, $p = .15$, PS was significantly different across the groups $F(3,65) = 5.21$, $p < 0.01$, with post hoc analysis indicating the difference to be between severe TBI and control participants ($p < 0.01$) and suggesting that the skills required in these tasks, such as selective attention, working memory, speed of output, and decision-making, differentiate between the groups.

With regards to the adaptive measure (VABS), repeated measures MANCOVA (covarying for SES) was conducted. Results indicated no significant main effect of group, $F(3,65) = 1.66$, $p = 0.19$, and no interaction effect, $F(3, 65) = 2.11$, $p = 0.11$, but a significant effect of time, $F(1, 65) = 4.47$, $p = .04$. As can be seen in Table III, parental observations suggest that TBI groups performed more poorly over time, with the control group's adaptive abilities remaining stable. The severe TBI group showed the most decline in adaptive skills from pre-injury to 5-years post-injury (mean = 12 points). These results indicate that parents of these children were reporting a lack of expected development in a number of adaptive function areas. Furthermore, when analysing the 5-year VABS data in isolation, results indicate a significant effect of group, $F(3,64) = 4.26$, $p = .01$, with the largest difference between the severe TBI and control groups (16.8 points). As with FSIQ, there was a significant difference between groups in the number scoring more than 1 *SD* below the mean (Fig. 1).

Attentional Measures

Sustained Attention. MANCOVA was conducted at 5 years post-injury to examine the number of total correct

Table III. Cognitive and Adaptive measures 5 Years Post-TBI

	Mild TBI	Moderate TBI	Severe TBI	Control
Cognitive measures				
FSIQ *M* (*SD*)a,b,c,*	106.4 (16.7)	100.0 (14.9)	84.5 (20.0)	114.1 (17.0)
VIQ *M* (*SD*)a**	101.3 (14.5)	95.9 (13.3)	84.8 (17.2)	109.0 (20.2)
PIQ *M* (*SD*)a,b,c*	111.3 (22.0)	105.5 (17.3)	88.4 (22.1)	117.8 (13.1)
FFD *M* (*SD*)	104.8 (15.1)	97.8 (17.0)	91.3 (16.1)	111.4 (19.2)
PS *M* (*SD*)a*	101.8 (15.7)	99.8 (15.1)	86.9 (21.2)	113.5 (11.4)
Adaptive measures				
VABS total***				
Pre-injury *M* (*SD*)	109.8 (14.3)	111.4 (15.4)	106.1 (16.6)	112.4 (18.9)
5 years post-TBI *M* (*SD*)	101.9 (7.6)	99.7 (11.6)	94.1 (14.1)	110.9 (10.3)

FFD, freedom from distractability; FSIQ, full scale IQ; TBI, traumatic brain injury; VABS, Vineland Adaptive Behaviour Scale.

[a]Significant difference between severe and control groups.

[b]Significant difference between severe and moderate TBI groups.

[c]Significant difference between severe and mild TBI groups.

*$p < .01$. **$p < .05$. ***Significant effect of time, $p < .05$.

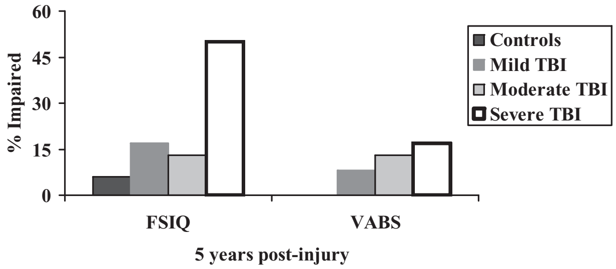

Figure 1. Intellectual and adaptive functioning.

responses and total number of errors on the codes transmission task. Analysis revealed no significant difference between the groups for either outcome variables, $F(3,65) = 1.33$, $p = .27$ and $F(3,65) = 1.48$, $p = 0.23$, respectively. Visual inspection of the group means revealed a trend where controls performed best, with more correct responses and least errors, and the severe TBI group presented with most errors (Table IV). For total correct responses "clinically" significant ESs were identified between mild TBI group and controls (ES = 1.1), moderate TBI group and controls (ES = 0.9), and severe TBI group and controls (ES = 1.7). For number of errors, a moderate ES was evident between mild TBI and control groups (ES = 0.6) and moderate TBI and control groups (ES = 0.6), with a "clinically" significant ES seen between severe TBI and control groups (ES = 0.9).

