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**The Impact of Early Childhood Traumatic Brain Injury on the Transition  
to School**

A thesis

submitted in partial fulfilment  
of the requirements for the degree

of

**Master of Social Sciences**

at

**The University of Waikato**

by

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2014

## **Abstract**

Traumatic brain injury (TBI) is a common cause of pervasive and long lasting disability and injury. The outcomes of TBI in young children can be particularly detrimental, due to the impact on both current functioning and the ability to acquire new skills. Preschool children are at heightened risk of sustaining TBI. The impact of TBI can cause difficulties across a many domains including: cognitive and intellectual ability; academic achievement; executive function (EF); adaptive and behavioural functioning; and social competence. Deficits in any of these areas can place a child at increased risk of difficulties across their transition to formal schooling, which can subsequently lead to problems in later school performance. The first aim of this study was to examine the impact of TBI on cognitive and behavioural functioning in preschool children, at 12 and 24 months post-TBI. A second aim was to compare functional outcomes for children 24 months post-TBI, compared to a control group.

A population-based sample of 15 children, who sustained TBI at the age of 4 years old, were followed up over 24 months post-injury. The vast proportion of these children had sustained mild TBI. Parent ratings of behaviour, along with child performance measures of cognitive functioning were explored at 12 and 24 months post-TBI. The children with TBI were then compared to a community recruited, age-matched group of children ( $n = 15$ ) at 24 months post-TBI. Parent and teacher reports of behavioural and adaptive functioning, EF, and social competence were examined, along with the children's self-report of behavioural functioning. Child performance measures of cognitive, intellectual and academic performance were also compared across the two groups.

The results showed that both behavioural and adaptive difficulties decreased from 12 to 24 months after TBI, with internalising problems showing the greatest decline. Cognitive functioning remained stable and within the average range over this time. Comparisons between the TBI and Control group at 24 months post-TBI found comparable mean scores across nearly all measures and domains. The TBI group obtained lower scores (marginally significant) on measures of estimated IQ compared to the control group. While not statistically significant, a high proportion of the TBI group had elevated scores for externalising behaviours, peer problems and overall social difficulties. This highlights the need to screen for behavioural and social difficulties, with early intervention where necessary, to reduce the risk of difficulties during the school transition. Further longitudinal research on early TBI is recommended to explore these areas further.

## **Acknowledgements**

I would first like to thank my main supervisor Dr Nicola Starkey for the continual encouragement and support over the last two years. Your availability, patience and invaluable advice helped me to persevere through the hard times and keep the end goal in sight. I would also like to thank my second supervisor Dr Kelly Jones. It was reassuring to know I could contact you with any queries, or if I needed advice. Thank you both for sharing your knowledge and for the prompt and helpful feedback to keep me on track.

To everyone in the COBIC team – who put up with my never-ending questions – thank you for the feedback, support, and most of all your company in the office over the last two years. To all of the children and families that took part in this study, thank you for allowing us into your homes. Your willingness to give of your time and to complete so many assessments was greatly valued and appreciated.

To my family and friends, thank you for the endless support and encouragement. Without you all, this process would have been impossible. A special thanks to my mum Lynda; for the endless hours babysitting and helping care for my family so I could do assessments and have time to write. To my beautiful children, thank you for all of the cuddles and kisses that helped me get through the late nights. You all coped so well with the changes in routines over these last few months. Finally, to my amazing husband David, who made this whole process possible. Thank you for your ceaseless efforts in looking after the kids and the house, so I could have more time to work. Your support, understanding, and most of all your endless encouragement were invaluable over these past two years.

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## **The Impact of Early Childhood Traumatic Brain Injury on the Transition to School**

The early years of a child's life are a time of rapid development and growth. These preschool years represent a critical period where vital skills are emerging and setting the foundation on which all future learning will be built. Any interruption to normal development during this time can markedly alter developmental trajectories, not only impacting on brain maturation but also how a child comprehends and interacts with the world around them (Muscara, Catroppa, & Anderson, 2008).

One of the most frequent causes of disruption to childhood development is traumatic brain injury (TBI; Anderson et al., 1997). Childhood TBI is a prominent health problem, causing significant injury and disability both worldwide and across New Zealand. TBI can have long-term consequences with difficulties potentially persisting for years after injury (Crowe, Babl, Anderson, & Catroppa, 2009; Langlois, Rutland-Brown, & Wald, 2006). While a considerable amount of research exists on the impact of TBI on adults and school-age children, less is known about the impact on younger children. The focus of this study was to examine functional outcomes after TBI in 4 year old children, 24 months post-injury. As the children entered formal schooling over this time, particular attention was paid to the impact of TBI on skills associated with successful school transition.

### **The Definition of TBI**

The World Health Organisation (WHO) defines TBI as “an acute brain injury resulting from mechanical energy to the head from external physical forces” (Carroll, Cassidy, Holm, Kraus, & Coronado, 2004, p. 115). Operational signs of

TBI after an injury to the head include: loss of consciousness; post-traumatic amnesia (PTA); confusion; or neurological abnormalities (New Zealand Guidelines Group, 2006). TBI can be classified as either closed (where both the skull and dura remain unpenetrated), or penetrating (where an object penetrates the skull). While penetrating head injuries result in more localised focal brain injury, closed head injury – which is most commonly associated with TBI – often results in more diffuse cerebral damage (Giza & Prins, 2006).

TBI can be further categorised based on measures of injury severity. The most commonly used method of classification of TBI severity is the Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974). The GCS measures the conscious state of an individual and examines their responses across the areas of motor response, verbal response and eye opening. Scores range from 3 to 15, with lower scores on the GCS representing greater injury severity. A score of 8 or under is classified as severe TBI, 9-12 moderate TBI, and 13-15 mild TBI. The severity of TBI can also be classified using Posttraumatic Amnesia (PTA) scores as follows: duration of PTA of 7 days or more is associated with severe TBI; 1 to 6 days represents moderate TBI; and less than 24 hours represents mild TBI (Shores, Marosszeky, Sandanam, & Batchelor, 1986).

### **The Epidemiology of TBI**

**Incidence of TBI.** Differences in methodology across studies have resulted in somewhat varying reports of the incidence of TBI. Bruns and Hauser's (2003) review of the incidence of TBI found that, in general, higher-income countries report an overall rate of roughly 200 cases per 100,000 person-years. They note, however, that many incidence studies only look at cases of TBI involving hospitalisation. A vast majority of individuals who sustain milder forms

of TBI are only seen in Emergency Departments (ED), while others do not even seek any form of medical attention (McKinlay et al., 2008). As a result, these findings are believed to underestimate the true incidence of TBI.

In the United States at least 1.4 million people are reported to sustain TBI each year, with an overall annual rate of 506 per 100,000 population (Langlois, Rutland-Brown, & Thomas, 2004). A review of the incidence of mild TBI (mTBI) by Cassidy et al. (2004) suggested that rates of mTBI may be even higher - more likely in excess of 600 per 100,000 people. A recent population based study, conducted in New Zealand (NZ), supports this premise with an overall incidence of 790 per 100,000 person-years (Feigin et al., 2013). This higher rate is reflective of the inclusion of TBI cases from all sources, including self-referral and referral from General Practitioners.

**Incidence of childhood TBI.** Approximately 475,000 of the cases of TBI that occur annually in the United States are for children under 15 years of age (Aaro Jonsson, Catroppa, Godfrey, Smedler, & Anderson, 2013). Children between the ages of 0 to 4 years were found to have the highest rate of TBI with an incidence rate of 1,121 cases per 100,000 person years. Over 90% of these children were treated in Emergency Departments (ED), with no further hospitalisation required (Langlois et al., 2004).

This high rate of TBI in young children can also be seen in New Zealand. A birth cohort study examining the incidence of TBI found that by the age of 25, 32% of the participants had sustained some form of TBI (McKinlay et al., 2008). The 0 to 5 year old age group also had the highest incidence of TBI with an average annual rate of 1, 850 cases per 100,000 children. The more recent study

by Feigin et al. (2013) also reported a high rate with 1,300 cases per 100,000 person-years for children between the ages of 0 to 4.

**Injury severity.** Around 70 to 90% of cases of TBI are reported to be mild in severity (Cassidy et al., 2004; McKinlay et al., 2008). This percentage can vary depending on how the cases of TBI were located (e.g. via admission to hospital). A study from Victoria, Australia, examined the severity of TBI cases that were located via either presentation to ED, or by admission to hospital, for children between 0 to 16 years of age. They found that 89% of the TBI cases were mild, 8% moderate, and the remaining 3% severe (Crowe et al., 2009). Feigin et al. (2013) reported that within the 0-4 age band 97% of the TBI cases were mild in nature. This incidence of mild TBI for preschool children was significantly higher than for any other age group. The high level of mild cases may reflect the study methodology, where a vast number of cases were located via other sources, outside of hospital admissions (Feigin et al., 2013).

**Gender differences.** Throughout literature gender differences are consistently found, with a majority of TBI's occurring in males (Bruns & Hauser, 2003; Cassidy et al., 2004; Feigin et al., 2013). Feigin et al. (2013) reported that males accounted for 63% of the total number of TBI cases. In contrast, some researchers have suggested that gender differences may be less obvious in preschool children. McKinlay et al. (2008) found that gender differences were less marked for the 0-4 year age group than for all other age groups. Crowe et al. (2009) also reported similar rates of gender in children aged 2 and under. However, from 3 years of age males once again showed an increased incidence of injury.

**Mechanism of injury.** TBI as result of a fall or motor vehicle accident (MVA) remain the leading overall causes of TBI (Cassidy et al., 2004; New Zealand Guidelines Group, 2006). McKinlay et al. (2008) suggest that the mechanism of injury varies depending on age, with MVA more common in older adolescents, and falls more predominant in younger children. They found that for children aged 0-4 at time of injury, TBI due to a fall accounted for 67% of cases; with exposure to a mechanical force (i.e. being hit by an object) the next highest on 10%. In contrast, only 3 % of the injuries were the result of a MVA (McKinlay et al., 2008). This finding of falls being the main mechanism of injury in preschool children is consistently reported in literature (e.g. Cassidy et al., 2004; Crowe et al., 2009; Feigin et al., 2013; Langlois et al., 2006).

**Ethnicity and SES.** A number of international studies have reported a pattern of heightened risk of TBI in ethnic minority populations (Langlois, Rutland-Brown, & Thomas, 2005; Whitman, Coonley-Hoganson, & Desai, 1984). This pattern has also been found in New Zealand. A hospital-based incidence study by Barker-Collo, Wilde, and Feigin (2008) reported a higher incidence of TBI for Maori and Pacific Island populations than was found for the remaining population. Feigin et al. (2013) also found that Maori people had a greater rate of TBI than all other ethnic groups; however, much of this difference was observed for people over the age of 35. Bruns and Hauser (2003) suggest that while TBI incidence is often higher for minority groups, these results are confounded by socio-economic factors. Langlois et al. (2005) also stress that caution should be taken when interpreting differences across ethnicity. They argue that ethnicity itself is not a risk factor; rather, it is a marker for the TBI risk factor of social-economic status (SES). Research from both New Zealand and overseas has

highlighted this relationship between lower SES and increased risk of TBI (Barker-Collo et al., 2008; Bruns & Hauser, 2003; Chiu et al., 1997)

### **The Impact of TBI**

**Mild TBI in children.** Injury severity is consistently found to be the most reliable predictor of outcomes after TBI, with more severe injury being associated with worse outcomes across all domains (e.g., Anderson, Morse, Catroppa, Haritou, & Rosenfeld, 2004; Ewing-Cobbs, Fletcher, Levin, Iovino, & Miner, 1998; Taylor et al., 2002). The impact of mild TBI (mTBI), however, remains contentiously debated. While a considerable amount of research now exists on outcomes after childhood mTBI, there is still no consensus, with findings ranging from no differences found (Goldstrohm & Arffa, 2005) to reports of long-term impairment (McKinlay, Dalrymple-Alford, Norwood, & Fergusson, 2002; Wrightson, McGinn, & Gronwall, 1995). Even literature reviews on mTBI in childhood and adolescence have been unable to resolve the debate (Carroll et al., 2004; McKinlay, 2010; Satz, Zaucha, McCleary, & Light, 1997). The high rate of mTBI in preschool children highlights the need for clearer understanding of the potential impact of mTBI on this age group.

Some researchers purport that outcomes can differ depending on the severity of the mTBI (Hessen, Nestvold, & Sundet, 2006). McKinlay and colleagues (McKinlay, Grace, Horwood, Fergusson, & MacFarlane, 2010) suggest more severe mTBI is associated with increased risk of persisting problems, while milder TBI has no discernable lasting difficulties. A vast majority of preschool children that experience TBI are classified as mTBI (Feigin et al., 2013). Due to the high number of children that sustain mTBI, even if only a fraction of these

children experience deficits in functioning after injury, this still translates to a substantial burden on society (Keenan & Bratton, 2006).

**The public health burden of TBI.** The high incidence of preschool TBI impacts on not only the child and their family, but on society at large (Thurman, Alverson, Dunn, Guerrero, & Sniezek, 1999). TBI is a significant health concern, costing an estimated \$1 billion annually in hospitalisation costs for children 17 years and under in the United States alone (Schneier, Shields, Hostetler, Xiang, & Smith, 2006). This estimate does not even consider additional costs such as ongoing rehabilitation and loss of income for family members caring for children with TBI.

In the United States, approximately 5.3 million people (roughly 2% of the population) live with some form of disability associated with TBI (Thurman et al., 1999). Advances in medical care now mean that an increased number of people are surviving TBI, which has led to more people living their life with long-term disabilities (Ponsford, 2013a). This is particularly true with children who, due to their young age at injury, have more years to live with the consequences of TBI.

**The burden of TBI on families.** Childhood TBI can impact extensively on both family members and other people involved in the daily life of a child with TBI. Family burden problems are often reported after childhood TBI, particularly after more severe injuries (Aitken et al., 2009; Anderson, Catroppa, Haritou, Morse, & Rosenfeld, 2005). Ponsford (2013b) argues that TBI can be just as distressing for family members, as they are often the ones having to provide additional care and assistance to the injured child.

Stress and worry about their child's functioning across academic and psychosocial domains are commonly reported by parents after childhood TBI (e.g. Aitken et al.,

2009; Prigatano & Gray, 2007; Souza, Braga, Filho, & Dellatolas, 2007). Limond, Dorris, and McMillan (2009) found that 43% of school-age children (with mild to severe injuries) had some form of difficulty that impacted on their functioning in everyday life. These difficulties can place strain on the family unit. Taylor et al. (2001) found that increased child behavioural problems 6 months after TBI predicted higher family burden and parental psychological distress at 12 months post-TBI. Increased levels of family burden are important to understand, as caregiver burden can, in turn, influence recovery and outcomes for the child with TBI (Aitken et al., 2009).

**The impact of TBI on early child development.** The effects of TBI on a child's brain differ in several ways to that of adult TBI. It is commonly accepted that a child's developing brain is more vulnerable to insult (Giza & Prins, 2006). For a long time this malleability, or plasticity as it is otherwise known as, was considered a great advantage when it came to recovering from brain insult. For this reason, childhood TBI has historically received little attention, as it was believed that this brain plasticity resulted in less impairment for children (Lenneberg, 1967). In recent times however, the obvious cognitive and behavioural impairments that commonly occur after childhood TBI have led researchers to question how beneficial plasticity really is after TBI (Giza & Prins, 2006).

Plasticity is described as the ability of the central nervous system (CNS) to “respond in a dynamic manner to the environment and experience via modification of neural circuitry.” (Anderson, Spencer-Smith, & Wood, 2011, p. 2198). While this plasticity has many benefits in a developing brain, problems can occur after TBI if these processes are disrupted. One problem with the plasticity

debate is that most of the research on developmental plasticity has looked at focal lesions, whereas childhood TBI often results in a diffuse brain injury (Giza & Prins, 2006) Diffuse injury results in more widespread cerebral damage, and consequently less healthy tissue is available to compensate and aid recovery (Anderson et al., 1997; Giza & Prins, 2006).

More recent research suggests that instead, young children may be more vulnerable to TBI due to immaturity of their developing brain (Anderson et al., 2005; Dennis, 2000; McKinlay et al., 2010). Brain insult at this age has the potential to significantly disrupt development by not only impacting established skills, but also the ability to acquire new skills (Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2001). It is believed that the young brain undergoes a period of rapid development during the preschool years. This “rapid development” hypothesis proposes that skills emerging during this critical stage are at greater risk of disruption after insult (Anderson et al., 1997; McKinlay et al., 2010). Taylor and Alden (1997) suggest that any negative outcomes associated with a younger age are most evident in children less than 7 years of age, when compared to older children. Preschool children have few skills consolidated at this young age (Anderson et al., 2004). Thus a TBI during this period may have a significant impact on a child’s current functioning and ongoing development, placing them at greater risk of persisting difficulties (Dennis, 1988).

Another theory associated with early TBI is that of “growing into” deficits (Taylor & Alden, 1997; Wrightson et al., 1995). It is proposed that deficits in skills that are not fully developed until later childhood/adolescence may not become apparent until the child is older and starts failing to progress as expected. This may be due to deficits in skill acquisition, or an inability of the child to

handle the increasing expectations and demands placed on them as they age (Dennis, 1988).

One such period where demands and expectations increase is during the transition to school. This dramatic change in environment and expectations can place even further strain on a child trying to recover from TBI. This in turn, can impact on the child's ability to successfully navigate this transition period. The following sections will highlight the importance of a successful school transition, before examining the impact that preschool TBI may have on the a child's functioning and ability to settle into school life.

### **The School Transition**

The transition to school is, universally, one of the first major life transitions that young children face (Ramey & Landesman-Ramey, 2010). For most children in New Zealand, this transition occurs on their fifth birthday and signifies the start of a new stage of life. This transition into formal education can be a daunting time for many children and brings with it challenges as they adjust to new classroom routines, rules and expectations that can be vastly different from their home life (Pianta & Rimm-Kaufman, 2006).

The school transition period is considered an important time, as these early school experiences are thought to pave the way and impact on later school success (Ramey & Landesman-Ramey, 2010; Raver & Knitzer, 2002; Seven, 2010). Rimm-Kaufman and Pianta (2000) propose that any change, however minor, in the developmental trajectory over this transition period can have an exaggerated effect on children's school outcomes and academic success. Children who struggle in their early school years are also at increased risk of problems with

social, emotional and behavioural development later in life. (The Child Mental Health Foundations and Agencies Network (FAN), 2000).

This widely accepted view of the importance of the transition period for later school success has led to considerable interest in factors that may either hinder or support a successful school transition. The term “school readiness” is often used to describe characteristics or qualities that are considered beneficial for a successful transition to school. While debate remains over what exactly constitutes a “school ready” child some of the suggested factors will be discussed below.

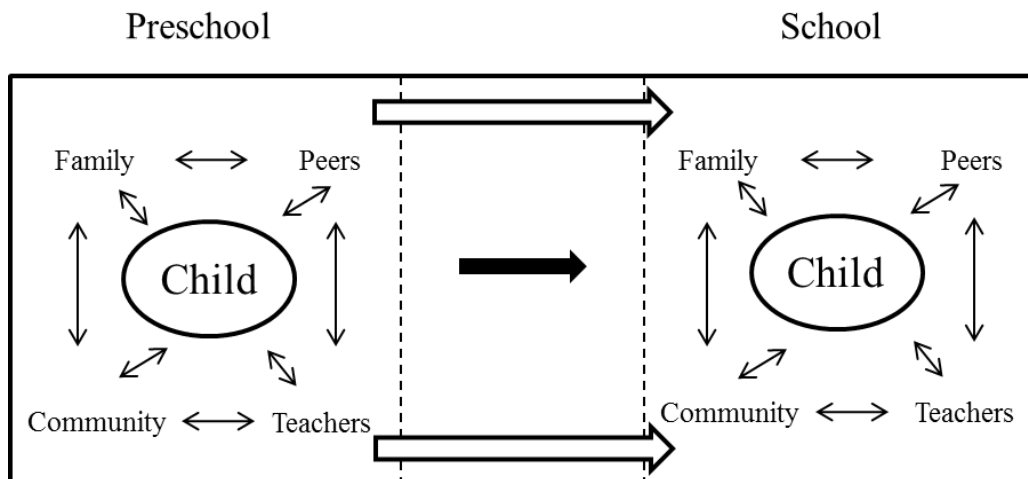
**School Readiness.** Throughout the literature on school readiness there have been many factors that are linked with a “successful” school transition. Some of the risk and protective factors associated with early school outcomes are shown in Table 1. This list is not exhaustive, and represents areas of interest in relation to this study. Raver and Knitzer (2002) suggest that the greater the number of risk factors a child is exposed to, the greater the risk of problems in early schooling. Protective factors, on the other hand, may protect or buffer the child and mitigate the effect of risk factors, especially those factors that cannot be changed (e.g. minority status or maternal age; (e.g. minority status or maternal age; Langford, 2010).