Similar outcome was evident for the Score! task for total number of correct responses. MANCOVA revealed no statistically significant results, $F(3,65) = 1.10$, $p = 0.36$. Again, as suggested above, a dose-response relationship was evident on visual inspection of the data (Table IV), where the control group achieved the highest score and the severe group the lowest score. "Clinically" significant ESs were evident between the severe TBI and control groups (ES = 0.9) and the severe and mild TBI groups (ES = 0.9).

Selective Attention/PS. Selective attention was measured through the SS task with regards to total number correct, $F(3,65) = 1.52$, $p = .22$, and total time taken, $F(3,65) = 2.06$, $p = 0.12$, with results indicating no significant difference between the groups on these measures. For number correct, moderate ESs were obtained between the mild (ES = 0.5) and moderate TBI (ES = 0.6) and control groups, as well as between the moderate and severe TBI groups (ES = 0.5). "Clinically" significant ESs were evident between the severe TBI and control group (ES = 1.8) and the mild and severe TBI groups (ES = 1.2). With regard to time taken, a moderate ES was evident between moderate and severe TBI groups (ES = 0.6). A motor control component was also undertaken and investigated in terms of total number correct and total time taken. For these outcome variables, while there was no significant difference between groups for the total number correct, $F(3,65) = 1.49$, $p = .23$, there was a significant difference for the speed component, $F(3,65) = 5.84$, $p < .01$. These results suggest that on this relatively simple task of motor control, the severe TBI group took significantly more time to complete the task in comparison to the mild ($p = .03$), moderate ($p = .01$), and control ($p < .01$) groups.

Shift/Inhibitory Control. The OWs task was used to measure the shift/inhibitory control components of attention (Table IV). As results in each section of this task yielded a similar pattern, only the same world total time taken, OW total time taken, and OW total minus the same world Total will be discussed. With regards to the same world total time taken, MANCOVA revealed a significant difference between the groups, $F(3,65) = 4.74$, $p = 0.01$. Similarly, for OW total time taken, a significant difference was again evident between the groups, $F(3,65) = 3.62$, $p = .02$. Post hoc analysis indicated the differences to be between the moderate and severe for same world ($p = .01$) and control and severe ($p = .01$, $p = .02$) groups for Same and OW. When investigating the OW Total minus the same world Total, MANCOVA did not reveal a significant difference between the groups, $F(3,65) = 0.46$, $p = 0.71$. Again, in general, these results represent the control group as working most efficiently and the severe TBI group poorest.

Divided Attention. The score DT task was analyzed with regards to total animals correct, total numbers correct, and total correct. MANCOVA revealed nonsignificant results for total animals correct, $F(3,65) = 2.49$, $p = 0.07$, and total numbers correct, $F(3,65) = 1.51$, $p = 0.22$. Significant results were evident for total correct, $F(3,65) = 2.78$, $p = 0.05$, with an almost significant difference between the severe and control groups ($p = 0.06$). These results (Table IV) suggest that when it was necessary to obtain a correct score for both animals and number in the same trial, then the severe TBI group performed below the other groups.

Predictors of Attentional Measures. As mentioned previously, variables used in these analyses were injury variables (GCS, localization of lesion), SES, acute child function (FIQ), developmental factor (age at acute assessment), and pre-injury abilities (VABS, PIC-Factor 1). Block 1 included age at acute assessment and pre-injury PIC-Factor 1, with all other variables entered in block 2.

Hierarchical regression analysis indicated that, as expected for a domain that is developing through childhood, age at acute assessment was a consistently significant predictor of performance across all attentional domains, with the following variables demonstrating significant

Table IV. TEA-Ch Attentional Measures 5 Years Post-TBI

	Mild	Moderate	Severe	Control
Sustained attention				
Code transmission				
Total correct *M* (*SD*)	33.8 (5.1)	34.5 (6.7)	32.1 (8.1)	37.4 (3.2)
Total errors *M* (*SD*)	6.8 (5.7)	7.0 (7.6)	8.9 (8.1)	2.6 (6.9)
Score!				
Total correct *M* (*SD*)	7.7 (1.4)	7.4 (3.0)	6.4 (2.4)	8.0 (1.8)
Selective attention				
Sky search task				
MC number correct *M* (*SD*)	17.9 (1.7)	19.0 (1.9)	18.6 (1.5)	18.5 (0.8)
MC time taken *M* (*SD*)a,b,c*	21.9 (7.3)	21.3 (8.5)	32.8 (15.7)	19.4 (8.7)
SS number correct *M* (*SD*)	18.3 (1.3)	18.2 (2.9)	16.7 (4.6)	18.9 (1.2)
SS time taken *M* (*SD*)	108.8 (38.0)	99.0 (33.9)	118.2 (46.3)	103.1 (37.0)
Shift/inhibitory control				
Opposite worlds task				
SW1 time taken *M* (*SD*)**	14.7 (3.2)	12.9 (3.5)	15.3 (4.0)	12.1 (3.0)
SW2 time taken *M* (*SD*)b,c*	13.2 (2.0)	12.8 (3.4)	17.3 (7.1)	12.1 (3.1)
SWT time taken *M* (*SD*)b,c*	27.8 (4.5)	25.7 (6.1)	32.7 (9.8)	24.1 (5.9)
OW1 time taken *M* (*SD*)b,c**	17.3 (3.7)	16.3 (4.6)	21.1 (7.9)	15.6 (3.5)
OW2 time taken *M* (*SD*)	18.3 (4.6)	16.8 (5.6)	20.2 (6.6)	15.3 (4.8)
OWT time taken *M* (*SD*)b,c**	35.7 (7.9)	33.0 (9.6)	41.3 (13.4)	30.9 (7.4)
OWT minus SWT *M* (*SD*)	7.8 (6.3)	7.3 (5.7)	8.8 (9.8)	6.8 (4.2)
Divided attention				
Score DT				
Animal- total correct *M* (*SD*)	9.0 (1.1)	8.9 (1.3)	7.9 (1.7)	9.3 (0.9)
Tones total correct *M* (*SD*)	5.7 (2.1)	6.3 (3.1)	5.0 (2.6)	6.9 (2.3)
Total correct *M* (*SD*)c**	5.3 (2.1)	5.9 (3.1)	4.1 (2.3)	6.6 (2.2)

CI, confidence interval; OW, opposite world; MC, motor control; SS, sky search; SW, same world; TEA-Ch, Test of Everyday Attention for Children; time taken, seconds.

[a] Significant difference between mild and severe TBI groups.

[b] Significant difference between moderate and severe TBI groups.

[c] Significant difference between control and severe TBI groups.

$^{**}p < .05$. $^{*}p < .01$.

findings: CT, total correct and total errors; Score, total correct; SW, total time; and OW, total time all in block 1 of the regression function. When the other predictors were entered in block 2, age at acute assessment was again a significant predictor (CT, total correct and total errors; SS, time taken; SS : MC, time taken; Score, SW : total time; and OW: total time). With respect to injury-related predictors, lesion location predicted score; total correct and GCS score was associated with performances on SW: total time and OW: Total time. Pre-injury factors contributed to results for CT, Total correct (VABS pre-injury), and score DT, Total Correct (PIC pre-injury). Finally, acute intellectual levels explained a significant proportion of the variance on two measures of selective attention/PS (SS, Time taken and SS, MC time taken). Details of the results of hierarchical regressions across attention domains are provided in Tables V and VI. Results for sustained attention suggest that age at injury and location of lesion are strongest predictors. Selective attention/PS results showed that age at injury was again important, as well as intellectual functioning during the acute stage. For shifting attention/inhibitory control, age at acute assessment and severity of injury are important predictors. Pre-injury attentional functioning was the strongest predictor for divided attention.

Discussion

These results provide support for the presence of persisting attentional and speed of processing difficulties following TBI sustained during early childhood. Post-injury differences are likely to be attributed to injury-related factors as all TBI groups were functioning similarly before the TBI. Of note, SES differed significantly between the groups at 5 years post-injury, with more severe injury associated with decreases in SES.