Table 1  
*Risk and protective factors associated with the success of school transition*

<b>Risk Factors</b>	<b>Protective Factors</b>
<b>Child Factors</b>	
Cognitive deficits	Higher level of cognitive functioning
Behavioural and adjustment problems	Stable, functional behaviour
Problems with peer relationships	Ability to form and maintain friendships
Problems with relationships with teachers	Positive child-teacher relationship
<b>Parent/Caregiver Factors</b>	
Low level of maternal education	Higher level of maternal education
Single parent home	Two parents at home
Low family functioning	High family functioning
<b>Environmental Factors</b>	
Low social economic status	Higher social economic status
Belonging to a minority group	

*Note:* Adapted from Huffman, Mehlinger, and Kervian (2000).

As shown in Table 1, many factors – including family and social environment – influence children’s development and transition to school (e.g. Dockett & Perry, 2007; Langford, 2010). In light of this, Rimm-Kaufman and Pianta (2000) proposed a dynamic effects model of the transition to school that can be seen in Figure 1. This model shows the bidirectional relationships between the child and the social environment they live within, as well as emphasising that these relationships develop and change over time. As a child transitions to school, there continues to be evolving interactions between both the child and those people and organisations around them. Rimm-Kaufman and Pianta (2000) stress the importance of considering not only the child but the context they live within, including family and school factors, when examining the transition to school. While this model highlights the importance of the context the child lives within, due to the limited scope of this study, characteristics related to the child and family environment were the focus of the current research.



*Figure 1.* The ecological and dynamic model of transition, adapted from Rimm-Kaufman and Pianta (2000).

**The Impact of TBI on School Transition.** Many of the risk factors related to a poor school transition (as shown in Table 1) can also be negatively affected by childhood TBI. These include a child’s ability to engage and maintain functional relationships with those around them (e.g., Fabes, Gaertner, & Popp, 2006), as well as difficulties in behavioural and cognitive functioning after TBI (e.g., Raver & Knitzer, 2002). Environmental risk factors of poor school transition – such as low SES and belonging to a minority group – are also risk factors associated with childhood TBI.

TBI has the ability to disrupt or hinder development over multiple areas of child functioning including: cognitive and intellectual functioning; academic achievement; executive functioning; behavioural and adaptive functioning; and social competence (Muscara et al., 2008). Skills in these areas are important, as they aid in both the transition to school and later school outcomes

During the school transition, the increasing complexity of cognitive tasks – as well as the different classroom expectations – means that this transition can

add even further burden to a child suffering from TBI. Anderson and Catroppa (2006) highlight that children who experience more pronounced impairments after TBI may need long-term rehabilitation and support, especially across developmental periods such as the school transition. The following sections of this report will examine the impact of childhood TBI on each of the previously mentioned areas of functioning, in relation to early child development and the potential impact on school transition.

### **The Impact of TBI on Cognitive, Intellectual and Academic Functioning**

**Cognitive and intellectual ability.** A vast number of studies on childhood TBI have focused on the impact of injury on cognitive functioning. Long term cognitive difficulties have been well documented, particularly after moderate and severe TBI, with deficits reported across areas such as intellectual functioning, processing speed, memory and attention (Anderson & Catroppa, 2006; Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2005a). Impairments in these areas can impact on young children's ability to interact successfully with the world around them. Problems in cognitive functioning can also lead to secondary deficits in vital areas, such as academic achievement and social competence (Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2000).

Substantial research on the long-term impact of childhood TBI has been undertaken by Anderson and colleagues. A longitudinal study from their research laboratory in Australia has investigated functional outcomes of TBI on children up to 10 years post-injury (e.g., Anderson et al., 2000; Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2005b; Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2009; Anderson, Godfrey, Rosenfeld, & Catroppa, 2012; Anderson et al., 2004; Anderson et al., 1997).

Anderson et al. (2004) examined the impact of TBI on neurobehavioural outcomes on children injured between the ages of 2:0 years and 6:11 months, up to 30 months post-injury. Children with mild ( $n = 14$ ), moderate ( $n = 46$ ), or severe ( $n = 24$ ) TBI were compared to a community recruited control group ( $n = 33$ ). Intellectual functioning of the children was assessed using the Bayley Scale of Infant Development, Preschool and Primary Intelligence Scale—Revised (WPPSI-R), or the Wechsler Intelligence Scale for Children—III (WISC-III), depending on the age of the child at testing. They found that acute scores of overall intellectual ability (FSIQ) were significantly lower for the severe TBI group than all other groups. The mean FSIQ score for the severe group was below the ‘Average’ range, despite pre-injury measures indicating prior age-appropriate development. No significant differences were found between the control group and either the mild or moderate TBI groups, with the mean FSIQ score for each group in the average range.

Anderson et al. (2005b) extended on these findings by comparing the children who sustained TBI at a younger age (3:0-7:11 years,  $n = 53$ ) to an older TBI group (8:0-12:11 years;  $n = 69$ ), across the same measures of intellectual functioning. No significant difference was observed between the two age groups for either the mild or moderate TBI children, up to 30 months post-injury. Children with mild or moderate TBI – for both age groups – showed some recovery in functioning over the first 12 months, with recovery curves stabilising from 12 to 30 months post-TBI. In contrast, the performance of the severe TBI children was related to their age at injury. While both groups had mean FSIQ scores in the low average range, the recovery trajectories differed. The older severe TBI group showed the greatest recovery over the first 12 months, before

recovery slowed between 12 to 30 months post-injury. On the other hand, the younger severe TBI group showed flatter recovery curves, with only slight improvement over the 30 months post-TBI. Anderson et al. (2005b) suggest that these results support the “double-hazard” effect; the combination of younger age at injury, along with more severe injury, results in the poorest outcomes after TBI.

A follow-on study by Anderson et al. (Anderson et al., 2009), for children injured between 3 and 7 years of age, examined intellectual outcomes up to 5 years post-TBI. While the severe group showed no recovery over the 12 to 30 month period, from 30 months to 5 years the developmental trajectory appeared to stabilise. Anderson et al. (2009) suggest that from 30 months, these children were beginning to acquire new skills and make age appropriate gains. This finding is in opposition to the ‘grow into deficits’ hypothesis (which suggests that young children with TBI fall further behind over time). Of note, while these children with severe TBI were showing age-appropriate development, no catch up in recovery was apparent, with these children still having a mean FSIQ score well below the control, mild and moderate TBI groups at 5 years post-TBI.

This low FSIQ mean score for the severe group (for children 2 to 7 years old) was still apparent at 10 years post-TBI; highlighting the pervasive and long-lasting impact of severe TBI on intellectual functioning in young children (Anderson, Catroppa, Godfrey, & Rosenfeld, 2012). No signs of ‘growing into deficits’ were seen; all TBI groups showed stable recovery curves from 5 to 10 years post-injury, with age-appropriate gains made.

These findings clearly show the long term impact of severe TBI on intellectual functioning, with little evidence of difficulties after mTBI. Satz and colleagues (Satz, 2001; Satz et al., 1997) suggest that while a slight change in

cognition may be found acutely for mTBI, this change is normally transient with no obvious long-term difficulties.

While most research has found little support for the deficits in overall levels of cognitive or intellectual functioning after mTBI (e.g. Catroppa, Anderson, Morse, Haritou, & Rosenfeld, 2007; McKinlay et al., 2002), some research suggests that difficulties may be present for more specific areas of cognitive functioning. Gerrard-Morris et al. (2010) compared cognitive functioning of children (3 to 6 years of age) with complicated mild to severe TBI, to an orthopaedic injury (OI) comparison group. While generalised cognitive difficulties were only found for the severe TBI group, both the moderate and mild complicated groups showed persisting difficulties across tests of auditory working memory and inhibition at 18 months post-TBI.

Another study by Anderson and colleagues (Anderson et al., 2001) looked at outcomes over 30 month's post-TBI for children sustaining mTBI between 3 to 7 years of age. While they also found comparable results between the mTBI and control groups across intellectual ability and receptive language skills, two small but significant differences across measures of high-level language skills (verbal fluency and storey recall) were reported. These differences were present at 30 months post-TBI with the mTBI group performing lower than the control.

Chapman et al. (2010) purports that one of the most consistent findings after childhood TBI is the extreme variability of outcomes. They argue that you cannot predict how individual children will recover based solely on group results. While the severe group in their study performed worse on measures of verbal discourse (compared to the mild and moderate groups) a few children within the severe group still showed fairly good recovery after injury.

Some researchers suggest that children with severe TBI, who have unusually good outcomes after injury, may have higher levels of cognitive reserve. Cognitive reserve refers to “the ability to optimize or maximize performance through differential recruitment of brain networks” (Stern, 2002, p. 451). Cognitive reserve theory suggests that children with higher cognitive abilities – and therefore higher cognitive reserve – may be buffered to some extent from the impact of TBI (Dennis, 2000; Fay et al., 2010).

Fay et al. (2010) undertook a study to examine the role of cognitive reserve on post-concussive symptoms (PCS) after mTBI. They found that the cognitive ability of the mTBI children moderated PCS; children with lower cognitive abilities were more likely to experience PCS than children with higher cognitive abilities, when compared to an (OI) control group. This was particularly true for children with complicated mTBI. Fay et al. (2010) suggest that a complex interaction exists between injury severity and cognitive abilities during recovery from mTBI.

Deficits in cognitive abilities after TBI can also have a flow-on impact on a child’s academic performance. The potential impact on academic abilities after TBI is further discussed below.

**Academic achievement after childhood TBI.** The impact of cognitive functioning on academic achievement can be seen across both normal developmental literature and research on childhood TBI (e.g. Catroppa et al., 2009; Fulton, Yeates, Taylor, Walz, & Wade, 2012). Educational outcomes during the transition to school can have a persisting impact on both later school success, and employment opportunities later in life (Barnes, Dennis, & Wilkinson, 1999; Ramey & Landesman-Ramey, 2010).

It has been suggested that skills that are developing during the time of injury may be vulnerable to insult after TBI (e.g. Wrightson et al., 1995). Barnes et al. (1999) found that children who sustained TBI before the age of 6.5 years had a greater risk of difficulties in word decoding and reading comprehension than older children. These skills form the basis of formal reading and are not developed until after a child starts school. Problems in these areas for young children with TBI provide support for this notion that skills not developed at the time of injury are more vulnerable, due to potential difficulties with skill acquisition (Dennis, 1988).

Anderson et al. (2006) examined educational outcomes of children (2:0 to 6:11 years old at injury) up to 30 months post-TBI. Children with mild ( $n = 14$ ), moderate ( $n = 46$ ), or severe TBI ( $n = 24$ ) were compared to a healthy control group ( $n = 33$ ) on the Wide Range Achievement Test third edition (WRAT-3), which assessed reading, writing and arithmetic skills. They found that the mild TBI group performed comparably to the control group across all academic measures. While the moderate TBI group initially showed some difficulties, particularly for reading, by 30 months post-TBI their scores had increased and were similar to the mTBI and control group scores. This suggested substantial recovery in academic functioning after moderate TBI. In contrast, the severe TBI group showed global academic difficulties up to 30 months post-TBI, with mean scores in the lower end of the 'average' range.

Catroppa and colleagues (Catroppa, Anderson, Morse, Haritou, & Rosenfeld, 2008) followed on from Anderson et al. (2006) by examining educational performance of these children (2:0 to 6:11 years old at injury) at 5 years post-TBI. The academic ability of the severe TBI group was significantly lower than the control group at 5 years post-TBI across reading, spelling and

arithmetic, as measured by the WRAT-3. While the severe group performed below the 'average' range for all academic areas examined, the control, mild and moderate TBI groups had scores in the 'average' range across all areas. These results support the notion that children who experience severe TBI at an earlier age have persisting academic problems.

Ewing-Cobbs et al. (2004) examined the academic achievement of children (between 5 to 15 years) who sustained mild/moderated ( $n = 34$ ) or severe TBI ( $n = 43$ ) up to 5 years post-TBI. Investigation of recovery curves after TBI found that younger children had more decelerated growth curves than older children, supporting the notion that TBI at a younger age may impact on the acquisition of certain academic skills. They also found that while the severe group improved over time, they still showed greater difficulties across all measures of academic functioning than the mild/moderate TBI group.

Ewing-Cobbs and colleagues (Ewing-Cobbs et al., 2004; Ewing-Cobbs et al., 1998) argue that while academic scores of children with moderate or severe TBI may recover over time (and be in the average range), these scores are not always in line with academic performance within the classroom setting. They suggest that scores on individually administered tests of academic abilities may not reflect the problems that children may experience within the school environment.

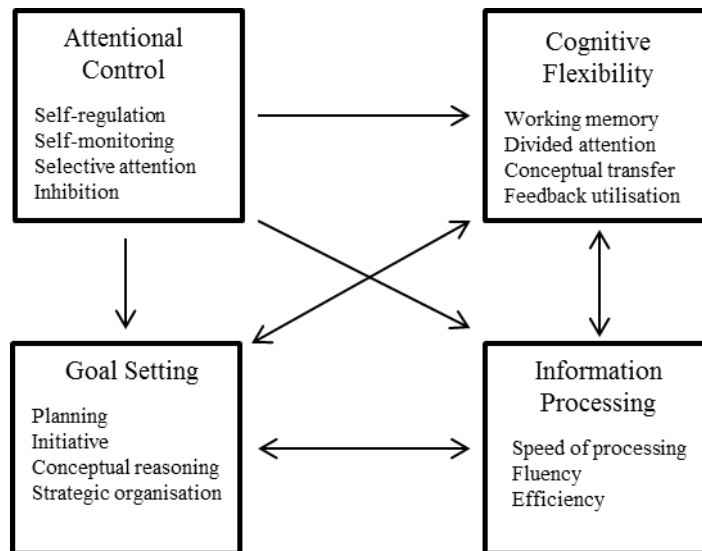
Ewing-Cobbs et al. (2006) examined academic outcomes on children who sustained TBI, before the age of 6, on average 5.7 years after TBI. The Woodcock Johnson Tests of Achievement, Third Edition (WJ III ACH; Richard W Woodcock, K S McGrew, & N Mather, 2001) was used to compare children with moderate/severe TBI to a control group, across measures of academic ability. The

TBI group were found to have lower levels of academic functioning than the control group across various areas, including measures of reading skills, mathematical abilities and writing fluency. TBI also impacted on the children's academic performance within the classroom, with 48% of the TBI group having either failed a grade or needing special educational services.

One way that academic achievement can be impacted after childhood TBI is via deficits in higher-order cognitive functioning, otherwise known as executive functions. The next section explores the importance of executive functions on child development and the potential impact of TBI on these skills.

### **Executive Functioning**

**The Importance of Executive Function on Development.** One of the more prevalent and persisting outcomes after childhood TBI is disruptions to Executive Function (EF; Nadebaum et al, 2007). EF refers to an inter-related set of higher-order cognitive processes that are responsible for purposeful, goal-directed or future-orientated behaviour (Ayoub & Fischer, 2006; Gioia, Isquith, Guy, & Kenworthy, 2000). While there is still debate over what exactly constitutes EF, certain themes consistently emerge, including self-regulation, impulse control, working memory and attentional capacity (Anderson, 2008). The umbrella construct of EF is not limited to cognitive processes but also involves the regulation of behavioural and emotional responses (Gioia et al., 2000). Anderson (2002) proposes a model of EF where EF is conceptualised as an overarching control system made up of four separate but inter-related domains including cognitive flexibility, attentional control, goal setting and information processing (as seen in Figure 1).



*Figure 2.* The executive control system, a conceptual framework of executive function adapted from Anderson (2002).

EF is also thought to play an important part in other areas of functioning including cognitive and academic skills (such as reading and mathematics), as well as behavioural, emotional and social skills (Anderson, 2002; Anderson, 2008; Espy, Bull, Kaiser, Martin, & Banet, 2008; Graziano, Reavis, Keane, & Calkins, 2007). EF skills are also considered an important aspect of school readiness (Blair, 2002). Ayoub and Fischer (2006) purport that the biggest difference for children entering school is their varying capabilities in regards to EF, in particular, their ability to learn, organise and regulate their emotions. The obvious importance of EF on a child’s development, and impact on factors associated with successful school transition, highlights the need to understand further the effects of TBI on EF in early childhood.

The vulnerability of EF after childhood TBI is thought to be related to the prolonged development of EF, beginning in infancy and extending through to late adolescence (Anderson, 2008; Muscara et al., 2008). It is also believed that EF processes are mediated by the prefrontal region of the brain, which is particularly

vulnerable to insult after TBI (Anderson & Catroppa, 2005; Ayoub & Fischer, 2006). Recent research suggests that individual domains of EF have different developmental trajectories, and therefore may be differentially impacted by TBI depending on the age of injury (Anderson, 2008; Anderson, Anderson, Jacobs, & Smith, 2008; Smidts, Jacobs, & Anderson, 2004).

**Impact of TBI on Executive Function.** While a vast amount of research has been undertaken on cognitive outcomes after TBI, much less attention has been given to EF outcomes following early childhood TBI. Research has also been hindered by problems such as difference in the definition of EF, small sample sizes and a lack of ecologically valid measures of outcome over this young age group (Anderson & Catroppa, 2005; Anderson & Ylvisaker, 2009).

Nadebaum and colleagues (Nadebaum, Anderson, & Catroppa, 2007) examined the impact of EF 5 years post-injury on children under the age of 7, at time of TBI. They undertook a prospective, cross-sectional study comparing 54 children with mild to severe TBI to 17 uninjured control children. Overall EF, along with specific areas of cognitive flexibility, information processing, goal setting and attentional control were examined, along with parent ratings of behavioural executive functioning. They found that children with mild or moderate TBI showed no obvious difference in performance from the control group across all EF areas examined up to 5 years post-TBI.

In contrast, while no global deficit in EF was evident, impairment in specific areas of EF were present at 5 years post-TBI for children with severe TBI. This group scored significantly lower than the control group across areas of cognitive flexibility, information processing and goal setting. No difference between the groups was found for attentional control. Children with severe TBI

were also rated lower on behavioural manifestations of EF as measured by the Behavior Rating Inventory of Executive Function scale (BRIEF; Gioia et al., 2000). This included problems such as adapting to new situations and short attention spans (Nadebaum et al., 2007).

A follow-on study of this cohort of children was also conducted 10 years after TBI (Beauchamp et al., 2011). They found the differences in certain EF domains were still seen for children with severe TBI. At 10 years post-injury deficits were only seen in the areas of goal setting and processing speed, although mean scores for these measures were still in the low average to normal range, suggesting only a mild impairment. Somewhere between the five year and 10 year assessments, impairment in cognitive flexibility appeared to have resolved with mean scores in the normal range for all groups 10 years post-injury. They also found no significant difference on the BRIEF (bar the initiate scale). Beauchamp and colleagues (2011) suggest that lingering EF deficits at 10 years post-TBI are no longer mirrored by inappropriate behaviours in everyday life and instead are only noticeable via specific cognitive tests of EF.

Another study by Chapman and colleagues (Chapman et al., 2010) looked at EF alongside behavioural and social competence outcomes after early childhood TBI. Children who had sustained either a moderate ( $n = 55$ ) or severe ( $n = 21$ ) TBI between the ages of 3 to 7 years were compared to an OI group ( $n = 93$ ), up to 18 months post-injury. The executive functioning of the children was measured via parent ratings from the BRIEF, with the General Executive Composite (GEC) used as a broad-based measure of EF. Children with severe TBI were found to have impaired performance in overall EF more often than the OI group, across the 18 months post-injury. At 18 months post-TBI, 42 % of the

severe group were in the clinically elevated range for the BRIEF summary GEC score compared to only 10% of the OI group. While the moderate TBI group had a larger proportion of children in the clinically elevated range than the OI group, these differences were not statistically significant.

As EF skills continue to develop right through into adolescence, long-term follow-up is especially vital for children injured at a young age; the full extent of difficulties in EF may not become evident until later years (Anderson & Catroppa, 2005). EF skills are also important, as they are reported to play a role in the development of other vital areas of child functioning, including social competence. The importance of social functioning in relation to the school transition is explored below.