Intellectual and Adaptive Abilities

As expected, intellectual functioning was most compromised at 5 years post-injury for children with severe

Table V. Significant Predictors of Sustained and Selective (Processing Speed) Attention at 24 Months Post-Injury

	Predictor variables	CT : total correct	CT : total errors	Score! : total correct	SS : time taken	SS : MC—time taken
Block 1	Age at acute assessment					
	t	2.63	−2.90	2.15	–	–
	Beta	0.44	−0.48	0.37	–	–
	Sigma	0.01	0.01	0.04	–	–
Block 2	Age at acute assessment					
	t	2.58	−3.56	–	−2.86	−2.73
	Beta	0.50	−0.67	–	−0.49	−0.47
	Sigma	0.02	<0.01	–	0.01	0.01
	Lesion localization		–			
	t	–	–	−2.09	–	–
	Beta	–	–	−0.35	–	–
	Sigma			0.05	–	–
	VABS–pre-injury					
	t	2.01	–	–	–	–
	Beta	0.37	–	–	–	–
	Sigma	0.05	–	–	–	–
	FIQ-acute					
	t	–	–	–	−3.11	−2.48
	Beta	–	–	–	−0.62	−0.50
	Sigma	–	–	–	<0.01	0.02
	R^2 step 1	0.18	0.20	0.12	0.14	0.08
	R^2 step 2	0.32	0.36	0.36	0.47	0.46
	Model F	$F(7,35) = 1.90$, $p = .11$	$F(7,35) = 2.29$, $p = 0.06$	$F(7,35) = 2.24$, $p = 0.06$	$F(7,35) = 3.55$, $p = 0.01$	$F(7,35) = 3.42$, $p = 0.01$
	R^2 square change	0.14	0.16	0.24	0.33	0.38
	Sigma *F* change	0.36	0.25	0.10	0.01	0.01

CT, code transmission; MC, motor control; SS, sky search; VABS, Vineland Adaptive Behaviour Scale.

TBI, a finding that confirms the results of previous research (Catroppa & Anderson, 2003a; Chadwick, Rutter, Brown, Shaffer, & Traub, 1981a; Chadwick, Rutter, Shaffer, & Shrout 1981b; Chadwick, O., Rutter, M., Shaffer, D., & Shrout 1981b; Jaffe et al., 1992, 1993; Jaffe, Polissar, Fay, & Liao, 1995). This study was also interested in the FFD and PS factors from the WISC-III, with a view to examining the sensitivity of these components of traditional clinical evaluation. No significant differences were evident between the groups for the FFD Index; however, visual inspection of the data (Table III) suggests a dose-response relationship, where the control group performed the best and the severe TBI group the poorest, with 20.1 points difference between these groups. On the PS Index, a significant difference was evident between the severe TBI group and controls (26.6 points), where again a dose-response relationship was found with the control group completing tasks quickest, followed by the mild, then moderate, and severe TBI groups. These findings are in accordance with previous research that identified deficits in speed of processing following brain injury (Catroppa & Anderson, 2003b; Catroppa & Anderson, 2005; Donders & Warschausky, 1997). Of interest, all TBI groups, in particular the severe group, showed more variability in performance in this domain, as indicated by a larger standard deviation. Subtle co-ordination difficulties observed post-TBI (Catroppa et al., 1999) may explain performance in the processing skills area.

Adaptive functioning results from the VABS that suggested similar skills across all groups of pre-injury. Interestingly, all groups showed some decline from pre- to post-injury scores with the largest decline evident for the severe TBI group. While mean group results continue to fall within the "average" range, they suggest that parents are not reporting expected development in adaptive function, stressing the need for further follow-up of these children, particularly in times of transition.

Attentional Tasks

Results on the attentional- and information-processing tasks indicated a consistent dose-response relationship even 5 years post-injury, suggesting persisting impairments in this domain associated with significant TBI.

Table VI. Significant Predictors of Shift and Divided Attention at 24 Months Post-Injury

	Predictor variables	SW total time	OW total time	Score DT: total correct
Block 1	Age at acute assessment			
	t	−3.71	−2.75	–
	Beta	−0.58	−0.46	–
	Sigma	<0.01	0.01	–
	Pre-injury PIC			
	Factor 1			
	t	–	–	−2.54
	Beta	–	–	−0.41
	Sigma	–	–	0.02
Block 2	Age at acute assessment			
	t	−4.93	−3.86	–
	Beta	−0.80	−0.68	–
	Sigma	<0.001	<0.01	–
	Pre-injury PIC			
	Factor 1			
	t	–	–	−2.47
	Beta	–	–	−0.40
	Sigma	–	–	0.02
	GCS			
	t	−2.16	−2.06	–
	Beta	−0.31	−0.33	–
	Sigma	0.04	0.05	–
	R^2 step 1	0.30	0.20	0.23
	R^2 step 2	0.53	0.43	0.39
	Model F	$F(7,35) = 4.44, p < .01$	$F(7,35) = 3.03, p = .02$	$F(7,35) = 2.53, p = .04$
	R^2 square change	0.23	0.24	0.16
	Sigma *F* change	0.04	0.71	0.25

GCS, glasgow coma scale; OW, opposite world; PIC, Personality Inventory for Children; SW, same world.