### **Social Competence**

**The Importance of Social Competence.** The area of social competence in early childhood is one that has received increasing attention in recent years. Social competence is thought to play an important role in not only academic success, but also on a child's current and later well-being and mental health (Denham et al., 2003; Huffman et al., 2000; Raver & Knitzer, 2002). Social competence skills developed during preschool years can impact on how well a child transitions into school, as well as their ability to interact with others throughout their life (National Scientific Council on the Developing Child, 2004).

While a range of definitions still exist for social competence, one main theme involves an individual's ability to effectively interact with those around them, including their parents, teachers and peers (Fabes et al., 2006). A socially competent school-aged child is able to: cooperate with peers and make friends; has sufficient communication and language skills; is able to regulate their

emotions and understand the emotions of others; and is able to control their anger (Bierman & Erath, 2006; The Child Mental Health Foundations and Agencies Network (FAN), 2000). Deficits in any of these areas can cause problems such as poor social interactions and rejection or unacceptance by their peers (Denham, 2006). This can cause a negative spiral, as these social problems can result in a reduction of social experiences, and opportunities to develop further social skills. This in turn may result in the child falling even further behind socially (Ladd, 1990; Yeates & Anderson, 2008).

The school transition is also a time where children have to learn to interact with other children and adults outside of their family (McWayne, Cheung, Wright, & Hahs-Vaughn, 2012). The teacher-child relationship plays an important role in how a child settles into school and on later school performance. Children who are able to form a positive relationship with their teacher are more likely to enjoy school and achieve more than children with a more negative teacher-child relationship (Denham, 2006).

During the preschool years, relationships with peers become a crucial tool for continuing socialisation (Bierman & Erath, 2006). Unlike family members, children can be much less tolerant of poor social behaviour and less inclined to continue interacting with a child who exhibits poor social interactions (Fabes et al., 2006). Ladd (1990) suggests that children who were able to make and sustain new friends over their first year of school tended to advance in academic performance over the year. On the other hand, early peer rejection was predictive of not only lower academic performance over the first year of school, but also school avoidance and less positive attitudes towards school in general.

Problems in social functioning can occur either directly – via interruption of a certain cognitive or social skill – or secondarily through reduction of social opportunities and interactions. These deficits in social skills may also present in different forms, such as appearing as problem behaviour, or as psychological distress (Beauchamp & Anderson, 2010). Difficulties may arise when teachers, or other individuals, fail to understand that problem behaviour (for example) may be the result of poor social functioning, rather than just misbehaviour (Jantz & Coulter, 2007).

**The Impact of TBI on Social Competence.** As with EF, higher level social skills are believed to be mediated by the frontal regions of the brain (Beauchamp & Anderson, 2010). As previously mentioned in the EF section, these frontal regions are particularly vulnerable to insult after TBI.

While more research now exists on outcomes after preschool TBI, few of these studies have examined social competence at this young age. Research on the social competence of school-age children has found that children with moderate or severe TBI have poorer social skills than a control group, as rated by both parents and teachers (Ganesalingam, Sanson, Anderson, & Yeates, 2006). Difficulties in social and emotional competence – such as poor interpersonal skills and a decrease in the number of friends – are also reported to be one of the areas of greatest worry and concern for parents of children with TBI (Aitken et al., 2009; Prigatano & Gray, 2007).

A study by Limond et al. (2009) looked at parent ratings of QOL and emotional and behavioural functioning after childhood TBI. Children between the ages of 5 to 15 years were followed up between 2 to 5 years post-TBI. The Strengths and Difficulties Questionnaire (SDQ; Goodman, 1999) was used to

compare 47 school-aged children with mild or moderate/severe TBI to a normative population (Meltzer, Gatward, Goodman, & Ford, 2000). Difficulties after TBI were most common for the Pro-social and Emotional Symptoms subscales of the SDQ. They found that children with TBI had difficulties with pro-social behaviour and emotional functioning. They also had higher rates of hyperactivity, conduct problems, and peer problems than would be expected based on a normative sample.

Yeates et al. (2004) also looked at the social outcomes of children aged 6 to 12, who had sustained moderate ( $n = 56$ ) or severe TBI ( $n = 53$ ). These children were compared to an OI group ( $n = 80$ ), on average, 4 years post-injury. Social functioning of the children was examined using the subscales Social Competence and Social Problems from the Child Behavior Checklist (CBCL; Achenbach, 1991). The severe TBI group had greater difficulties in the areas of social competence and social problems than the OI group. These differences were especially prominent when severe TBI was associated with lower family functioning, or fewer family resources. These findings add to literature that suggests social outcomes after TBI are moderated by family and environmental factors (Taylor et al., 2002; Yeates et al., 2004).

Yeates et al. (2004) also reported very little recovery in social functioning over time; group differences stabilised from 12 months post-injury, with no signs of any further recovery after this time. These results emphasise the potential for persisting problems in social functioning after childhood TBI. Measures of EF were also found to contribute to social outcomes after TBI (Yeates et al., 2004). This is in support of the notion that EF plays a critical role in the development of

social competence (Ganesalingam et al., 2006; Ganesalingam, Sanson, Anderson, & Yeates, 2007; Yeates & Anderson, 2008).

Not all studies have reported deficits in social competence after TBI. Crowe and colleagues (Crowe, Catroppa, Babl, & Anderson, 2012) examined social outcomes of 53 children with mild or moderate/severe TBI, injured before the age of 3. They found no difference between the TBI groups and a non-injured control group when assessed, on average, 40 months post-injury. Chapman et al. (2010) followed children aged between 3 and 7 at injury, for 18 months after TBI. They also found only minimal difficulties for social competence for TBI group versus an OI group. Given the relatively young age at the follow-up assessments, it may be that difficulties in social functioning are not yet apparent. Deficits may not emerge until children are older and social functioning and expectations placed on the child increase (Chapman et al., 2010). Research is necessary to follow up these younger children into later school years to examine longitudinal outcomes of social competence after TBI.

### **Behavioural and Adaptive Functioning**

The final area to be examined is the impact of behavioural functioning on a child's transition to school. Adaptive and behavioural outcomes after preschool TBI will also be explored, in relation to the potential difficulties they may cause during this transition period.

**Behavioural Functioning and Early Development.** A young child's behavioural and adaptive functioning plays a vital role during their transition to school (Raver & Knitzer, 2002). Preschool children with externalising behaviour difficulties (such as increased aggression and hyperactivity) are at greater risk of persistent externalising behavioural patterns, not only during early school years,

but throughout their life (Silver, Measelle, Armstrong, & Essex, 2005).

Behavioural problems in the classroom can also have a negative impact on the child's academic skills such as language, mathematics and literacy outcomes (Bulotsky-Shearer & Fantuzzo, 2011; Graziano et al., 2007). Children with behavioural problems are also more likely to drop out of school and undertake delinquent behaviour as teenagers (Silver et al., 2005).

Behavioural problems can also impact on those around the child. Arnold and colleagues (Arnold, McWilliams, & Arnold, 1998) found that disruptive behaviour was the biggest challenge that teachers encountered within the classroom. The importance of the teacher-child relationship was highlighted in the social competence section as a factor in children's academic, emotional and social development (Hamre & Pianta, 2001; The Child Mental Health Foundations and Agencies Network [FAN], 2000). Teachers may have lower levels of tolerance for children with behavioural difficulties, and in turn react more negatively to them (Graziano et al., 2007). Children who are considered hard to teach may receive less positive feedback and instruction from their teacher than children with more pro-social behaviour. They may also receive less positive reinforcement for cognitive achievements, as teachers are less likely to recognise these skills in children with perceived problem behaviours (Arnold et al., 1999; Raver & Knitzer, 2002). These factors can all lead to a poor teacher-child relationship, which in turn can influence the child's academic performance, along with their attitude towards school and learning (Graziano et al., 2007; Ladd, 1990).

**Impact of TBI on Behavioural and Adaptive Functioning.** Deficits in behavioural functioning are commonly reported after childhood TBI. Difficulties include problems with both internalising (intrapersonal behaviours such as anxiety

and depression) and externalising behaviours (e.g., hyperactivity and aggression; Ganesalingam et al., 2006; McKinlay et al., 2010; Taylor et al., 2001; Thaler et al., 2010). Having to cope with changes in children's behaviour after TBI is one of the prominent causes of stress and worry for families (Anderson et al., 2006). Behavioural deficits after childhood TBI can be long lasting, with little evidence of recovery (Anderson et al., 2005; Kinsella, Ong, Murtagh, Prior, & Sawyer, 1999; Taylor et al., 2002).

Lower levels of adaptive function can also be seen, especially after severe TBI (Anderson, Le Brocque, et al., 2012; Arroyos-Jurado, Paulsen, Merrell, Lindgren, & Max, 2000; Ganesalingam et al., 2006). Adaptive functioning describes a child's ability to function and take part in everyday life. This includes areas of socialisation, communication and daily living skills – such as age appropriate skills in self-care and independence (Reynolds & Kamphaus, 2004). Anderson et al. (2005) examined the adaptive functioning of 150 children between the ages of 3 and 12, who had sustained mild to severe TBI. While the mild group had stable adaptive scores (as measured by the Vineland Adaptive Behaviour Scale [VABS]), the moderate and severe TBI groups showed a decrease in adaptive functioning over the 30 months post-injury. This decline was seen across the areas of socialisation, communication and daily-living skills.

Using this same cohort of children, Anderson et al. (2001) focused on the adaptive functioning of children 3 to 7 years old with mild TBI ( $n = 17$ ) compared to a control group ( $n = 35$ ), up to 30 months post-TBI. They found that parent ratings of the child adaptive abilities from the VABS were comparable to the control group across all time points. A study by Anderson et al. (2006) also examined this same cohort of children between 2 to 7 years of age. They found

that while the moderate and severe TBI group reported slight decreases in adaptive functioning over time, the mild and control groups recorded increases in adaptive abilities over 30 months post-injury.

Chapman et al. (2010) also examined the behavioural outcomes of children, between the ages of 3 and 7, up to 18 months post-TBI. They used the CBCL parent form to examine parent ratings of child behaviour on the externalising, internalising and ADHD subscales. Children in the severe group ( $n = 21$ ) were found to have significantly greater levels of new onset behavioural problems than an OI group ( $n = 93$ ). Externalising behaviour was found to be raised across all assessment time points; this is in line with previous research, showing the long-term impact of more severe TBI on externalising behaviour (Anderson et al., 2006; Yeates & Taylor, 2006). On the other hand, no significant difference was seen between the OI and moderate TBI ( $n = 55$ ) groups.

One issue with Chapman et al. (2010) findings was that the severe TBI group had higher levels of pre-morbid behavioural difficulties. Continuing debate exists as to whether or not behavioural problems found after TBI are in fact the result of the TBI, or if they are influenced by pre-injury factors. Some researchers argue that children with TBI are more likely to have pre-injury difficulties in areas such as developmental and behavioural functioning, and therefore are not a fair representation of the general population (e.g., Asarnow et al., 1995; Goldstrohm & Arffa, 2005).

Goldstrohm and Arffa (2005) allege that while preschoolers who sustained mild or moderate TBI had increased levels of behavioural problems, pre-morbid behavioural functioning accounted for most of these difficulties six months post-injury. They concluded that mild or moderate TBI had little persisting impact on

behavioural functioning. This study however, only looked at outcomes for TBI six months after injury. In this short time frame it may be that deficits have yet to appear. Behavioural problems may not become more apparent until the child is older, when increased expectations are placed on behavioural functioning (Fabes et al., 2006).

In contrast, Donders (1992) contests that deficits in pre-morbid psychosocial functioning occur no more often for children with TBI, than for the general population. (Anderson et al., 2005a) also purport that pre-injury characteristics, such as pre-injury behaviour, were insufficient to explain post injury differences in cognitive functioning between the TBI severity groups. Other studies by Anderson and colleagues (Anderson et al., 2009; Vicki A. Anderson et al., 2006) have found similar pre-injury functioning for children with mTBI compared to children without TBI.

Chapman et al. (2010) also highlight that while their severe TBI group had higher behavioural difficulties pre-TBI, they also showed increasing levels of behaviour problems over time. This could suggest that increased deficits in behavioural disturbance are still seen after severe TBI, over and above pre-injury behavioural levels. It is difficult, however, to reliably assess premorbid functioning post-injury. The ideal way of accurately identify pre-injury behavioural functioning is via cohort studies.

A study by McKinlay et al. (2010) used a birth cohort study from New Zealand to examine the long-term impact of mTBI on the behavioural outcomes of children, under the age of five at injury. They further separated the category of mTBI into an inpatient mTBI group (children that had been admitted to hospital for less than 2 days;  $n = 28$ ), and an outpatient mTBI group (children that were

seen by their GP or at an Accident and Emergency Centre;  $n = 84$ ). The remaining children in the birth cohort that had not received a head injury of any form made up the control group ( $n = 807$ ). Parent and teacher ratings of the child's behaviour were examined using items adapted for the Rutter and Conners Questionnaires (in line with the Diagnostic and Statistical Manual – Third Edition [DSM-III] criteria for Oppositional Defiant Disorder [ODD]/Conduct Disorder [CD] and Attention Deficit Hyperactivity Disorder [ADHA]; Fergusson, Horwood, & Lloyd, 1991). Children in the more severe inpatient mTBI group were more likely to experience adverse externalising behavioural outcomes between the ages of 7 to 13 than both the control group and the outpatient mTBI group. The inpatient group had more symptoms of ADHD, and ODD/CD, as well as increased levels of hyperactivity/inattention. On the other hand, the outpatient group scores were similar to the control group. An additional “other hospital accident” group was created to take into account factors linked with hospitalisation, and this too was found to have scores comparable with the outpatient and control groups. These results suggest that for some children, mTBI can result in significant impairment in behavioural functioning that persists over time. Other children however – with less severe mTBI – appeared to have no long lasting deficits in behavioural functioning.

Many studies on behavioural outcomes after childhood TBI rely on parent reports of child behaviour. While parent ratings provide valuable insight on a child's behaviour in their home and social setting, children's behaviour in a classroom setting can be vastly different (Yeates & Taylor, 2006). Yeates and Taylor (2006) examined the behavioural and emotional outcomes of children between 6 and 12 years as reported by their teachers on the CBCL teacher form.

Children with moderate ( $n = 56$ ) or severe TBI ( $n = 53$ ) were compared to an OI group ( $n = 80$ ). They found that children with severe TBI had higher teacher ratings of behavioural problems than the OI group, up to four years post injury. Rather than showing specific behavioural problems, more generalised behavioural difficulties were present, highlighting the broad range of adjustment problems that can occur after childhood TBI. Behavioural functioning in the TBI groups also showed no improvement over time, suggesting that these problems can be long-lasting. These behavioural problems were also predictive of children's academic performance, emphasising the role of behavioural adjustment on school achievement (Yeates & Taylor, 2006).

Goldstrohm and Arffa (2005) also stress the complexity of preschool TBI and suggest that outcomes may differ depending on other factors, outside of injury severity. Current research highlights the need to examine factors such as the family and social environment and the role they play on recovery after TBI. The impact of social factors on TBI outcomes is discussed briefly below.

### **The Impact of the Family and Social Environment Outcomes after TBI**

It is widely recognised that there is considerable variability in individual outcomes after childhood TBI, even within severity groups (Anderson et al., 2005; Taylor et al., 2008). It is now commonly accepted that outcomes after childhood TBI involves a complex interaction between injury characteristics, developmental variables and the family and social environment of the child (Anderson et al., 2005; Yeleswarapu & Curran, 2010).

Different variables seem to influence outcomes after childhood TBI. Social and behavioural outcomes appear to be more strongly predicted by factors relating to the social and environmental circumstances of the child, whereas

cognitive outcomes are more predicted by injury factors relating to the TBI (Gerring & Wade, 2012; Muscara, Catroppa, Eren, & Anderson, 2009; Taylor et al., 2002; Yeates et al., 2004; Yeates, Taylor, Walz, Stancin, & Wade, 2010). Yeates et al. (2010) suggest that cognitive functioning is related to the integrity of the central nervous system (CNS), and consequently is less affected by environmental variables. On the other hand, social and behavioural outcomes are impacted by both CNS integrity and characteristics of the child's home and social environment.

The TBI Common Data Elements work group (CDE) highlight the need to examine risk and protective factors – such as family functioning, parent-child interactions and SES – and the impact they have on recovery after childhood TBI (Gerring & Wade, 2012). Understanding what factors may place a child at greater risk of deficits following TBI – or conversely potentially protect them from problems – is particularly important when it comes to assessing rehabilitation options after TBI.

For children that are younger at time of injury, proximal factors – such as family function and parent-child interactions – are especially important, as young children have less influence from outside sources on their development. Factors associated with family environment can play a vital part in subsequent outcomes and recovery in young children after TBI (Crowe et al., 2012; Taylor et al., 2001). Some suggested that detrimental effects of TBI may be buffered by more positive family functioning and social environments (Taylor et al., 2002; Yeates et al., 2004; Yeates et al., 2010). Levels of family functioning, along with SES and parental mental health, have also been found to predict intellectual ability, social competence and behavioural functioning after childhood TBI (Crowe et al., 2012).

Parental marital status may also impact on a child's recovery after TBI (Tompkins et al., 1990).

### **Summary and Aims**

Preschool TBI is a prominent health concern that can detrimentally impact the lives of children, families and society at large. Young children are at particular risk due to the high incidence of TBI in this age group, along with the potential for TBI to disrupt both current functioning and ongoing development. Additional strain can be placed on a child when they have to navigate the transition to school. How successfully a child can make this transition can impact on later academic performance, behaviour, and their social functioning across their lives.

Skills associated with a successful transition include cognitive ability, behavioural functioning and social competence. All of these areas can be negatively affected after TBI. Moderate or severe TBI is commonly associated with deficits in the following areas: cognitive and intellectual abilities; academic achievement; executive functioning; adaptive and behavioural functioning; and social competence. The impact of mild TBI is less understood across preschool TBI, with inconsistent findings throughout literature. The shortage of methodologically sound research on preschool TBI – particularly for areas of EF, social competence and mild TBI – highlights the need for further research on this age group.

The current study sought to address some of these gaps in literature by investigating the impact of TBI on a population-based sample of children, who were 4 years old at time of injury. Children were assessed across a wide range of domains including: cognitive and intellectual functioning; academic performance; executive functioning; adaptive and behavioural functioning; and social

competence. These skills were focused on, as they are all associated with a child's successful transition to school. Children were followed up over the 24 months post-TBI. The aims and hypotheses of this study were as follows:

**Aim 1:** To examine outcomes of cognitive, behavioural and adaptive functioning of the TBI group at 12 and 24 months post-injury. It was hypothesised that cognitive functioning of the TBI children would remain stable, and within the average range, between 12 and 24 months post-TBI. Behavioural difficulties were predicted to increase from 12 to 24 months, with a decrease in adaptive abilities over this same period.

**Aim 2:** To investigate whether children, who sustained a TBI at age 4, differed from a community based control group across various measures of everyday functioning at 24 months post-injury. Parent and teacher rated measures of behavioural and adaptive functioning, social competence, and executive functioning were examined - along with child measures of cognitive, intellectual and academic abilities. It was hypothesised that children in the TBI group would perform more poorly across all overall composite scores for each measure examined.

## Method

### Participants

**TBI group.** Participants for the TBI group were initially recruited via the Brain Injury Incidence and Outcomes New Zealand in the Community (BIONIC) study. This was a population-based study that sought to examine the incidence and outcomes of TBI across all age groups (Theadom et al., 2012). Participants were recruited for the BIONIC study if they had experienced a TBI between the period of March 1st, 2010 and February 28th, 2011. Inclusion criteria involved living in Hamilton City (urban), or in the Waikato District (rural), New Zealand. This geographical area was selected for the study as it contained a representative sample of the overall population of New Zealand (Statistics New Zealand, 2006). Participants were also required to have lived within this designated region for at least one year prior to their head injury. No other exclusion criteria were employed for the TBI group.

The definition of TBI used by the BIONIC study was based on the World Health Organisation (WHO) definition, as recommended by the NZ Guidelines Group (NZGG; 2006). TBI was defined as “an acute brain injury resulting from mechanical energy to the head from external physical forces” (Carroll et al., 2004, p. 115). Operational criteria for a classification of TBI involved the participant reporting at least one of the following symptoms following their head injury: 1) disorientation or confusion; 2) loss of consciousness; 3) post-traumatic amnesia; or 4) other neurological abnormalities (e.g. seizure, intracranial lesion or focal neurological signs).

With children, medical or behavioural changes also needed to be observed directly after the head injury – alongside signs of a head trauma – in order for a

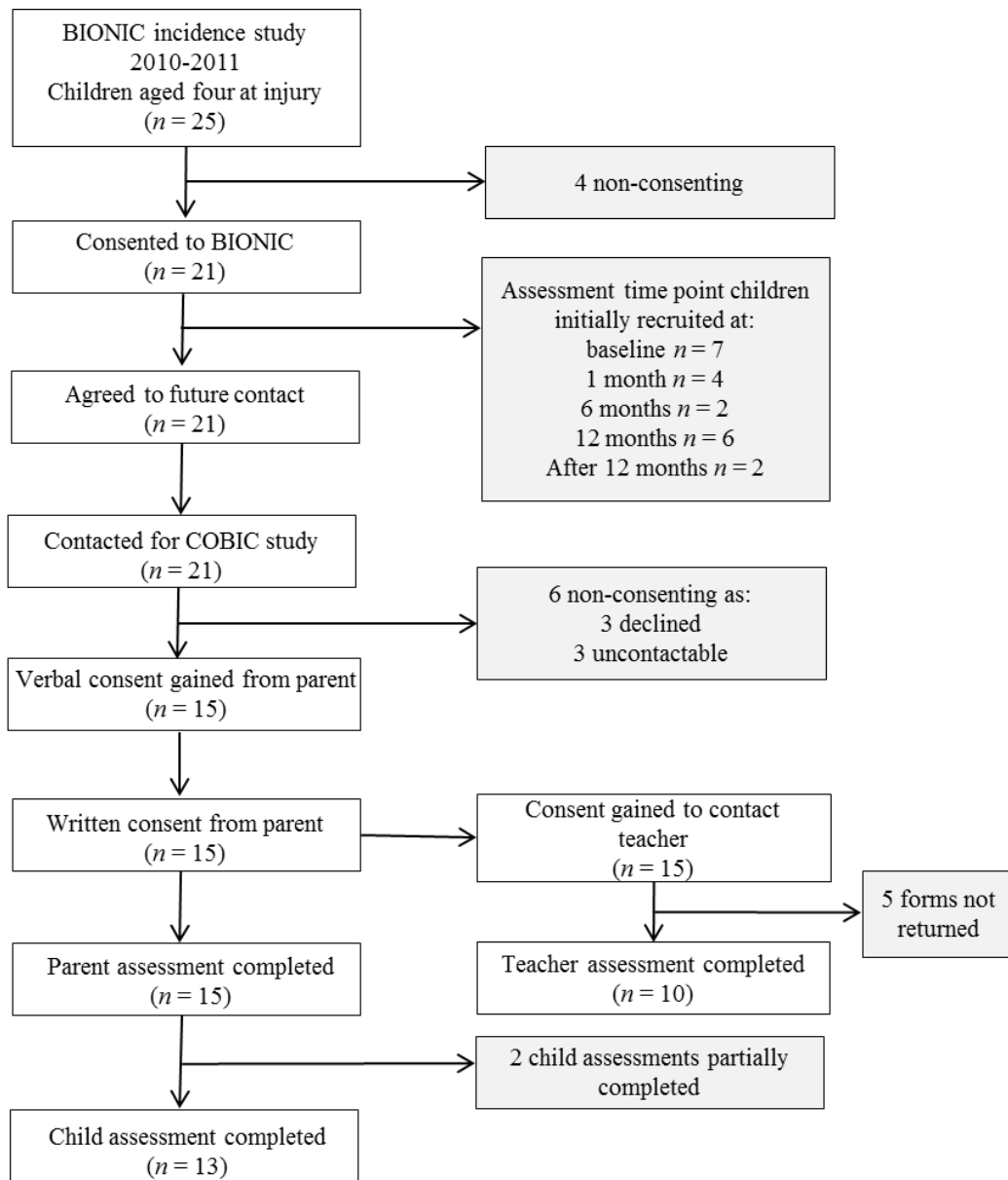
classification of TBI. Observable changes included signs or symptoms such as vomiting, persistent crying, being very quiet (out of character), irritability, lethargy, sleepiness, food refusal, disorientation, headaches, or being described as ‘out of sorts’ (Theadom et al., 2012). Further in-depth detail of the methodology used in the original BIONIC study can be found in Theadom et al. (2012).

Those participants that consented to be part of the BIONIC study were followed up over the 12 months following their TBI. During the 12 month post-injury assessment participants and their parents were asked if they gave their permission to be contacted regarding any related studies. This current study was part of a larger longitudinal study known as the Consequences of Brain Injury in Childhood (COBIC) study, which followed on from the BIONIC study by investigating the outcomes of TBI on children (0 to 16 years old) at 24 months post-injury.

For this current study, any families with children that were 4 years old at date of injury, who had agreed to contact regarding future studies, were contacted and invited to take part in a 24 month follow-up assessment. Inclusion criteria for the current study included any participants that were eligible for the BIONIC study and who were between the age of 4 years 0 months and 4 years 11 months 30 days at date of injury.

The recruitment of participants from the BIONIC study into the current study is shown as a flowchart in Figure 3. Two of the children from the TBI sample were unable to complete all assessment measures. Two of the measures (WISC-IV and WJ III ACH) required a substantial understanding of the English language and these two children only spoke English as their second language. One of these children was also unable to complete the second child assessment (WJ III

COG) due to a change in family circumstances that prevented the completion of the assessment within the designated timeframe.



*Figure 3.* Flowchart showing the recruitment and assessments completed for children in the TBI group.

**Control group.** Control participants were recruited to match the age and gender of the TBI participants at their 24 month post-injury assessment. As a result, recruitment into the control group required participants to be between the age of 6 years 0 months and 7 years 0 months. Like the TBI group, participants

recruited for the control group also had to be residents of either Hamilton City or the Waikato District.

Participants for the control group were recruited predominately through flyers that were sent home from school to the parents of children that were in the targeted age group. In order to try and recruit a control group of similar socio-economic status to the TBI group, any school where a child with TBI attended was approached first and asked for permission to hand out flyers about the study. If this was unsuccessful, other schools of similar decile rating or location were then approached, throughout both Hamilton City and the Waikato District. If the school was unsure about sending flyers home they were instead asked if an advertisement could be put in their school newsletter. Children were also recruited to the control group via the friend-control method. In this case, the parents of the children in the TBI group were asked if they knew any other children the same age, who might be interested in taking part.

Exclusion criteria for the control group included any child that had previously experienced a TBI. The main exclusion question asked was “Has your child ever hit their head so hard that you sought medical attention?” If the parent or caregiver was unsure about any previous head injury their child had sustained, additional questions were asked to ascertain the severity of the injury. Any children that would have met the criteria for TBI in the BIONIC study were excluded from the control group. As the TBI participants were originally recruited as part of a population-based study, no further exclusion criteria were used for the control group.

**Sample characteristics.** The sample characteristics of the TBI and Control groups are shown in Table 2. The two groups were compared across

demographic variables, using either the likelihood ratio statistic ( $L\chi^2$ ) or t-test, as applicable. The total sample contained 18 boys and 12 girls. While the sample contains a higher number of boys than girls – reflecting a greater incidence of TBI in males than females – there was no difference between the two groups in relation to gender. No difference was found between the TBI or control group in relation to if they lived in urban Hamilton versus rural Waikato ( $L\chi^2 (1) = 0.60, p = .70$ ), or for which ethnicity they identified as ( $L\chi^2 (2) = 2.43, p = .32$ ). The control group did however have a significantly higher SES than the TBI group ( $t(28) = -2.33, p = .03$ ).

Table 2  
*Sample characteristics of participants at 24 month assessment*

Child Characteristics	Group			
	TBI (n=15)		Control (n=15)	
Male, <i>n</i> (%)	9	(60.0)	9	(60.0)
Classified Ethnicity				
NZ European, <i>n</i> (%)	9	(60.0)	10	(66.7)
NZ Māori, <i>n</i> (%)	5	(33.3)	2	(13.3)
Other ethnicity, <i>n</i> (%)	1	(6.7)	3	(20.0)
Urban, <i>n</i> (%)	9	(60.0)	11	(73.3)
School decile, <i>Mdn (range)</i>	6	(9.0)	6	(7.0)
Socioeconomic status, <i>M (SD)</i> <sup>a</sup>	52.5	(21.1)	68.4	(16.0)
Age at injury (in years), <i>M (SD)</i>	4.6	(0.3)	NA	NA
Age at 24 month assessment (in years), <i>M (SD)</i>	6.6	(0.3)	6.6	(0.3)
Time since injury at 24 month assessment (in years), <i>M (SD)</i>	2.0	(.06)	NA	NA

*Note:* TBI = traumatic brain injury; NA = not applicable  
<sup>a</sup> significant difference between TBI and control (t-test,  $p < .05$ ).

***Injury characteristics.*** Information about the severity and other characteristics of the TBI can be found in Part 1 of the Results section.

***Ethnicity.*** Each child’s parent/caregiver was provided with a list of different ethnicities (including an option of “other – please specify”) and asked to

indicate which of those ethnicities the child identified as. Parents were able to choose as many ethnicities as applicable. In line with the initial BIONIC study methodology (Feigin et al., 2013), in instances where several ethnicities were chosen a prioritisation system was used to obtain a single ethnicity. Participants were classified as NZ European, Māori, or other. The category of ‘other’ was a heterogeneous group, with all other ethnicities aggregated due to the small number of individuals in the remaining ethnic categories. Children with mixed ethnicity were classified in the following order: (1) any child that identified as Māori, regardless of any other ethnicities selected, was classified as “Māori”; (2) any remaining children who had identified with mixed-ethnicity were classified as “other”.

*Medical history.* There were no parent-reported intellectual, development, or behavioural problems for either the TBI or Control group at the time of 6-year old assessment (24 months post-TBI). Very few health problems were reported by parents across both groups; the most commonly reported health problems being asthma, allergies, and eczema. One child in the Control group was diagnosed with epilepsy.

## **Materials**

A range of measures were used that examined various domains of functioning commonly found to be susceptible to TBI, such as cognitive, behavioural and social functioning. Standardised measures were chosen that followed on from those measures used in the original BIONIC study. This helped ensure that comparisons could be made more easily over time, and across age groups. Measures chosen by BIONIC covered a large age range, as well as being

fairly brief and straightforward to administer. Shortened forms were also used where applicable to limit assessment time for the children.

**Demographic and background information.** Demographic information relating to both the child and their parent/caregiver was collected using a questionnaire during the BIONIC initial assessment, and again at the current two year assessment time point. Data collected on the parent/caregiver included information such as their age, gender, occupation, educational attainment and their marital status. Questions were also asked about the parent/caregivers mental health. Information on the medical history of the child along with any pre-injury behavioural, learning or developmental problems were also collected.

***Socio-economic status (SES).*** The socio-economic status of the family unit was estimated based on the occupation of the parents/caregiver living in the same household as the child. The occupation for each parent/caregiver was coded using the Australia and New Zealand Standard Coding of Occupations (ANZSCO), which is available on the Australia Bureau of Statistics (ABS) website ([www.abs.gov.au](http://www.abs.gov.au)). These codes were then converted into scores using the Australian Socioeconomic Index 2006 (AUSEI06; McMillan, Beavis, & Jones, 2009). The AUSEI06 was used as there is no socio-economic index available in New Zealand based on the ANZSCO codes.

Scores on the AUSEI06 scale range from 0 to 100, with labourers receiving the lowest scores and medical professionals the highest values. Higher scores on the AUSEI06 are indicative of higher SES. When a parent/caregiver was not in current paid employment, the codes for the AUSEI06 were estimated based on the respondent's highest level of education (McMillan et al., 2009). In situations where a family unit had two parents/caregivers living in the home, the

parent with the highest AUSEI06 score was used as an estimate of SES for that family.

***Traumatic brain injury characteristics.*** The TBI severity for each participant was classified based on Glasgow Coma Scale (GCS), with the scores as follows: mild (GCS score of 3 to 8), moderate (score 9 to 12) or severe (score of 13 to 15; Teasdale & Jennett, 1974). Scores for the GCS were recorded either at the scene of the accident, or on admission to hospital or medical centre. Where no GCS was reported on medical files, the TBI was classified as mild, as GCS scores were unable to be retrospectively assigned.

Due to the high number of TBI cases that were mild in severity, further classification was used to distinguish mTBI. Participants with mTBI were classified as either ‘low-risk’, ‘medium-risk’, or ‘high risk’ based on criteria developed by Servadei, Teasdale, and Merry (2001). This criteria classified mTBI using both measures of GCS and PTA scores, along with the presence or absence or various neurological (e.g. impaired vision or speech), clinical (e.g. amnesia or vomiting) and risk factors (e.g. pre-trauma epilepsy). A copy of the table used in the original BIONIC study to classify mTBI can be found in Appendix A.

***Hospital Anxiety and Depression Scale (HADS).*** The HADS was used in to assess parent/caregiver levels of depression and anxiety. The HADS is a brief 14 item self-report questionnaire, developed by Zigmond and Snaith (1983) to examine levels of depression and anxiety in non-psychiatric populations. It is comprised of an Anxiety subscale and a Depression subscale, with seven of the items related to each subscale.

The Anxiety subscale assesses the respondent’s worries and fears with statements such as “Worrying thoughts go through my mind” and “I can sit at ease

and feel relaxed”. The depression subscale primarily examines the respondent’s ability to feel pleasure (anhedonia) with statements such as “I can laugh and see the funny side of things” and “I feel as if I am slowed down.” Both the HADS Depression and Anxiety subscales were used in this current study, as an indication of the current mental health status of the parent/caregiver.

The HADS is scored on a 4-point Likert scale, with scores ranging from 0 to 3 for each question. The respondents are asked to select the response that best described how much time over the previous week each statement applied to them. The minimum score for each subtest is 0 with a maximum score of 21. Higher scores on both subtests suggest greater difficulty with depression or anxiety. A score between 0 -7 on either subscale is considered to be within the normal range, while a score of 8 - 10 is suggestive of the possibility of the respective mood disorder. Conversely, a score above 11 on either subscale is considered to indicate the likely presence of that particular mood disorder (Snaith, 2003).

The HADS has been extensively used, both in non-psychiatric hospitals settings (as it was initially designed for) and within the general population (Bjelland, Dahl, Haug, & Neckelmann, 2002). In total, the questionnaire takes between 2-5 minutes to complete and can be independently completed by the respondent.

The concurrent validity of the HADS is considered to be good, with correlations between the HADS and other commonly used questionnaires for depression and anxiety ranging from 0.60 and 0.80 (such as the State-Trait Anxiety Inventory, Beck Depression Inventory and the Symptom Checklist 90 Scale; Bjelland et al., 2002). The HADS is deemed to perform well in screening

and assessing the probable presence of depression and anxiety disorders across not only medical and psychiatric patients, but also within the general population.

**Performance based measures of child functioning.** Measures of child cognitive functioning (WJ III COG), intellectual ability (WISC-IV) and academic achievement (WJ III ACH) were completed to assess the children's functioning across these domains.

*The Woodcock-Johnson®III Tests of Cognitive Abilities (WJ III COG).*

The WJ III COG was administered to examine the general level of cognitive ability of the TBI group over time (post-TBI), as well as in comparison to a healthy control group. The WJ III COG was completed at all assessment time points for the original BIONIC study (i.e., baseline, 1 month, 6 months and 12 months). For the current study, both the TBI group and Control group completed the WJ III COG as part of the 6-year old assessment (24 months post-TBI).

The WJ III COG is an individually administered, norm-referenced measure that was designed to assess the general and specific cognitive functioning of individuals between the ages of 2 to 90 years and over (Woodcock, McGrew, & Mather, 2001). The WJ III COG is centred on the Cattell-Horn-Carroll (CHC) theory of cognitive abilities, which is a comprehensive framework of the structure of human cognitive abilities (McGrew & Woodcock, 2001).

The standard battery consists of 10 subtests, with an additional 10 subtests in the extended version. For the current study, the standard battery was administered along with three of the additional subtests - taking approximately 75 minutes to administer. Details of the subtests that were administered, along with information on the task required for each subtest, are shown in Table 3. A General Intellectual Ability (GIA) score was also obtained that is an index of general

cognitive functioning. The GIA is calculated based on the scores from the first seven subtests (as shown in Table 3).

Table 3  
*Summary of WJ III COG subtests administered and tasks required*

Subtest	Task required*
1. Verbal Comprehension	Four orally presented tasks of: naming pictured objects, providing synonyms and antonyms, and completing analogies
2. Visual-Auditory Learning	Learning and recalling pictographic representations of words
3. Spatial Relations	Identify from a series of shapes the pieces needed to form a complete shape
4. Sound Blending	Synthesise a series of orally presented sounds (syllables/phonemes ) to form a whole word
5. Concept Formation	Identifying what is different about drawings inside a box from drawings that are outside the box
6. Visual Matching	Rapidly identify and circling the two numbers that are identical across a row of numbers, and repeating this process for a specified time period
7. Numbers Reversed	A list of digits are presented orally (progressing from 2 to 7 numbers) and must be repeated in reverse order
8. Incomplete Words	Identify orally presented words that are missing phonemes
9. Auditory Working Memory	Retaining a mixed set of numbers and words and reordering them, before repeating first the words in order presented, followed by the numbers in order presented
10. Visual-Auditory Learning Delayed	Recall and relearn pictograph representations learnt in Test 2 after a delay of 30 minutes to 8 days from initial presentation.
14. Auditory Attention	Identifying orally presented words amid increasing levels of background noise
16. Decision Speed	Identify and circle the two objects in a row of pictures that are the most closely associated
20. Pair Cancellation	Rapidly identify and circle instances of a repeated pattern of two objects

*Note:* Definitions of tasks required from Mather & Jaffe (2002, p. 19-22).

As this current study was interested in the overall cognitive functioning of the children, the overall GIA scores were examined and compared across the TBI and Control groups at the 6-year old assessment (24 months post-TBI). For the

TBI group, who also completed the WJ III COG during initial BIONIC assessments, when no GIA score was able to be calculated, their Brief Intellectual Ability (BIA) scores were examined instead. The BIA is comprised of the following three subscales: Test 1, Verbal Comprehension; Test 5, Concept Formation; and Test 6, Visual Matching. By the 12 month post-TBI assessment, all children who completed the WJ III GOG in the TBI group had GIA scores available.

The WJ III COG was scored using the Australian Adaptation (Version 1.0.1) of the WJ III Compuscore Scoring & Profiles Program – which is available from the publishers (Riverside Publishing, Rolling Meadows, Illinois). The scoring software allows for grade and age equivalents, along with standard scores ( $M = 100$ ,  $SD = 15$ ), percentile ranks and discrepancy scores to be calculated. The WJ III COG also computes several different cluster indices, including the cognitive performance cluster and other clinically useful cluster scores.

Internal consistency for the WJ III COG is good, with reliability coefficients for the cluster indices (standard battery) ranging from 0.88 to 0.97 for children aged 6 years old. Test-retest correlations were undertaken for skills linked with the cognitive category of Thinking Ability (e.g., Incomplete Words and Concept Formation subtests). Correlations for children between 2 to 7 years old ranged from 0.70 to 0.82 (after a retest interval of 1 to 2 years; McGrew & Woodcock, 2001).

*The Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV)*. The WISC-IV is a clinical measure commonly used to evaluate the intellectual ability of children and adolescents between the age of 6 years 0 months and 16 years 11 months (Wechsler, 2003). It is an individually

administered test that provides an overall broad measure of a child's general intellectual functioning (i.e. full scale IQ [FSIQ]), along with information on more specific areas of cognitive functioning. The core measure consists of 10 subtests with an additional five supplemental subtests available.

The Australian standardised edition of the WISC-IV was used in the current study. Normative data for the WISC-IV Australian version was derived from a census-matched sample of children and adolescents from Australia, and is considered a representative sample of the Australian general population. The WISC-IV has good internal consistency, with reliability coefficients for the composite scores ranging from 0.83 to 0.96 for 6 year-old normative sample. Test-retest stability coefficients also provided evidence of score stability, with corrected index coefficients ranging from 0.85 to 0.92 for ages 6 to 7 (with a mean test-retest interval of 32 days; Wechsler, 2003).

The current study used a short version of the WISC-IV as recommended by Sattler and Dumont (2004) that was comprised of four subtests. Any short version of the WISC-IV can only provide an estimated FSIQ (EFSIQ). The EFSIQ has a standardised mean score of 100 along with a standard deviation of 15. The subtests used, along with descriptions of the tasks required by the children, are shown in Table 4. This particular short form has reliability and validity coefficients of 0.94 and 0.93 respectively (Sattler & Dumont, 2004). The sum of the scaled scores for each subtest of this short form can be converted into an EFSIQ using the table A-11 from Sattler and Dumont (2004, p. 314). This short version took approximately 20 minutes to complete.