Depending on the specific cerebral region impacted by injury and its level of maturity at the time of injury, differential outcome may be evident for the attentional areas investigated.

For measures of sustained attention, despite clinically significant ESs, statistical findings indicated no significant differences across groups. This finding was unexpected as previous research has often found that children who sustain a severe TBI perform more poorly than those with a lesser injury or when compared with a control group (Anderson et al., 2006; Catroppa & Anderson, 2003a; Timmermans & Christenson, 1991; Kaufman et al., 1993). Possible explanations may lie in the characteristics of the task itself. Both sustained attention measures were auditory-based, whereas much of the previous research mentioned above used visually based tasks (e.g., continuous performance paradigms). Perhaps, for visually based sustained attention tasks, participants with TBI find it more difficult to maintain perseverance as they must actively attend to and organize the stimuli presented and determine their rate of response. In contrast, during an auditory task, the participant is provided with external "structure" through the regulated rate of stimulus presentation. Further, as neither of the tasks employed in this study were of extended duration, it may be argued that they were not tapping sustained attention. However, previous research utilizing a 6-min experimental version of the CPT was able to detect significant differences in group performances between TBI and control groups (Catroppa & Anderson, 2003a). Finally, in contrast to many traditional-sustained attention measures, speed of processing was not a crucial aspect of performance on these tasks, with presentation time allowing even children with TBI sufficient time to process incoming information. Thus, it may be that the current findings are reflecting sustained attention skills without the influence of PS. However, our ES analyses suggest that those who sustained a TBI may be at increased risk of sustained attention deficits, stressing the need to monitor these children in busy educational, social, and then vocational environments.

For selective attention, as measured by the SS task, while not always significant, results were in the expected direction. Unexpectedly, the speed component was not significantly different on the more complex experimental task, perhaps suggesting that the moderate–severe TBI groups benefited more so from the practice trial and were then more confident during the experimental task. These results provide partial support for findings in the adult literature where reduced speed of information processing has been implicated as a confounder on tasks measuring attentional skills (Anderson & Pentland, 1998; Ponsford & Kinsella, 1992; Stuss et al., 1989). However, as noted previously for sustained attention, ES were significant between TBI and control groups, as well as between the severe TBI and mild–moderate TBI groups, suggesting that adaptively and in every-day life, those sustaining moderate–severe TBI may be compromised in situations where selective attention is required to fulfil task demands, especially under timed conditions.

Results for the shifting/inhibitory control measure supported a dose-response relationship, where the control group performed quickest, with least errors, and the severe TBI group the slowest, suggestive of more errors. The mild and moderate TBI groups performed similarly and were intermediate between control and severe groups. An alternative explanation for the results may be that the severe group did not in fact make more errors, but exhibited slowed information processing on both the simple and more complex task, requiring more time to inhibit, shift mindset, and process the stimuli to make an appropriate response. Further coding of error patterns will be beneficial to investigate whether the difficulty is one of shifting attention, one of speed, or an integration of both.

The divided attention task was complex, requiring the dual processing of simultaneous information. When analyzing each source of information independently, there were no significant results, indicating that all groups were able to either count the tones correctly or identify the animal presented. In contrast, when both the number of tones and the animal were required to be correct in the same trial, a significant difference emerged between the severe and control TBI groups, indicating that this dual processing task was particularly complex and demanding for those children who had sustained a severe TBI. This finding implies that if in a "busy" and often noisy environment such as the classroom, where multiple task demands may be acting, those children who had sustained a moderate–severe injury may be compromised.