Table 4  
*Composition of the short form of the WISC-IV*

Subtest	Composite the subtest is part of	Task*
Similarities	Verbal Comprehension	The child is presented with two words that represent common objects or concepts and must describe how they are similar. E.g. "In what way are a pencil and a piece of chalk alike?"
Vocabulary	Verbal Comprehension	For picture items, the child is shown a picture and for verbal items the examiner reads aloud a word. The child's task in both instances is to provide a definition of what that picture or word means. E.g. "What is a ball?"
Matrix Reasoning	Perceptual Reasoning	The child is shown an incomplete matrix and must select the missing piece from five response options
Symbol Search	Processing Speed	The child has to scan a search group and indicate whether the target symbol matches any of the symbols in the search group in a specified time limit

*Note:* \*Definitions of tasks taken from WISC-IV Technical and Interpretative Manual (Wechsler, 2003, p. 14-18).

***The Woodcock-Johnson®III Tests of Achievement (WJ III ACH).*** The WJ III ACH was used at the 6 year-old assessment for both the TBI and Control group. The WJ III ACH was developed alongside the WJ III COG with the purpose of examining the current academic strengths and difficulties of an individual (Woodcock et al., 2001). It is an individually administered comprehensive measure suitable for individuals between the ages of 2 to 90.

The WJ III ACH is made up of 12 standard subtests, with an additional 10 subtests available in the extended version. The WJ III ACH is available in two equivalent versions: Form A and Form B. A Brief version of Form B was used in the current study to reduce administration time. This battery took approximately

30 minutes to complete. The Brief version administered included six subtests from the standard battery. The subtests administered, along with the cluster indices that they contributed to, and the task required for each subtest are shown in Table 5.

Table 5  
*WJ III ACH academic clusters and subtests administered*

Academic cluster indices	Subtest	Task required
Brief Achievement	1. Letter-Word Identification	Identify and pronounce isolated letters or words
	10. Applied Problems	Listen to, then analyse and solve practical math problems
	7. Spelling	Written spelling of words that are orally presented
Brief Reading	1. Letter-Word Identification	Identify and pronounce isolated letters or words
	9. Passage Comprehension	Say out loud the missing word in a written sentence
Brief Math	10. Applied Problems	Listen to, then analyse and solve practical math problems
	5. Calculation	Solve mathematical equations presented on paper
Brief Writing	7. Spelling	Written spelling of words that are orally presented
	11. Writing Samples	Write a sentence based on a picture or demand given

*Note:* Definitions of tasks required from Mather & Jaffe (2002, p. 23).

Academic cluster indices derived from the subtests completed included: Brief Achievement; Brief Reading; Brief Writing; and Brief Mathematics. As with the WJ III COG, the WJ III ACH standard scores ( $M = 100$ ,  $SD = 15$ ) were computed using the Australian Adaptation (Version 1.0.1) of the WJ III Compuscore Scoring & Profiles Program (Riverside Publishing, Rolling Meadows, Illinois). Further cluster scores can be computed with the administration of the full standard battery.

Internal consistency is high for the WJ III ACH, with reliability coefficients for all of the cluster scores (standard battery) ranging from 0.88 to

0.98. Test-retest correlations are also acceptable, with correlations for the cluster indices ranging from 0.74 to 0.96 (1 year interval) for children between the ages of 4 and 7 (McGrew & Woodcock, 2001).

The WJ III ACH was chosen for this current study, as it is one of the recommended measures for use in TBI research on children by the Common Data Elements Workgroup on TBI (McCauley et al., 2012). The WJ III ACH was used to compare the TBI and Control group across broad measures of academic functioning. For this reason, the cluster indices of Brief Achievement, Brief Writing, Brief Mathematics and Brief Reading were used in this current study.

**Measure of executive function.** The Behavior Rating Inventory for Executive Function (BRIEF) was used to explore the overall executive function (EF) skills of the TBI and Control group children, as reported by their parent and teacher, at the 24 month (6 year-old) assessment. The BRIEF is a standardised questionnaire designed to examine EF behaviours of children and adolescents in their everyday environment (Gioia et al., 2000). Both parent- and teacher-report forms are available for children between the ages of 5 and 18 to provide a broad picture of the child's functioning across a variety of settings. The BRIEF was also designed for use across a wide range of children, including those with TBI. The Paediatric Common Data Elements (CDC) Workgroup also recommends the BRIEF as one of the preferred measures to use for research on the impact of childhood TBI on EF (McCauley et al., 2012).

Both the parent and teacher forms of the BRIEF contain 86 items. These items contribute to eight clinical scales that have been empirically derived and measure different aspects of EF. Two composite indexes (i.e., Meta-cognition Index [MI] and Behavioural Regulation Index [BRI]) are derived from the clinical

scales, along with an overall Global Executive Composite (GEC) score. The BRI reflects “the child’s ability to shift cognitive set and modulate emotions and behaviour via appropriate inhibitory control,” while the MI highlights “the child’s ability to initiate, plan, organise and sustain future orientated problem solving in working memory” (Gioia et al., 2000, p. 20). Validity scales (Inconsistency and Negativity) are also derived from the standard items. Table 6 shows the composition of BRIEF forms, along with an example item from each clinical scale.

Table 6  
*Composition of the BRIEF parent and teacher forms*

	Composite	Clinical scale	Item example
Global Executive Composite (GEC)	Behavioural Regulation Index (BRI)	Inhibit	"Interrupts others"
		Shift	"Acts upset by a change in plans"
		Emotional Control	"Overacts to small problems"
	Meta-cognition Index (MI)	Initiate	"Does not take initiative"
		Working Memory	"Has short attention span"
		Plan/Organise	"Has good ideas but cannot get them on paper"
		Organisation of Materials	"Cannot find things in room or school desk"
Monitor	"Makes careless errors"		

Items in the BRIEF are scored on a 3-point Likert scale with the response options of ‘Never’, ‘Sometimes’, and ‘Often’. Each item is a statement that describes possible behaviour in children. The respondent has to specify how often, in the past 6 months, that particular statement has been a problem for the child. Both the parent and teacher forms can be independently completed by the respondent and take approximately 10 to 15 minutes.

Once completed, the BRIEF forms were scored using software available from the publishers (PAR, Lutz FL). This software computes raw scores, T-scores

and percentile norms for all of the composite and clinical scales based on a large normative sample from United States. T-scores have a mean of 50 and a standard deviation of 10; with higher scores indicating a greater level of EF difficulty. A T-score of more than 65 is considered to be clinically significant (Gioia et al., 2000).

Internal consistency is high for both the parent and teacher versions of the BRIEF, with Cronbach's alpha coefficients for the three composites ranging from 0.94 to 0.97 for the parent form and 0.97 to 0.98 for the teacher form. Test-retest reliabilities also ranged from 0.84 to 0.88 for the parent form (average 3 week interval), and 0.90 to 0.92 for the teacher form (average 3.5 week interval; Gioia et al., 2000).

The parent and teacher forms were used in this current study to examine the overall EF of the TBI and control group children across everyday settings. As an overall measure of EF was of interest, the GEC, MI and BRI were used as broad measures of EF.

**Measures of behavioural and adaptive functioning.** The Behavior Assessment Scale for Children – Second Edition (BASC-2) was used to examine the children's behaviour and adaptive functioning as reported by their parent, teacher, and via self-report. The BASC-2 is a norm-referenced assessment tool that was published in 2004. It was designed to measure aspects of behaviour, personality and self-perceptions of children and young adults (Reynolds & Kamphaus, 2004). The BASC-2 is described as a multi-method and multidimensional system, as it incorporates observations of the child's behaviour over several settings (home and school), as well as assessing both negative (clinical) and positive (adaptive) behavioural characteristics. It includes parent, teacher and self-report forms for children or young adults ranging from 2 through

to 25 years of age, with self-report forms also available from 6 years of age. The Parent Rating Scale for Pre-schoolers (PRS-P) was used at the initial assessments, up to 12 months post-TBI, while the Parent Rating Scale for Children (PRS-C) was used for the 24 month follow-up assessment. The current study also used the Teacher Rating Scale for Children (TRS-C), as well as the Self-report of Personality Interview (SRP-I; for children aged six to seven).

The PRS-P and -C, along with the TRS-C, consist of 134, 160 and 139 items respectively. Items are scored on a 4-point Likert scale, with the response options of 'Never', 'Sometimes', 'Often' and 'Almost Always'. Table 7 shows the composition of the PRS-C and the TRS-C forms, including the primary scales and composite scores created from these scales, along with example items for each scale. The PRS and TRS predominately contain the same scales, with just a few differences. The TRS has a scale for 'Learning Problems' and 'Study Skills', as well as the composite scale of 'School Problems', while the PRS has the primary scale 'Activities of Daily Living'. The PRS-P differs from the PRS-C, in that it does not assess the scales of 'Conduct Problems' or 'Leadership'. The PRS and TRS are designed for parents and teachers to complete independently, and take approximately 10 to 20 minutes to fill out. If the parent is uncomfortable with reading, the items can be read out loud by a researcher.

The Externalising Problems composite is characterised by disruptive behavioural problems, such as impulsivity or aggression. The Internalising Problems composite, on the other hand, can refer to behaviours that may go unnoticed as they are not disruptive in nature, such as excessive worry or self-reproach. Adaptive Skills composite encompasses characteristics that are considered essential for functioning across not only the home and school

environment, but also within the community and with peers. This includes skills such as organisation, pro-social skills, and appropriate emotional control and expression. The School Problems composite reflects skills that can impact on academic achievement, such as problems with attention and motivation. Finally, both the PRS and TRS include the Behavioural Symptoms Index (BSI), which is a broad composite that examines the overall level of problem behaviours observed (Reynolds & Kamphaus, 2004).

Table 7  
*Composition of the BASC-2 PRS-C and TRS-C forms*

Composite	Primary Scales	Item example
Behavioural Symptoms Index (BSI)	Hyperactivity	"Cannot wait to take turn"
	Aggression	"Teases others"
	Depression	"Is easily upset"
	Atypicality	"Acts confused"
	Withdrawal	"Refuses to join group activities"
Externalising Problems	Attention Problems	"Has a short attention span"
	Hyperactivity	"Is unable to slow down"
	Aggression	"Bullies others"
Internalising Problems	Conduct Problems	"Disobeys"
	Anxiety	"Worries"
	Depression	"Cries easily"
Adaptive Skills	Somatisation	"Expresses fear by getting sick"
	Adaptability	"Shares toys or possessions with others"
	Social Skills	"Encourages others to do their best"
	Leadership	"Gives good suggestions for problem solving"
	Functional Communication	"Is unclear when presenting ideas"
	Activities of Daily Living (PRS form only)	"Has trouble following regular routines"
School Problems (TRS form only)	Study skills (TRS form only)	"Has good study habits"
	Learning Problems	"Does not complete tests"
	Attention Problems	"Pays attention"

The BASC-2 includes a large general normative sample that is considered a representative sample of the U.S. population. Internal consistency (Cronbach's alpha) is good for the PRS and TRS forms. On the PRS-P form, Cronbach's alpha scores for the composite measures ranged from 0.90 – 0.93. The PRS-C and TRS-C forms both had Cronbach's alpha scores for the composites between 0.90 – 0.94 and 0.88 – 0.97 respectively, using the combined 6-7 year old norms (Reynolds & Kamphaus, 2004). Good test-retest reliabilities are also reported, based on a median time span of 6 weeks for both the TRS and PRS forms. Test-retest reliabilities for the composite scores ranged from 0.81 – 0.86 for the PRS-P; 0.78 – 0.92 for the PRS-C; and 0.84 – 0.93 for the TRS-C form.

The SRP-I was also completed by the children at 24 months post-TBI (at six years of age). This form requires the researcher to read the questions aloud to the participant, and takes approximately 10-20 minutes to complete. It is comprised of 65 items that require a 'yes' or 'no' response. Table 8 shows the composition of the SRP-I form and the composite score of Emotional Symptoms Index (ESI). The ESI is comprised from all seven primary scales of the SRP-I, and provides an overall indication of serious emotional problems, with elevated scores indicating the probable presence of serious emotional disturbances (Reymolds & Kamphaus, 2005).

The SRP-I has good internal consistency, with coefficient alphas ranging from 0.72 – 0.82 for the primary scales and 0.94 for the ESI composite. Test-rest reliability estimates (with an average of 15 days between test administrations) were between 0.56 – 0.79 for the scales and 0.94 for ESI composite (Reymolds & Kamphaus, 2005).

Table 8  
*Composition of the BASC-2 SRP-I form*

Composite	Primary Scales	Item example
Emotional Symptoms Index (ESI)	Attitude to School	"I like going to school"
	Attitude to Teachers	"My teacher likes other kids more than me"
	Atypicality	"Sometimes I can't stop what I am doing"
	Social Stress	"I am left out of things"
	Anxiety	"I worry about little things"
	Depression	"I feel sad a lot"
	Interpersonal Relations	"Other people make fun of me"

All of the forms used were scored using BASC-2 Assist Plus computer software (AGS Publishing, Circle Pines, MN). Using this software, the raw scores for each scale and composite are converted into both a T score ( $M=50$  and  $SD=10$ ), as well as a percentile. The BSI, Externalising and Internalising composite scales, and therefore the primary scales that contribute to them, represent the Clinical scales. High T-scores on these scales denote behavioural difficulties. For these clinical scales a T-score of 60 or above represents an 'At Risk' rating, while a score of 70 or above represents a 'Clinically Significant' rating. In contrast, a higher score signifies better functioning for the Adaptive Skills composite and its corresponding primary scales, along with the Interpersonal Relations scale on the SRP-I. In these instances, a T-score of 30 or below represents a 'Clinically Significant' rating, while a score of 31-40 represents an 'At Risk' rating.

As this current study was interested in the overall behavioural functioning of the children, the composite scores of BSI, Externalising Problems, Internalising Problems and Adaptive Skills from both the parent and teacher forms were used. The BSI, Externalising and Internalising Problems scores were used to examine potential behavioural problems, while the Adaptive Skills scale was used as an

indication of adaptive functioning. The self-report scores for the ESI, attitude to school, and attitude to teachers were also used in this current study to examine the children's attitude towards both their school and their teacher.

**Measures of Social Competence.** The Strengths and Difficulties Questionnaire (SDQ) was used to examine the social competence of both the TBI and control group children, as reported by their parent/caregiver and teacher. The SDQ is a brief, one page screen for behavioural, social or emotional problems in children and adolescents (Goodman, 1997). The SDQ can be used by both parents and teachers to gain understanding of social behaviours of children across several sources and environments. The SDQ is recommended by the CDE as a core measure to use for research when examining social role participation and social competence after TBI (McCauley et al., 2012).

Identical parent and teacher forms are available for children between the ages of 4 and 16 years, and take approximately 5 minutes to complete. A self-report form is also available for 11 to 16 year-olds. The SDQ is accessible free of charge from the official SDQ website ([www.sdqinfo.com](http://www.sdqinfo.com)), with over 40 translations available. An extended two page questionnaire is also available that includes additional questions on whether the respondent thinks that the child has difficulties that are impacting their everyday functioning (Goodman, 1999). This extended version was used in the current study.

The SDQ consists of 25 items that are scored on a 3-point Likert scale. The respondent is asked to rate each item as either 'not true', 'somewhat true' and 'certainly true', based on the child's behaviour over the previous 6 months (for parents) or over the current school year (for teachers). The 25 items examine a combination of attributes; some that are considered strengths, along with others

that are deemed difficulties. The 25 items are equally divided into five scales. These include the Hyperactivity Scale (e.g. 'Restless, overactive, cannot stay still for long'); Emotional Symptoms Scale (e.g. 'Many worries, often seems worried'); Conduct Problems Scale (e.g. 'Often has temper tantrums or hot tempers'); Peer Problems Scale (e.g. 'Generally liked by other children'); and Pro-social Scale (e.g. 'Helpful if someone is hurt, upset or feeling ill'). Each scale has a minimum score of 0 and a maximum score of 10.

The first four scales (excluding the Pro-social Scale) can be combined to give a Total Difficulties score, with a range of 0 to 40. Higher scores on these four scales, along with the Total Difficulties score, indicate greater difficulties in that area. On the other hand, higher scores in the Pro-social Scale indicate greater social functioning. This particular study looked at the Peer Problems Scale, Pro-social Scale and Total Difficulties score to obtain information relating to the children's relationship skills and social competence.

Good internal consistency exists for the parent questionnaire, with reliability coefficients ranging from 0.57 to 0.77 for the scales, and 0.82 for the Total Difficulties score for children aged 5 to 15 years. Teacher forms show slightly higher internal consistency, with reliability coefficients ranging from 0.70 to 0.88 for the scales, and 0.87 for the Total Difficulties score (Goodman, 2001). Test-retest reliability was also satisfactory, with all correlations ranging from 0.57 to 0.72 for the parent form and 0.65 and 0.82 for the teacher form. These scores were considered to be lower limit of true retest stability due to a larger than normal 4 - 6 month interval between testing (Goodman, 2001).

When completed, the SDQ forms were scored using a syntax created for SPSS that was available through the official SDQ website

(<http://sdqinfo.com/c1.html>). Due to a lack of a normative sample from New Zealand, norms from Great Britain were used to establish borderline and clinical score cut-off values. British norms were chosen as norms from Australia were either based on older children (i.e., Mellor, 2005), or only provided information for the cut-off for the clinical range and not the borderline range (i.e., Hawes & Dadds, 2004). The British normative sample was comprised of over 10,000 children aged between 5 and 15, with both parent and teacher norms available (Meltzer et al., 2000). Cut-off values were set at the point where 10% of the general population fell in the clinical range, and an additional 10% fell within the borderline range.

**Assessments completed at each time point.** Table 9 shows the measures that were completed at each time point for the participants, their parent/caregiver and their teacher. BIONIC assessments were completed at baseline, 1 month, 6 months and 12 months. Some TBI children, however, were not identified until some months after their injury and as a result lack data from earlier assessments.

Table 9  
*Measures assessed at each assessment time point for the parent, child and teacher*

Assessment time point	Measures assessed		
	Parent	Child	Teacher
At first BIONIC assessment	Questionnaire on socio-demographic information	WJ COG	NA
	BASC-2 PRS-P form		
	HADS questionnaire		
At subsequent BIONIC follow-up assessments	BASC PRS-P form	WJ COG	NA
	HADS questionnaire		
COBIC 24 month post injury assessment (Current study)	Questionnaire on socio-demographic information	WJ COG	BASC-2 TRS-C form
	BASC-2 PRS-C form	WJ-ACH (short form)	SDQ Teacher form
	HADS questionnaire	WISC (short form)	BRIEF Teacher form
	SDQ Parent form	BASC-2 SRP-I form	
	BRIEF Parent form		

*Note:* NA = not applicable.

## Procedure

This study was part of a larger longitudinal study (COBIC) that was a follow on from the original BIONIC study. Ethics approval was gained from both the Northern Y Ethics Committee and the School of Psychology Ethics Committee at the University of Waikato. Information on the procedure used by the BIONIC study for the initial recruitment and acute stage assessments can be found in Theadom et al. (2012).

**TBI group.** For the TBI group, contact information was extracted from the BIONIC study for participants that were within the targeted age range (between 4 years, 0 months, 0 days and 4 years 11 months, 30 days at date of injury) who had given permission to be contacted regarding future studies. An information pack containing information about the COBIC study, and what was involved for the current study, was mailed to the parent or caregiver of these participants at least one month before their two year assessment was due. Ten days after the letter had been sent researchers contacted the parent or caregiver via phone. When contact with the parent was achieved, the researcher explained the study in more detail and answered any questions the parents had. Verbal consent was then obtained for those families that were happy to take part in the study.

If a participant was unable to be contacted initially, the researcher then attempted to phone at different times and days. Any alternative contact numbers available for the participant were also tried. If contact was still unable to be achieved, a letter was sent to the address provided asking the parent or caregiver if they could contact the COBIC team. If there was no response from this letter, the researcher checked the telephone directory (white pages) to see if there were any listings for the parents of the participant. Any potential listing were contacted and asked if they knew the family in question. If no contact was able to be achieved after at least six weeks of trying, the participant was deemed to be un-contactable and was removed from the current study.

**Control group.** For the control group participants, parents contacted the COBIC team directly (via phone or email) if they were interested in finding out more information about the study. On receiving their phone call or email of interest, researchers first requested the child's age, where they lived and if the

child had ever had a TBI to confirm if the child was eligible for the study. Parents of children that were eligible were then sent further information about the study and what was involved for the assessments. Researchers then contacted the parents after one week to see if they were still interested in taking part and to answer any questions they had. Verbal consent was then obtained for those participants that wished to proceed.

**Assessment procedure.** For those families where verbal consent was obtained, the researcher organised a time that suited the main caregiver to complete written consent, along with the parent/caregiver questionnaire. Parents were also given the choice where they wished the assessment to take place. All of the parents chose to complete the questionnaire at their home address. At the initial assessment the researcher first explained the outline of the current study and what would be involved for both the caregiver and the child. The researcher also took the main caregiver through the information sheet that was sent out to participants, and clarified that the study was voluntary and any information collected was kept confidential (see Appendix B - Parent/Caregiver Information Sheet). The main caregiver was also asked if they had any questions, which were answered by the researcher before written consent was obtained (see Appendix C - Parent/Caregiver Consent Form).

The parent questionnaire took approximately one hour to complete. The researcher initially took the main caregiver through the demographic information and medical history section of the questionnaire. The researcher then explained the remainder of the form, including the parent rated measures of child behaviour and adaptive functioning and described how to answer each measure. The parent was then asked if they would prefer the researcher to read out the questions and

fill in the answers for them or if they wanted to complete the form by themselves. The researcher made it clear that if the parent had any queries at any point during the questionnaire to tell the researcher, so they could explain further to help ensure accurate collection of information.

The child assessments occurred over two or three sessions which took approximately three hours in total to complete. These assessments took place at either the child's home or school, depending on the preference of their parent. When assessments were completed at school, the school was contacted and a time organised which suited the teacher for the child to be out of class. In general, the WISC-IV, BASC SRP-I form, and the WJ III ACH were completed during the first session, while the WJ III COG was completed in a second session. If the participant was getting tired from the workload, a third assessment was organised to complete any remaining test measures. Children were offered breaks and snacks to eat during their assessment, as well as being provided with stickers and colouring activities as incentives between tasks and on completion of the session.

Where possible, the parent assessment, along with the first child assessment, were completed at the same time to shorten the overall time commitment on the family. This was achieved by either two researchers attending the assessment together (one completing the child assessment and one the parent questionnaire), or by the parent independently completing the questionnaire while a researcher was assessing the child. On completion of both the parent and child assessments, the child received a certificate of participation and a \$20 Warehouse voucher as compensation.

At the parent assessment, permission was also sought to contact the participant's teacher, inviting the teacher to fill out a questionnaire about how the

participant was going at school. Where consent was obtained, teachers were mailed a letter explaining the study and why they were contacted along with a copy of the teacher questionnaire. A prepaid envelope was included so that the teachers could readily post the forms back to the COBIC team when completed. Teachers were told that completion of the form was voluntary, but if completed, the teacher would receive a \$10 book voucher for their time.

### **Statistical Analysis**

Quantitative data analyses were undertaken using the computer software programme SPSS (version 20). An alpha level of .05 (two-tailed) was used throughout the analyses. Due to the small sample size, effect sizes as well as significance levels were calculated where applicable. Effect sizes associated with *t*-tests were reported using Cohen's *d*; where .2 is a small effect size, .5 medium and .8 large (Cohen, 1988). Prior to statistical analysis the data were examined for violations of test assumptions, such as normality. Where data was not normally distributed non-parametric tests were used.

The first part of the Results section examined the characteristics and outcomes of the TBI group, over 24 months post-injury. Descriptive statistics were used to investigate the injury characteristics of the TBI group. Dependent *t*-tests were then undertaken to compare the functioning of the TBI group at 12 months and 24 months post injury.

The second part of the Results section compared the TBI and control group at 6 years of age (24 months post-TBI). The main caregiver characteristics were first compared across the TBI and Control groups. An independent *t*-test, non-parametric Mann-Whitney test (*U*), or chi-square test was used, as applicable.

To investigate any differences in functioning between the TBI and Control groups at 24 months post-injury, a series of independent t-tests were then conducted to compare the two groups across all outcome measures. Where data was not normally distributed the non-parametric Mann-Whitney test ( $U$ ) was used. To further examine differences between the TBI and Control groups, the proportion of children in each group that met clinically significant cut-off values for each composite were compared using chi square analyses.

To explore the characteristics of TBI children that scored in the clinically significant range in three or more measures (at 24 months post-TBI), chi square analyses or independent t-tests were conducted between this subgroup and the remaining TBI children.

The final part of the Results section explored the relationship between parent and teacher reports of the children's functioning using correlation analyses (Pearson's  $r$  or spearman's  $r_s$  as appropriate).

## Results

### Part 1: The TBI Group Injury Characteristics and Outcomes over 24 Months

#### Post-injury

**Characteristics of the TBI sample.** The injury characteristics of the TBI group are presented in Table 10. All except one of the TBI children sustained a mild TBI of some description, with the remaining child sustaining a severe TBI. The highest proportion of children had a low risk mild TBI (40.0%). Nearly all of the children were injured in a leisure or play activity (86.7%); over half of the injuries taking place at a private house or compound (53.3%). The majority of the injuries were a result of a fall (60.0%), with the remainder due to exposure to a mechanical force (26.7%) or a traffic accident (13.3%). Referrals via the Hospital or through ACC were the most common ways that cases were located (both 33.3%).

Due to the small sample size, along with the vast majority of children sustaining mild TBI, all of the TBI children were treated as one group for all statistical analyses. The one child with severe TBI was left in the group as all of their scores were within the normal range, or for performance based measures, in the high average range.

Table 10  
*Injury characteristics of the TBI group*

TBI characteristics	<i>n</i>	(%)
Injury severity		
Mild, low risk	6	(40.0)
Mild, medium risk	4	(26.7)
Mild, high risk	4	(26.7)
Moderate	0	(0.0)
Severe	1	(6.7)
Place of injury		
Private house or compound	8	(53.3)
Recreational area	2	(13.3)
Highway /road /street	1	(6.7)
Daycare	1	(6.7)
Other	3	(20.0)
Activity at time of injury		
Leisure/play	13	(86.7)
Sport	1	(6.7)
Conflict situation	1	(6.7)
Mechanism of injury		
Fall	9	(60.0)
Exposure to mechanical force	4	(26.7)
Traffic/Motor vehicle accident	2	(13.3)
Where case located		
Accident and Emergency Centre	1	(6.7)
General Practitioner	3	(20.0)
Waikato Hospital	5	(33.3)
ACC	5	(33.3)
Self-referral	1	(6.7)

### **Cognitive and behavioural outcomes of TBI sample over the 24**

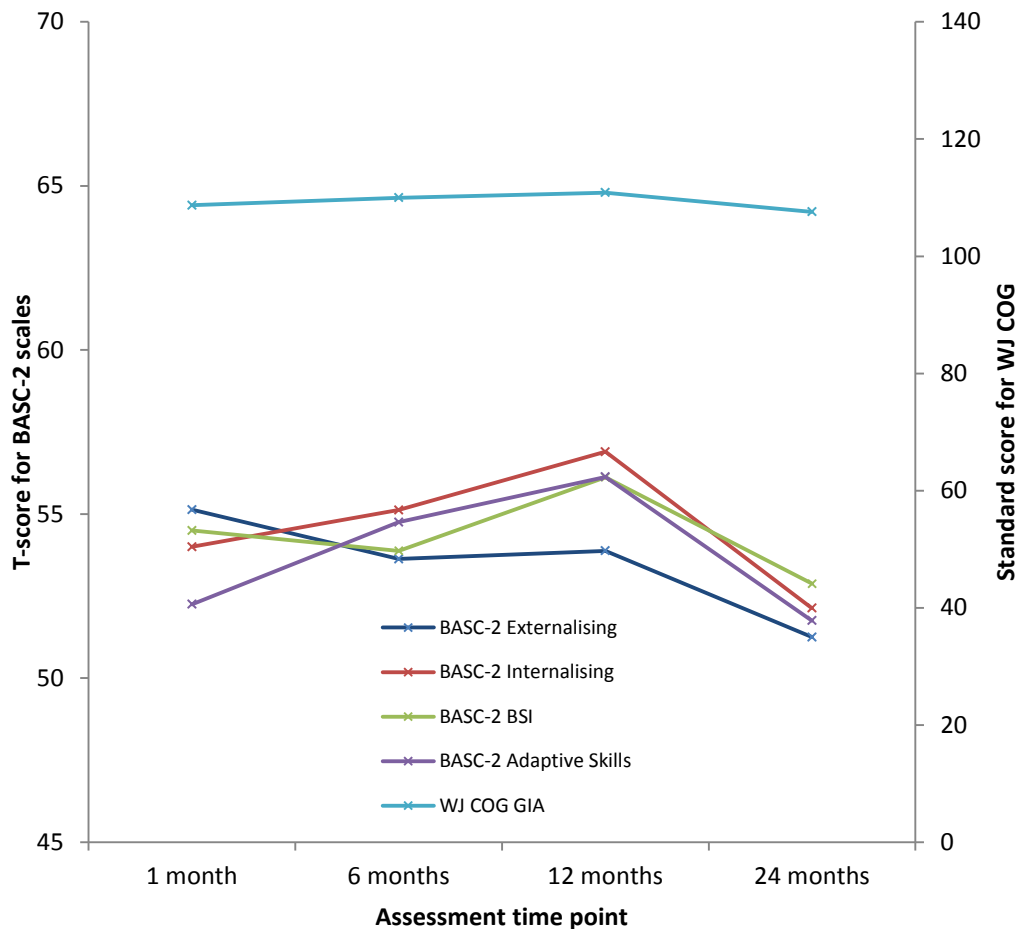
**months post-TBI.** To investigate any change in functioning for the TBI group over time, cognitive and behavioural outcomes of the TBI group were examined over 24 months post-injury (1 month, 6 months, 12 months, and 24 months). The cognitive functioning of the TBI group was explored by comparing mean scores

on the WJ III COG composite of either the General Intellectual Ability (GIA) or Brief Intellectual Ability (BIA). The BIA score was used in place of the GIA score if the children were too young to complete enough of the WJ III COG to calculate the GIA composite.

The behavioural functioning of the TBI group was also examined over this time by looking at changes in scores across the BASC-2 composites of Externalising Problems, Internalising Problems, Adaptive Ability and the Behavioural Symptoms Index (BSI). Figure 4 represents the BASC parent scores and the WJ III COG scores for the TBI children who had data available from one month post injury through to 24 months post injury.

Figure 4 shows that the WJ COG BIA or GIA scores were similar across all time points with a range of only 3.29. These scores were all within the normal range, and above the standardised mean score of 100. The BASC-2 externalising composite showed a slight decline over time with the mean (*M*) scores decreasing from 55.13 at one month, to 51.25 at 24 months. On the other hand the remaining three BASC-2 composite scores peaked at 12 months, before decreasing again at 24 month time point. All of these scores were still within the normal range. Of note, a decrease in the BASC-2 Adaptive skills score from 12 months (*M* = 56.13) to 24 months (*M* = 51.75) represented a decline in the perceived adaptive functioning of the children from the parents perspective.

Due to small number for children with data from this one month time point (*n* = 8) no further statistical analyses were carried out.



*Figure 4.* The BASC-2 parent composite scores and the WJ-COG GIA or BIA score over 24 months post injury for eight children with TBI.

Note: WJ COG = Woodcock Johnson III Test of Cognitive Abilities; GIA = General Intellectual Ability; BIA = Brief Intellectual Ability; BASC-2 = Behavior Assessment System for Children 2<sup>nd</sup> Edition; BSI = Behavioural Symptoms Index; TBI = traumatic brain injury.

As more of the TBI group had data available at the 12 month time point, dependent t-tests were carried out to examine any change in scores between the 12 month and 24 month assessment time points. Table 11 shows the results for the dependent t-tests, for both the WJ COG and BASC-2 composite scores, between the 12 and 24 month points. While the WJ COG GIA/BIA score and the BASC-2 Externalising and BSI scores all showed a slight decline over time, these changes were not significant. The BASC-2 Internalising and Adaptive skills composite scores on the other hand, both showed a significant decrease over time. A decrease in Internalising behaviour represents a decrease in parent-reported

behavioural difficulties in this area, while the decrease seen in adaptive skills suggests a decrease in desired functional behaviours.

Table 11  
Paired samples t-test for TBI group for 12 months and 24 months post-injury

Measure	n	Assessment Time point				t	(df)	p	Effect size (d)
		12 months		24 months					
		M	(SD)	M	(SD)				
WJ COG									
GIA/BIA	12	105.30	(16.77)	103.30	(17.75)	1.45	(11)	.18	.12
BASC-2									
Externalising	11	52.73	(13.56)	50.36	(13.27)	1.69	(10)	.12	.18
Internalising	11	54.18	(8.42)	48.82	(9.69)	3.06	(10)	.01*	.59
BSI	11	53.27	(12.95)	50.64	(13.63)	1.92	(10)	.08	.20
Adaptive Skills <sup>a</sup>	11	58.55	(10.21)	53.91	(11.71)	2.98	(10)	.01*	.42

Note: WJ COG = Woodcock Johnson III Test of Cognitive Abilities; GIA = General Intellectual Ability; BIA = Brief Intellectual Ability; BASC-2 = Behavior Assessment System for Children 2<sup>nd</sup> Edition; BSI = Behavioural Symptoms Index; TBI = traumatic brain injury.

<sup>a</sup> higher scores indicate better functioning.

\* p < .05

## Part 2: Comparisons of the TBI and Control Groups at 24 Months Post-TBI

**Characteristics of the main caregiver.** To determine if there were any differences between the parents of the TBI and Control groups, characteristics associated with the main caregiver were analysed using independent t-tests or chi-square analyses as appropriate. Due to the small sample size and expected cell frequencies of less than five, the likelihood ratio test statistic ( $L\chi^2$ ) was used. The results presented in Table 12 show that there were no significant differences between the groups for the following: age of the main caregiver ( $t(25) = -1.08, p = .29$ ); marital status ( $L\chi^2(2) = 1.43, p = 1.00$ ); and the number of main caregivers currently receiving treatment for depression ( $L\chi^2(1) = 0.38, p = 1.00$ ). The main caregivers of the control group were, however, more likely to be more highly qualified than the TBI group ( $L\chi^2(2) = 7.41, p = .04$ ). The caregiver

assessments were predominately completed by the mothers of the children, however there was no significant difference in relation to main caregiver gender across the two groups ( $L\chi^2(1) = 1.20, p = .60$ ).

Table 12

*Sample characteristics of the main caregiver at 24 month assessment*

Main caregiver characteristics	Group			
	TBI ( <i>n</i> = 15)		Control ( <i>n</i> = 15)	
Age of main caregiver, <i>M</i> ( <i>SD</i> ) <sup>a</sup>	38.0	(5.4)	40.2	(4.9)
Female, <i>M</i> ( <i>SD</i> )	12	(80.0)	14	(93.3)
Highest level of education of main caregiver <sup>b,c</sup>				
Primary school, <i>n</i> (%)	0	(0.0)	0	(0.0)
High school, <i>n</i> (%)	7	(50.0)	1	(6.7)
Polytechnic, <i>n</i> (%)	4	(28.6)	8	(53.3)
University, <i>n</i> (%)	3	(21.4)	6	(40.0)
Marital status				
Married, civil union, de facto, <i>n</i> (%)	10	(66.7)	11	(73.3)
Separated, divorced, widowed, <i>n</i> (%)	4	(26.7)	4	(26.7)
Never married (single), <i>n</i> (%)	1	(6.7)	0	(0.0)
Currently receiving treatment for depression, <i>n</i> (%)	2	(13.3)	1	(6.7)

*Note:* TBI = traumatic brain injury; NA = not applicable.

<sup>a</sup>TBI group *n* = 14; <sup>b</sup>significant difference between TBI and control ( $L\chi^2$  test,  $p < .05$ ); <sup>c</sup> TBI group *n* = 14, control group *n* = 13.

To investigate differences in the current mental health status of the parents in the TBI and control groups, a Mann-Whitney U-test was used to compare the two groups across the total scores on the HADS Anxiety and Depression scales. As shown in Table 13, the median scores and interquartile range of both the Anxiety and Depression scales were similar across both the TBI and Control groups, with no significant difference observed between the groups, for either scale. A score of greater than 11 on either scale of the HADS is considered to indicate the likely presence of the relevant mood disorder. One parent from the TBI sample had a

score in this range for both the Anxiety and Depression scales, with no parents from the Control groups recording scores in this range for either scale.

Table 13

*Main caregiver scores on HADS for the TBI and Control group*

Subscale	Group				U	z	p
	TBI (n=15)		Control (n=15)				
	Mdn	(25 <sup>th</sup> , 75 <sup>th</sup> )	Mdn	(25 <sup>th</sup> , 75 <sup>th</sup> )			
HADS Anxiety	4.0	(2.0, 5.0)	4.0	(2.0, 5.0)	109.50	-0.13	.91
HADS Depression	2.0	(0.0, 3.0)	1.0	(0.0, 3.0)	104.50	-0.34	.75

*Note:* TBI = traumatic brain injury; HADS = Hospital Anxiety and Depression Scale; 25<sup>th</sup> and 75<sup>th</sup> = 25th and 75th percentiles.

**Comparison of TBI and Control groups at 24 months post-injury.** To investigate if the TBI group differed from a control group, in relation to skills associated with a successful school transition, comparisons between the two groups were conducted using independent t-tests. All comparisons between the TBI and Control group were undertaken at the 6-year old assessment time-point (24 months post-TBI). Ratings of the child's behaviour, executive functioning and social competence were examined, along with performance based measures of the child's cognitive, intellectual and academic abilities. Each of these domains was individually examined; first by comparing the means of the two groups, followed by an investigation of the number of participants in the clinically significant range for each group.

Due to the significant difference between the TBI and Control groups for SES, analysis of variance (ANOVA) and analysis of covariance (ANCOVA; with SES as a covariate) tests were also undertaken and compared for each measure (where independent t-tests had been used). Using SES as a covariate was found to make no difference to the between group results found on the ANOVA and

independent *t*-tests. As a result, the independent *t*-tests were reported, as the ANCOVA findings added no new information.

***Behavioural and adaptive functioning.*** Composite scales from the BASC-2 for parent, teacher and child self-report were analysed to examine behavioural and adaptive functioning in a child's everyday setting. Table 14 shows the results of the independent *t*-tests between the TBI and Control groups, for the composite scores for all three reports of the BASC-2. The parent ratings for Internalising Problems, Externalising Problems and the BSI composite mean scores were similar across the two groups. The Externalising Problems and BSI composites, however, showed greater variability within the TBI group. For the Adaptive skills composite, the TBI group were rated slightly higher functioning by their caregivers than the Control group; however, this difference was not significant.

The teacher ratings for Internalising, Externalising and BSI composite scores were higher for the Control group than the TBI group. While these differences were not significant, a medium effect size was present for the BSI composite. The teachers also rated the TBI group as higher functioning than the Control group on the Adaptive Skills composite; however, this difference was not significant. Near identical mean scores were found between the two groups for the teacher-rated composite scale of 'Attitude towards School'. Caution must be taken when interpreting the teacher ratings, as the sample size, particularly for the Control group teacher forms, was small. Teacher data was only available for two thirds of the TBI group and just under half of the control group.

The mean self-report ratings for the Emotional Symptoms Index (ESI) composite were similar between the TBI and Control group. While the difference between the groups was not statistically significant, the Control group had a more

negative attitude towards their teacher, while the TBI group had a more negative attitude towards school. The TBI group's mean T-score of 58.27 was also close to the cut-off score of 60 for the 'At risk' range.

Table 14  
*T-scores for BASC-2 parent, teacher and self-report composite scales for the TBI and Control group*

Version	Composite	Group				<i>t</i>	<i>(df)</i>	<i>p</i>	Effect size <i>(d)</i>
		TBI <i>(n=15)</i>		Control <i>(n=15)</i>					
		<i>M</i>	<i>(SD)</i>	<i>M</i>	<i>(SD)</i>				
Parent									
	Externalising	53.20	(15.19)	52.93	(10.70)	0.06	(28)	.96	.02
	Internalising	50.07	(12.85)	49.20	(13.20)	0.18	(28)	.86	.07
	BSI	53.07	(16.15)	52.47	(11.10)	0.12	(28)	.91	.05
	Adaptive Skills <sup>a</sup>	52.47	(13.60)	49.07	(10.57)	0.77	(28)	.45	.29
Teacher <sup>b</sup>									
	Externalising	48.40	(9.96)	54.00	(17.59)	-0.84	(15)	.41	.44
	Internalising	46.00	(7.50)	47.71	(8.18)	-0.45	(15)	.66	.24
	BSI	48.80	(10.14)	54.43	(11.91)	-1.05	(15)	.31	.55
	Adaptive Skills <sup>a</sup>	52.00	(11.44)	49.29	(10.72)	0.49	(15)	.63	.26
	School	49.60	(10.82)	49.57	(5.68)	0.01	(14.18)	.99	.01
Child									
	ESI	49.60	(9.52)	48.53	(8.59)	0.32	(28)	.75	.12
	Attitude towards Teacher	49.00	(9.71)	53.27	(11.34)	-1.11	(28)	.28	-.42
	Attitude towards School	58.27	(14.46)	53.27	(15.09)	0.93	(28)	.36	.35

Note: BASC-2 = Behaviour Assessment System for Children 2<sup>nd</sup> edition; TBI = traumatic brain injury; BSI = Behavioural Symptoms Index; ESI = Emotional Symptoms Index.