Predictors of Attentional Measures

Considering the continual development of attentional skills throughout childhood (Anderson, 2002; Betts et al., 2001; Manly et al., 1999; Rebok et al., 1997), it is not surprising that age at acute assessment is a significant predictor across attentional domains. For sustained attention, localization of lesion also appeared to have a significant impact. While one must be cautious in this interpretation since the lesions were classified broadly, and with a large difference in lesions across TBI groups, it may be suggested that certain areas of the brain support function in specific attentional domains, therefore injury to that brain area will lead to a specific impairment (Mirsky et al., 1991; Stuss et al., 1995). With regard to selective attention, predictor variables were not successful in explaining outcome. For all groups with TBI, a similar number of errors were made, perhaps due to the simplicity of the task or its strongly established developmental stage in this age group before injury. The speed component, while best predicted by age at acute assessment, was also associated with FSIQ. However, since the intellectual assessment includes tasks that are dependent on speed of processing, it is not surprising that intellectual ability at the acute stage is a predictor of a task with a speed component at 5 years post-injury. For shifting attention, injury severity was found to be predictive of outcome, with more severe injury associated with poorer performances at higher levels of task complexity. With regard to divided attention, regression analysis identified the pre-injury PIC-Factor 1 as the predictor of outcome. These results may suggest that children who were better able to be attentive before their injury are then better able to cope in challenging and demanding attentional environments.

Summary and Limitations

Severe TBI during early childhood results in specific attention and information processing deficits up to 5 years post-injury. As predicted, more severe TBI was associated with generalized attention and information-processing deficits. When taking into account a developmental perspective, predictions were partially supported. The earlier established skill of selective attention did not show a difference between groups, suggesting that this skill was more mature at time of injury, and therefore experienced least detriment. However, ES data suggests that clinically, and perhaps with a larger sample, the more severe TBI groups may struggle more so on tasks with a selective attention component. With regard to speed of processing, results provide some support for findings from the adult literature where slowed processing has been reported (Ponsford & Kinsella, 1992) post-TBI. However, as speed of processing develops during childhood–adolescence, this skill area may have been vulnerable in this sample where injury occurred at an early age. Psychomotor speed was also found to be problematic following severe TBI, possibly confounding performance on tasks of PS.

Similar to adult findings, evidence for impairments in sustained attention were not found in our child sample, not supporting the developmental perspective where one would expect that skills in a stage of development at the time of injury would be more comprised. However, ES data suggests that compared with a control group, children who sustained mild, moderate, or severe TBI are more vulnerable to difficulties in this area, and perhaps a larger sample, or the use of more demanding tasks, may have yielded significant statistical results. Further follow-up is required as they mature into adolescents and adults, and the ability to maintain attention over time to excel in the educational or vocational setting is essential. With respect to shifting attention, dose-related deficits were identified; however, it was difficult to separate attentional effects from speed of processing requirements. As expected, divided attention, due to its complexity and developmental trajectory was found most difficult by the severe TBI group.

The restricted age range of the participants may be seen as a limitation in the ability to generalize findings to other age groups; however, this study was interested in a young group as information pertaining to this age group is scarce, and where developmental issues are consistent across the group. A further potential limitation of the study is the use of parental recall of pre-injury measures to establish pre-injury functioning. Such an approach, while somewhat controversial, provides an opportunity to document pre-injury abilities. While this may result in some biased response patterns from the parent during this traumatic time, our data do not suggest this, with score distributions on this measure being consistent with those described in the test manual. Future studies may include both parent and teacher ratings to establish pre-injury status.

As the nature of the tasks utilized may have affected outcome, future research may be directed toward more accurate delineation of attentional skills and the measures used for their investigation, where tasks that manipulate attentional variables may produce more sensitive measures. The recruitment of a larger sample, where loss of subjects to follow-up and the possibility of differential attrition is further reduced, will also strengthen future studies. While this is common in all longitudinal research, results need to be considered with this problem in mind. A larger range of predictor variables, including family functioning variables may also be investigated. Future studies may include further follow-up of these children to allow for the systematic monitoring of these and other emerging skills, for example, executive skills, as the participants become adolescents and adults. Use of MRI technology and a genetic measure may also be implemented in the acute stages post-injury to determine whether such information assists in better prediction of those children who will require more intense intervention.

Conclusions

Findings from this study indicate that, compared with adults, attentional and PS deficits do occur and persist up to 5 years post-pediatric TBI, particularly following severe TBI in early childhood. Results show minimal impact of injury for children with mild TBI. Results suggest that those skills still in a stage of development at time of injury are more compromised and may not develop at a normal rate post-injury.

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