<sup>a</sup> higher scores indicate better functioning; <sup>b</sup> For teacher forms *n* = 10 for TBI and *n* = 7 for Control group.

**BASC cut-off scores.** Due to the large variability of scores within several of the BASC-2 composites for the TBI group, further investigation was undertaken to see how many children in each group had behavioural difficulties that were clinically significant. The T-scores for each child – across the parent and self-report BASC-2 forms – were classified as 'Normal', 'At risk', or 'Clinically

significant' (according to the cut-off values listed in the Method section). Teacher forms were not analysed using the cut-off scores due to the low number of forms returned. Likelihood ratio test analyses were then undertaken to compare the number of children from each group that scored within the 'At risk and clinically significant range', as well as the 'Clinically significant' range only (for both the BASC-2 parent and child report forms). Odds ratio scores were not calculated for these analyses due to the small sample size.

Table 15 shows that the proportion of children in both the 'At risk and clinically significant' and 'clinically significant' ranges were similar between the TBI and Control groups for the parent-rated Internalising Problems, BSI, and Adaptive Skills composites, with no significant differences found. For the Externalising Problems composite, the TBI group had a greater number of children in both cut-off categories compared to the Control group; however, this difference was not statistically significant. Of note, one third of the TBI group fell in the 'At risk plus clinically significant' category, with 20% of the TBI children in the clinically significant range.

Table 15

*Number of participants with BASC-2 parent-rated T-scores that exceeded clinical cut-offs*

	Group				$L\chi^2(df)$	$p$
	TBI		Control			
	$n$	(% of TBI)	$n$	(% of Control)		
<b>At Risk plus Clinically Significant</b>						
Externalising Problems	5	(33.3)	2	(13.3)	1.72 (1)	.39
Internalising Problems	2	(13.3)	2	(13.3)	0.00 (1)	1.00
BSI	4	(26.7)	3	(20.0)	0.19 (1)	1.00
Adaptive Skills	3	(20.0)	4	(26.7)	0.19 (1)	1.00
<b>Clinically Significant only</b>						
Externalising Problems	3	(20.0)	1	(6.7)	1.78 (2)	.48
Internalising Problems	1	(6.7)	2	(13.3)	1.73 (2)	1.00
BSI	2	(13.3)	1	(6.7)	0.38 (2)	1.00
Adaptive Skills	1	(6.7)	1	(6.7)	0.25 (2)	1.00

*Note:* BASC-2 = Behavior Assessment System for Children 2<sup>nd</sup> edition; TBI = traumatic brain injury; BSI = Behavioural Symptoms Index;  $L\chi^2$  = likelihood ratio statistic.

Table 16 presents the number of children that met the clinical cut-offs for the BASC-2 self-report form, for both the TBI and Control groups. A similar number of children in the TBI and Control groups were in the clinical cut-off ranges for the ESI composite, with no significant differences present. The Control group had a higher number of children that exceeded the clinical cut-offs for the 'Attitude towards teacher' scale, while the TBI group had a greater number of children meeting the clinical cut-offs for the 'Attitude towards school' scale. Neither of these differences was statistically significant. Of note, 40% of children in the TBI group were in the 'at risk plus clinically significant' range for Attitude towards school.

Table 16

*Numbers of participants with self-report BASC-2 T-scores that exceeded clinical cut-offs*

	Group				L $\chi^2$ (df = 2)	P
	TBI		Control			
	n	(% of TBI)	n	(% of Control)		
<b>At Risk plus Clinically Significant</b>						
ESI	2	(13.3)	1	(6.7)	0.38	1.00
Attitude towards teacher	2	(13.3)	4	(26.7)	0.85	.65
Attitude towards school	6	(40.0)	3	(20.0)	1.45	.43
<b>Clinically Significant only</b>						
ESI	1	(6.7)	0	(0.0)	1.42	1.00
Attitude towards teacher	1	(6.7)	2	(13.3)	0.85	.69
Attitude towards school	4	(26.7)	3	(20.0)	3.35	.36

*Note:* BASC-2 = Behaviour Assessment System for Children 2<sup>nd</sup> edition; TBI = traumatic brain injury; ESI = Emotional Symptoms Index; L $\chi^2$  = likelihood ratio statistic.

***Executive Function and Emotional Regulation.*** Composite scores of the BRIEF were examined to compare the executive functioning of the TBI and Control groups, as rated by their parents and teachers. Table 17 shows the results of independent t-tests between the TBI and Control groups for various composite scores of the BRIEF.

Similar mean scores were found between the TBI and Control groups across all composites, with no significant differences reported on both the parent and teacher reports of EF. One exception to this was the Teacher-rated BRI composite, where the control group was rated as having greater problems than the TBI group (with a medium effect size). The mean T-scores for each composite were all within the normal range, with similar variability in composite scores observed between both groups (except for the teacher-rated GEC composite, where the TBI group had greater variability).

Table 17

*T-scores for BRIEF parent and teacher composite scales for the TBI and Control groups*

Version	Composite	Group				<i>t</i>	<i>(df)</i>	<i>p</i>	Effect size <i>(d)</i>
		TBI <i>(n=15)</i>		Control <i>(n=15)</i>					
		<i>M</i>	<i>(SD)</i>	<i>M</i>	<i>(SD)</i>				
Parent									
	BRI	51.80	(12.61)	53.20	(11.33)	-0.32	(28)	.75	-.12
	MI	52.00	(11.43)	50.87	(11.77)	0.27	(28)	.79	.10
	GEC	52.53	(12.21)	52.40	(11.52)	0.03	(28)	.98	.01
Teacher <sup>a</sup>									
	BRI	48.80	(10.14)	54.43	(11.91)	-1.05	(15)	.31	-.55
	MI	54.00	(13.47)	52.57	(10.50)	0.23	(15)	.82	.12
	GEC	53.70	(14.56)	52.43	(8.04)	0.21	(15)	.84	.11

*Note:* BRIEF = Behavioural Rating Inventory of Executive Function; BRI = Behavioural Regulation Index; MI = Metacognition Index; GEC= Global Executive Composite; TBI = traumatic brain injury.

<sup>a</sup>For teacher forms *n* = 10 for TBI and *n* = 7 for Control group

***BRIEF Cut-off scores.*** The number of children that exceeded the clinical cut-off score on the parent-rated BRIEF composites (T-score = 65) were compared across the TBI and Control groups, using likelihood ratio tests analyses (as shown in Table 18). A similar number of children exceeded the clinical cut-off in the TBI and Control groups for all three of the composite scores of the BRIEF. There were also no significant differences between the two groups for the number of children in the clinically significant range for each composite.

Table 18

*Number of participants with BRIEF parent-rated T-scores that exceed clinical cut-offs*

Composite	Group		L $\chi^2$ ( <i>df</i> = 1)	<i>p</i>
	TBI <i>n</i> (% of TBI)	Control <i>n</i> (% of Control)		
Clinically Significant				
BRI	2 (13.3)	3 (20.0)	0.24	1.00
MI	2 (13.3)	2 (13.3)	0.00	1.00
GEC	3 (20.0)	2 (13.3)	0.24	1.00

*Note:* BRIEF = Behavioural Rating Inventory of Executive Function; BRI = Behavioural Regulation Index; MI = Metacognition Index; GEC = Global Executive Composite; TBI = traumatic brain injury; L $\chi^2$  = likelihood ratio statistic.

**Social Competence.** Scores from the SDQ scales were examined to compare parent and teacher ratings of social competence, for both the TBI and Control groups at 6 years of age. As the distributions for TBI and Control groups violated the assumption of normality, a non-parametric test for independent samples (Mann-Whitney *U*) was used instead of an independent *t*-test. As shown in Table 19, the parent-rated median scores – for both the Peer Problems and the Pro-social Behaviour scales – were the same between the TBI and Control groups. No significant differences were found between any of the scales (Peer-problems, Pro-social, and Total Difficulties) for either the parent or teacher version. The Total Difficulties scale also had a similar median score across the two groups; however, there was greater variability between the scores for the TBI group. No significant differences were found between the two groups for any of the parent-rated SDQ scales.

For the SDQ teacher form, the TBI and Control groups both had the same median score with similar variability for the scale of Pro-social Behaviour. There was a slight difference in the median score for the scale Peer Problems, with the Control group having a higher score, suggestive of greater difficulties. The

teacher reports also rated the Control children as having a higher Total Difficulties score than the TBI group; however, this difference was not statistically significant.

Table 19  
Mann-Whitney (*U*) scores for the SDQ parent and teachers scales for the TBI and Control groups

Version	Composite	Group		<i>U</i>	<i>z</i>	<i>p</i>	
		TBI ( <i>n</i> =15)	Control ( <i>n</i> =15)				
		<i>Mdn</i>	(25 <sup>th</sup> , 75 <sup>th</sup> )	<i>Mdn</i>	(25 <sup>th</sup> , 75 <sup>th</sup> )		
Parent							
	Peer Problems	1.0	(1.0, 4.0)	1.0	(0.0, 2.0)	90.00	-0.97 .35
	Pro-social <sup>a</sup>	9.0	(7.0, 10.0)	9.0	(7.0, 10.0)	110.50	-0.09 .94
	Total Difficulties	9.0	(1.0, 16.0)	8.0	(3.0, 12.0)	104.50	-0.33 .75
Teacher <sup>b</sup>							
	Peer Problems	0.5	(0.0, 3.5)	2.0	(0.0, 3.5)	25.50	-0.51 .63
	Pro-social <sup>a</sup>	8.0	(5.0, 10.0)	8.0	(4.3, 9.3)	26.00	-0.45 .66
	Total Difficulties	5.0	(1.0, 11.0)	13.0	(4.5, 13.5)	18.50	-1.25 .23

Note: TBI = traumatic brain injury; SDQ = Strength and Difficulties Questionnaire; <sup>a</sup> higher scores indicate better functioning; <sup>b</sup> For teacher forms *n* = 10 for TBI and *n* = 6 for Control group.

**SDQ cut-off scores.** The numbers of children that meet the cut-off values for the ‘Borderline’ and ‘clinical’ range on the parent-rated SDQ subscales were compared between the TBI and Control groups. While more children from the TBI group exceeded the cut-off values for all three SDQ subscales than the Control group, these difference were not statistically significant. Although a greater number of children from the TBI group were within the ‘Borderline plus clinically significant’ category for ‘Total Difficulties’ (40%), the same number of children were in the ‘Clinically significant only’ category for both groups. Of note, 26.7% of the TBI group were reported to have clinically significant problems with peer relationships.

Table 20

*Number of participants with parent SDQ T-scores that exceeded borderline and clinical cut-offs*

SDQ scale	Group		L $\chi^2$ (df = 2)	p
	TBI n (% of TBI)	Control n (% of Control)		
<b>Borderline plus Clinically significant</b>				
Peer problems	4 (26.7)	2 (13.3)	0.85	.65
Pro-social behaviour	2 (13.3)	1 (6.7)	0.38	1.00
Total Difficulties	6 (40.0)	3 (20.0)	1.45	.43
<b>Clinically significant only</b>				
Peer problems	4 (26.7)	2 (13.3)	0.85	.65
Pro-social behaviour	1 (6.7)	0 (0.0)	1.42	1.00
Total Difficulties	3 (20.0)	3 (20.0)	0.00	1.00

*Note:* SDQ = Strength and Difficulties Questionnaire; TBI = traumatic brain injury. L $\chi^2$  = likelihood ratio statistic.

### ***Child measures of academic, cognitive and intellectual functioning.***

Performance based measures of cognitive, academic and intellectual functioning of the children were examined using independent t-tests, to compare functioning across the TBI and Control groups. Table 20 shows the descriptive and inferential statistics for the various performance measures of child functioning for the TBI and Control group. The WISC-IV and the WJ III COG were used to examine intellectual and cognitive ability respectively, while the WJ III ACH composites were used to assess academic functioning.

The Control group scored higher on every measure of child performance, compared to the TBI group; however, these differences were not statistically significant. The TBI group also had greater variability of scores for each composite than the Control group. Of note, the difference between the two groups for the EFSIQ score was marginally significance with a large effect size present.

Medium effect sizes were also found between the TBI and Control groups on the WJ III COG GIA and WJ III ACH Mathematics and Writing composites.

Table 21  
*T-Scores for the WJ III ACH, WJ III COG, and WISC-IV for TBI and Control groups*

Measure	Composite	Group				<i>t</i>	<i>(df)</i>	<i>p</i>	Effect size <i>(d)</i>
		TBI <i>(n=14)</i>		Control <i>(n=15)</i>					
		<i>M</i>	<i>(SD)</i>	<i>M</i>	<i>(SD)</i>				
WJ ACH									
	Brief Achievement	106.14	(13.19)	108.93	(10.61)	-0.63	(27)	.53	.24
	Brief Reading	108.21	(11.90)	109.33	(10.49)	-0.27	(27)	.79	.10
	Brief Writing	108.36	(10.60)	113.0	(7.89)	-1.35	(27)	.19	.52
	Brief Mathematics	100.93	(19.81)	110.87	(13.63)	-1.58	(27)	.13	.61
WJ COG									
	GIA	101.57	(16.88)	107.67	(7.96)	-1.23	(18.2)	.24	.47
WISC <sup>a</sup>									
	EFSIQ	96.62	(12.00)	104.47	(7.91)	-2.07	(20.3)	.06	.81

*Note:* TBI = traumatic brain injury; WJ III COG = Woodcock Johnson Test of Cognitive Abilities; WJ III ACH = Woodcock Johnson Test of Academic Achievement; WISC-IV = Weschler Intelligence Scale for Children 4<sup>th</sup> Edition

<sup>a</sup> For WISC *n* = 13 for TBI group.

***Cut-offs for child performance measures.*** To further examine if there was any difference in the distribution of scores between the TBI and Control groups, individual scores for each performance measure were first classified into the following categories: ‘Low Average and below’, ‘Average’, and ‘Above Average’. Scores on the WISC-IV, WJ III COG and WJ III ACH composites of 89 or below were classified as ‘Low Average or below’. A score of 90 to 110 (for the WJ III COG or ACH), or 90 to 109 (for the WISC-IV) was classed as ‘Average, while a score of 111 or above (for the WJ III COG or ACH), or 110 and above (for the WISC-IV) was classified as ‘Above Average’. The proportion of children for the TBI and Control groups that were in each category was compared for each

measure, using the likelihood ratio test statistic. The results of these analyses are presented in Table 21.

For the WISC, 30.8% of the TBI group scored in the ‘Low Average and below range’; in comparison to none of the Control group participants within this range. A greater number of Control children were also in the ‘Above Average group than was found for the TBI group. A trend towards a statistically significant difference between the distributions of scores across the WISC-IV categories was found between the two groups.

A similar pattern was observed for the WJ III COG GIA scores, with 21.4% of the TBI group in the ‘Low Average and below’ range compared to none of the Control group. A similar percentage of the TBI and Control group were in the ‘Above Average’ category, with approximately a third of all children in this range. No significant difference in the distribution of scores between the two groups was found.

Finally, the WJ III ACH measure was examined in relation the children’s performance across the composites of ‘Brief Achievement’, ‘Brief Writing’, ‘Brief Reading’, and ‘Brief Mathematics’. On the Brief Achievement composite the TBI and Control groups had a similar proportion of children in each category, with no significant difference in the distribution of scores between the groups. Only one child from the TBI group (and no children from the Control group) was in the ‘Low Average and below’ range, while a large proportion of both groups were in the ‘Above Average’ range (42.9% and 46.7 % for the TBI and Control groups respectively).

Table 22

*Number of participants in each category across child measures of the WISC, WJ III COG and WJ III ACH*

Measure	Group				L $\chi^2$ (df = 2)	p	
	N	TBI		Control			
		n	(% of TBI)	N	n (% of Control)		
WISC EFSIQ	13			15		6.98	.08
Low Average and below		4	(30.8)	0	(0.0)		
Average		7	(53.8)	11	(73.3)		
Above Average		2	(15.4)	4	(26.7)		
WJ COG GIA	14			15		5.14	.16
Low Average and below		3	(21.4)	0	(0.0)		
Average		6	(42.9)	10	(66.7)		
Above Average		5	(35.7)	5	(33.3)		
WJ ACH Brief Achievement	14			15			
Low Average and below		1	(6.7)	0	(0.0)	1.50	1.00
Average		7	(50.0)	8	(53.3)		
Above Average		6	(42.9)	7	(46.7)		
WJ ACH Brief Reading	14			15			
Low Average and below		0	(0.0)	1	(6.7)	1.50	1.00
Average		8	(57.1)	7	(46.7)		
Above Average		6	(42.9)	7	(46.7)		
WJ ACH Brief Mathematics	14			15			
Low Average and below		3	(21.4)	1	(6.7)	1.84	.47
Average		7	(50.0)	7	(46.7)		
Above Average		4	(28.6)	7	(46.7)		
WJ ACH Brief Writing	14			15			
Low Average and below		0	(0.0)	0	(0.0)	0.83	.46
Average		7	(50.0)	5	(33.3)		
Above Average		7	(50.0)	10	(66.7)		

*Note:* TBI = traumatic brain injury; WISC = Weschler Intelligence Scale for Children; EFSIQ = estimated full scale intelligence quotient; WJ COG = Woodcock Johnson III Tests of Cognitive Abilities; GIA = general intellectual ability; WJ ACH = Woodcock Johnson Tests of Achievement.

The WJ III ACH Brief Reading had similar results to the Brief Achievement, with only one Control child (and no TBI children) in the 'Low Average and below' range. No significant difference in the distribution of scores was found between the TBI or Control groups. For the composite of Brief Mathematics, the TBI group had more children in the 'Low Average and below' range, while the Control group had more children in the 'Above Average' range. However, no significant difference in the distribution of scores between the two groups was found. The Brief Writing scale also showed similar proportion of children in each category, with no significant difference in the distribution of scores between the TBI and Control groups. No children were in the 'Low Average and below' range for either of the groups.

*Children in Three or More Clinical Domains.* Research on normal development suggests that children with more risk factors (variables associated with poorer outcomes) during the transition to school are at greater risk of worse outcomes in later school years. For this reason, both of the TBI and Control groups were further divided depending on if the children had scored in the clinical range for three or more measures, in an attempt to identify children who may be at higher risk. The measures examined to create this category included parent-rated measures of the BASC-2, BRIEF and SDQ, along with the performance based measures of the WISC, WJ III COG and ACH. The child self-report composite scale of ESI on the BASC-2 was also included. For the performance-based child measures, scores within the 'Low Average or below' category were classified as in the 'clinically significant' range.

If a child scored in the clinically significant range for at least one composite, they were given a score of one for that particular measure. The

numbers of measures with a score of one were then added together. Any child that received a score of three or higher was classified in the ‘three or more measures in the clinical range’ group.

One third ( $n=5$ ) of the TBI group were in the ‘three or more measures in clinical range’ group, whereas only 13.3% ( $n=2$ ) of the Control group was in this group. This difference, however, was not statistically significant. Due to the small number of control children that scored in the ‘three or more measures in clinical range’ group ( $n = 2$ ) no further statistical analysis was undertaken for this group.

To further examine if the children from the TBI group who scored in the ‘Three or more measures in clinical range’ differed in any way from the remaining TBI children, likelihood ratio analyses ( $L\chi^2$ ) were undertaken on demographic and parental variables. As shown in Table 23, there was a significant difference in the distribution of children across classified ethnicity between the two subgroups, with 80% of the ‘Three or more measures in clinical range’ group identifying as Maori. The distribution of scores across the ‘Current marital status’ category was also significantly different, with only 20% of the ‘Three or more measures in clinical range’ group in a married, civil union, or de facto relationship.

All of the children in the ‘Three or more measures in clinical range’ group resided in Hamilton (urban), with a significant difference in the proportion of the children living in urban or rural locations between the two groups. The two children in the TBI group with parents receiving treatment for depression were both in the ‘three or more clinical measures’ group. This difference in the number of caregivers receiving depression across the groups was marginally significant.

Table 23

*Sample characteristics of the TBI group for children that scored in the clinical range across three or more measures versus children that had less than three measures in clinical range*

TBI group characteristics	Three or more measures in clinical range (N = 5)		Less than three measures in clinical range (N = 10)		L $\chi^2$	(df)	p
	n	(%)	n	(%)			
Ethnicity of child					7.81	(2)	.02*
NZ Māori	4	(80.0)	1	(10.0)			
NZ European	1	(20.0)	8	(80.0)			
Other	0	(0.0)	1	(10.0)			
Child gender					0.00	(1)	1.00
Male	3	(60.0)	6	(60.0)			
Current marital status of main caregiver					8.10	(2)	.02*
Married, civil union, de facto	1	(20.0)	9	(90.0)			
Separated, divorced, widowed	3	(60.0)	1	(10.0)			
Never married (single)	1	(20.0)	0	(0.0)			
Main caregiver currently receiving treatment for depression	2	(40.0)	0	(0.0)	5.05	(1)	.10
Highest education level of main caregiver <sup>a</sup>					0.51	(2)	.79
Primary school	0	(0.0)	0	(0.0)			
High school	2	(40.0)	5	(55.6)			
Polytechnic	2	(40.0)	2	(22.2)			
University	1	(20.0)	2	(22.2)			
Urban	5	(100.0)	4	(40.0)	6.73	(1)	.04*

Note: TBI= Traumatic brain injury; L $\chi^2$  = likelihood ratio statistic.

<sup>a</sup>N = 9 for the 'less than three scores in clinical range' group.

\* p < .05

Independent *t*-tests were also undertaken to compare the TBI children in the 'three or more clinical measures' group to the remaining TBI children across the demographic variables of age of main caregiver and SES. Similar mean scores were found between the 'three or more clinical measures' group ( $M = 36.25$ ,  $SD = 5.24$ ) and the 'less than three clinical measures' group ( $M = 38.97$ ,  $SD = 5.49$ ) for the age of the main caregiver;  $t(12) = 0.89$ ,  $p = .39$ . In contrast, the SES score for

the ‘three or more clinical measures’ group ( $M = 33.80$ ,  $SD = 10.90$ ) was significantly lower than the ‘less than three clinical measures’ group ( $M = 61.88$ ,  $SD = 18.61$ );  $t(13) = 3.08$ ,  $p = .01$ . Caution, however, should be used when interpreting these  $t$ -tests due to the limitations of parametric tests with small and uneven sample size.

### **Part 3: Correlations between Parent and Teacher Ratings of Child**

#### **Functioning.**

To investigate how similar parent and teacher reports of child functioning were, correlation analyses were undertaken for measures of behaviour, executive function, and social competence. Due to the small sample size (particularly for the teacher forms), along with no significant differences between the TBI and Control groups across these measures, the analyses were conducted for the sample as a whole. A total of 17 children ( $n = 10$  for TBI group,  $n = 7$  for Control group) had both parent and teacher forms available and were included in all correlation analyses.

**Parent and teacher correlations for the BASC-2.** Pearson’s correlation analyses were conducted on the parent and teacher reports of the BASC-2. Small positive correlations were found for the BSI ( $r = .10$ ,  $p = \text{n.s.}$ ) and Adaptive Skills ( $r = .15$ ,  $p = \text{n.s.}$ ) composite scores. While moderate positive correlations were seen for Externalising ( $r = .36$ ,  $p = \text{n.s.}$ ) and Internalising Problems ( $r = .44$ ,  $p = \text{n.s.}$ ) composites, these correlations were not significant.

**Parent and teacher correlations for the BRIEF.** As with the BASC-2, correlation analyses (Pearson’s  $r$ ) were undertaken to examine the relationship between parent and teacher ratings of the children’s EF for the entire group of children. The correlations across the BRIEF composites of BRI ( $r = .16$ ,  $p = \text{n.s.}$ ),

MI ( $r = .14$ ,  $p = n.s.$ ), and GEC ( $r = .10$ ,  $p = n.s.$ ) were all small, with no statistically significant correlations present.

**Parent and teacher correlations for the SDQ.** Spearman's rank correlations ( $r_s$ ) between parent and teacher reports of social functioning were examined for the TBI and Control children as a whole. Spearman's rho was used, as the SDQ subscales were not normally distributed. The subscale of Pro-social Behaviour showed the most agreement, with a moderate positive correlation ( $r = .42$ ,  $p = n.s.$ ); this was, however, not statistically significant. A small positive correlation was found between the parent and teacher forms for the Peer Problems subscale ( $r = .15$ ,  $p = n.s.$ ), with very little correlation on the Total Difficulties subscale ( $r = .05$ ,  $p = n.s.$ ). Neither correlation was statistically significant.

### **Summary of Results**

The injury characteristics of the TBI group were examined and showed that all except one of the TBI group sustained mTBI, with a majority of the injuries occurring as a result of a fall. An investigation of the TBI sample, at 12 and 24 months post-TBI, found that the mean scores for overall cognitive functioning on the WJ III COG remained stable, and within the normal range over this time. A significant decrease in internalising behaviour was also observed, along with a decrease in externalising behaviours. While the mean adaptive functioning of the TBI group showed a significant decrease over this time, it was still well within the normal range at 24 months post-TBI.

Comparisons between the TBI and Control group caregiver characteristics (at 24 months post-TBI) found a significantly higher level of parental education attainment for the Control group, with no further differences observed.

Comparisons between the TBI and control group – across the measures of the BASC-2, BRIEF, and SDQ – found no significant differences between the two groups, with relatively comparable group mean scores for each composite (on parent, teacher, and self-report forms). The TBI group was actually rated by their teachers to have: fewer difficulties with Externalising Problems and better Adaptive Skills (on the BASC-2); lower overall social difficulties (SDQ); and better BRI scores (e.g. ability to modulate emotions; BRIEF), than the control group.

No significant differences were also found between the TBI and control groups, across these measures, for the proportion of children in either the ‘At risk plus clinically significant’ or ‘Clinically significant only’ ranges. While not significant, a high proportion of the TBI group had elevated scores for externalising behaviours, peer problems and overall social difficulties.

For performance-based measures, the Control group scored higher than the TBI group across all composites of the WISC-IV, WJ III COG and WJ III ACH. A marginally significant difference was found for the EFSIQ, with a large effect size. While not statistically significant, medium effects sizes were found for the WJ III ACH Brief Writing and Brief Reading composites, and the GIA composite on the WJ III COG. There were no significant differences between the two groups in regards to the proportion of children scoring in the ‘low average or below’ range, across all performance measures.

Children from the TBI group who had scores in the clinical range for three or more measures were found to: have significantly lower mean SES score; be more likely to identify as Maori; live in urban areas; and live with parents that were divorced/separated/widowed or single.

Correlation analysis between the parent and teacher reports of the BASC-2 (for all children) found moderate correlations for externalising and internalising composites; however, these were not statistically significant. Correlations between the parent and teacher forms of the BRIEF were small with no significant correlations across the composite scores. A moderate correlation was observed between the parent and teacher reports for pro-social scale of the SDQ but was not statistically significant.

## **Discussion**

This study investigated the impact of traumatic brain injury on 4 year-old children, 24 months post-TBI. Outcomes were examined across several areas of functioning associated with a successful transition to school. The areas examined included: behavioural and adaptive functioning; executive functioning; social competence; and cognitive, intellectual and academic functioning. The first aim was to explore cognitive, behavioural and adaptive functioning of the TBI children at both 12 and 24 months post-TBI. It was hypothesised that cognitive functioning of the TBI children would remain stable over the 12 to 24 month period, and within the average range. Behavioural difficulties were predicted to increase over this time, with a decrease in adaptive abilities over this same period.

The second aim was to compare functioning of the TBI children to a community control group at 24 months post-TBI (when children were 6 years old) across all of the domains mentioned above. It was hypothesised that due to the younger age of injury and the vulnerability of the brain during this critical period of development, children who sustained TBI would have poorer outcomes on both parent and teacher-rated measures of behavioural and adaptive functioning, EF, and social competence than a community control group. Worse outcomes across performance-based measures of cognitive, intellectual and academic functioning were also predicted.

### **The Impact of TBI on Cognitive and Behavioural Functioning 12 to 24 Months Post-TBI**

**Cognitive functioning over time.** As predicted, the mean scores of General Intellectual Ability (GIA) remained stable from 12 to 24 months post-TBI. The mean GIA scores were within the average range, and above the standardised

mean score of 100. As the majority of the TBI group had mild injuries, these findings are consistent with research from Anderson and colleagues (Anderson et al., 2001; Anderson et al., 2004), who found that children with mTBI had cognitive abilities in the average range. This finding was also in line with the assertion by Anderson and colleagues (Anderson, Catroppa, et al., 2012) that the pattern and degree of cognitive impairment at 12 months predicted long-term outcomes.

While the current study predominately focused on 12 and 24 month outcomes after TBI, limited data was also available for 1 month and 6 months post-injury outcomes. Due to the small sample size for TBI children that had data available from 1 month post-TBI assessment, no inferential statistics were able to be carried out. Results from descriptive statistics for these children, however, suggest that overall cognitive functioning remained comparable from 1 month to 24 months post-TBI. Anderson et al. (2005b) found that the mild and moderate TBI groups showed some recovery over the first 12 months post-TBI, with recovery curves stabilising from 12 to 30 months after injury. The children in this study did not show signs of any additional recovery (outside of expected developmental gains). This is most likely, however, due to the mTBI having little impact on the children's cognitive functioning to begin with, meaning little recovery was necessary (Anderson et al., 2005b).

**Behavioural and Adaptive functioning over time.** Contrary to the hypothesis, parent ratings of externalising, internalising and the overall level of problem behaviours decreased from 12 to 24 months. Internalising problems showed the greatest change, with a significant decline across time period. This finding, however, is similar to Chapman et al. (2010), who found no difference in

the onset of new behavioural problems for a moderate TBI group, when compared to an OI group over 18 months post-TBI.

As the TBI group was too small in this study to examine outcomes for different injury severity classifications across the mild TBI category, comparisons between McKinlay et al.'s (2010) study and the current study were difficult. McKinlay et al. (2010) further divided their mTBI group into more severe inpatient mTBI and milder outpatient mTBI groups. The current results are similar to their findings for their outpatient mTBI group, where no difference was found between the outpatient mTBI group and an OI group across time. This was in contrast to their finding of increased externalising problems over time for their inpatient mTBI group (McKinlay et al., 2010).

Descriptive analysis on a subgroup ( $n = 8$ ) of the TBI children, who had data available from 1 month post-injury, showed internalising behaviour increased over the first year post-TBI, before decreasing again over the second year. These results may tentatively suggest that, over the first 12 months post-TBI, this group had increasing internalising problems. However, between 12 to 24 months problem behaviours appear to have dissipated, with the mean score for internalising problems lower at 24 months than 1 month post-TBI.

This subset of TBI children was very small, limiting any further analyses to examine if this change was significant. Due to a lack of a control group during the earlier period after injury, no comparisons of these results could be made against the normal development of children across this time. This finding is, however, similar to research by Anderson et al. (2006). They found that children with mTBI showed an increase in internalising behaviours over the first 6 months post-injury, before returning to normal levels by 30 months post-TBI. They go on

to suggest that this may be the result of factors such as post-traumatic stress symptoms or post-concussional symptoms (Anderson et al., 2006).

In contrast to the behavioural outcomes, the TBI children were found to have a significant decrease in adaptive skills between 12 to 24 months – as predicted in the hypothesis – suggesting a lower level of positive functional behaviour at 24 months post-injury. This finding is similar to the decrease in adaptive functioning for moderate and severe TBI groups seen in Anderson et al. (2005). Their mTBI group, however, showed stable adaptive scores over the 18 months post-injury. Anderson et al. (2006) also found that their mTBI and control groups both increased in adaptive functioning over the 30 months post-injury. This is in contrast to the decrease seen in the current study.

While the mean Adaptive Skills score was significantly lower at 24 months post-TBI, it was still well within the normal range. The mean score for the Adaptive Skills at 12 months ( $M = 58.55$ ) was close to the ‘High’ range; this suggests that the parent ratings of adaptive function at 12 months post-TBI may have been unusually high. Later comparison of the TBI to a community control group (at 24 months post-TBI) also found that the TBI children had better adaptive skills at 24 months post-TBI than the control group. This decline in the perceived adaptive functioning of the TBI group (from 12 to 24 months post-TBI) may reflect a change in the parents’ expectations of the children’s adaptive abilities, as the children grow older.

### **Comparison of the TBI and Control Groups at 24 Months Post-TBI**

**Behavioural and adaptive functioning.** The results for behavioural and adaptive functioning of the TBI group did not support the hypothesis that children with TBI would have greater behavioural and adaptive difficulties than a control

group. At 24 months post injury, the TBI group (who had sustained an injury at 4 years of age) were found to have similar levels of parent-rated externalising and internalising behaviours to a community recruited control group. In contrast to predictions, the TBI group was also reported by their parents to have better adaptive skills than the control group. These findings are comparable with past research on mTBI (e.g., Anderson et al., 2001; Anderson et al., 2005; Chapman et al., 2010), where both behavioural and adaptive functioning were rated similar to a control group.

While the TBI and Control groups had comparable mean scores for externalising problems, greater variability was found within the TBI group. One third of the TBI group was in the 'At risk' or 'Clinically significant' category for this composite, compared to only 13.3% of the Control group. Twenty percent of the TBI group was also in the 'Clinically significant' range. While these differences were not significant, the proportion of TBI children with these high externalising behavioural scores suggests that this area should be examined further.

While not statistically significant, the TBI group was rated more positively by their teachers across both behavioural and adaptive functioning. This is in contrast to what was predicted. These findings were similar to those of Yeates and Taylor (2006), who found no significant differences in behavioural outcomes between the moderate TBI group and the OI control group (up to 4 years post-TBI). Caution must be advised, however, as a lower number of teacher forms were completed, particularly for the Control group (47% return rate). As a result, bias may be present in relation to which children had teacher forms returned. It may be that teachers were more likely to fill in forms for children with difficulties

in some area, which could result in an overestimation of behavioural difficulties of the Control group.

While no significant differences were found between the two groups in relation to their self-reported behavioural functioning, 40% of the TBI children were in the 'At risk' or 'Clinically significant' range for their attitude towards school. This high number of children with negative attitudes to school may impact on their later engagement with school (Denham, 2006).

**Executive functioning.** No significant differences were found between the TBI and Control groups across overall measures of executive functioning (at 24 months post-injury). Both parent and teacher ratings of everyday EF behaviours were comparable between the TBI and Control groups, with no significant between-group difference in the proportion of children scoring in the clinically significant range. One exception to this was that the Control group had a poorer mean score on the teacher-rated BRI composite of the BRIEF than the TBI group. While this difference was not significant, it had a moderate effect size. As discussed above, caution is advised when interpreting teacher ratings of the control group, due to the small sample size.

These findings were in line with past research (Beauchamp et al., 2011; Chapman et al., 2010; Nadebaum et al., 2007), which found that mild or moderate TBI resulted in no significant difference in either overall or specific areas of executive functioning when compared to a control group.

It is important to note, however, that EF skills are still emerging at this young age and may not be fully developed until late childhood/adolescence (Muscara et al., 2008). Further longitudinal research is required to see if children 'grow into' deficits – as proposed by Taylor and Alden (1997) – or if this pattern

of no impairment still exists when EF skills are matured. The younger age of the children at follow-up assessments meant fewer demands were placed on higher order cognitive process, such as abstract thinking. It may not be until the children are older, and increasing cognitive tasks are required of them, that deficits begin to emerge (Chapman et al., 2010; Crowe, Catroppa, Babl, & Anderson, 2013).

**Social competence.** The results from the measure on social competence also failed to support the hypothesis of lower levels of functioning of the TBI children. Comparable results were reported between the TBI and Control groups across the areas of pro-social functioning, peer problems and overall total difficulties in social functioning, as rated by their parent and teacher. As with the domains above, the Control group was rated by their teachers to have greater overall social difficulties than the TBI children. As previously discussed, there may have been potential bias in relation to the teachers that chose to complete the assessment. These results are in line with Crowe et al. (2012) who found no significant differences between the TBI groups and a control group, across areas of social functioning.

While not statistically significant, 40% of the TBI children were reported, by their parents, to have scores with the 'Borderline' or 'Clinically significant' range for the total difficulties scale on the SDQ. Parent-ratings of the TBI group also showed that 26.7% of the group had clinically significant peer problems. This finding is comparable to research by Limond et al. (2009), who reported that preschool children with TBI had higher rates of peer problems than was expected, based on a normative sample.

Difficulties with peer relationships and social competence can impact on a child's ability to successfully transition to school, which in turn can affect later

school outcomes (Ladd, 1990). These difficulties can be further compounded by the fact that these social problems can lead to reduced social interactions and opportunities. As a result, the child can fall even further behind socially (Yeates & Anderson, 2008). Yeates et al. (2004) found that no signs of recovery of social functioning were observed after 12 months post-TBI. This suggests that any difficulties present at this 24 month assessment point are likely to persist over time. Due to a shortage of research in this area for preschool children with TBI, these results highlight the need for longitudinal investigation to see if there is any change in social skills as they progress through school.

**Cognitive and Intellectual functioning.** The results for cognitive and intellectual functioning were less clear-cut, with only tentative support for the hypothesis that the TBI group would perform lower across these areas than a control group (24 months post-TBI). The estimated FSIQ of the TBI group was found to be lower than the Control group; this difference was marginally significant, with a large effect size. While not statistically significant, the overall cognitive functioning of the TBI group was also lower than the Control group, with a medium effect size. These findings of marginally significant estimated FSIQ differ slightly from previous studies (e.g., Anderson et al., 2001; Anderson et al., 2005; Anderson et al., 2004; Catroppa et al., 2007), where no significant differences were reported between the moderate or mild TBI groups compared to a control group. In line with this literature, the TBI group in the current study did have the mean scores for each measure within the average range for the TBI group.

Investigations into the proportion of children in the ‘Low average or below’ category showed that 30.8% of the TBI children scored within this range on the WISC-IV; In contrast, no children from the Control group scored in this

low range. This distribution of the scores across the WISC-IV for both groups was found to be marginally significant. One point to consider is that the lack of Control children in the lower ranges may suggest that the Control group is not necessarily a fair representation of the general population. If this was the case, and the Control group was higher functioning than would be expected from the general population, it could result in an overestimation of the difference between the two groups. Another potential explanation for the difference between the two groups was that the TBI group may have had lower cognitive functioning before their injury. The lack of pre-injury information on cognitive functioning meant this issue could not be examined.

While a vast majority of the TBI group sustained a mild injury, one child experienced a severe injury. This child, however, had some of the highest scores for cognitive and intellectual functioning across all of the children; this is in contrast to research on children with severe TBI, where persistent deficits are usually found (Anderson et al., 2005b; Anderson et al., 2004). This high level of post-TBI cognitive functioning suggests the child had a high level of pre-injury functioning, supporting the notion of cognitive reserve (Dennis, 2000; Fay et al., 2010; Stern, 2002). Stern (2002) suggests that high levels of cognitive reserve (as shown by cognitive ability) may buffer the impact of brain insult.

This child also had one of the highest estimates of SES. Aaro Jonsson et al. (2013) found that children with severe TBI had a better chance of recovery when there was higher family functioning. While family functioning was not directly assessed in this study, SES can provide a distal estimate on the family environment. For example, a child with higher SES may be more likely to have access to resources and support after their TBI. This child's results are not typical

for children with severe TBI, and therefore not a fair representation of the impact that severe TBI can have on young children.

**Academic Functioning.** The hypothesis of significantly lower academic performance at 24 months for the TBI group, compared to the Control group, was not supported by findings from the current study. The TBI and Control group had comparable performance across the areas of reading and overall achievement abilities. While not statistically significant, the TBI group did have lower mean scores for mathematics and writing skills than the Control group, with a medium effect sizes present. Of note, the Control group had mean scores for these two areas in the 'High Average' range, with all scores for the TBI group within the average range. No significant differences were found in the distribution of scores across any of the academic areas, between the TBI and Control groups.

These findings were similar to past research (Anderson et al., 2006; Catroppa et al., 2008), which found that the mild TBI group performed comparably to a control group across all academic areas. While Barnes et al. (1999) found that the TBI group had greater difficulties in skills associated with reading than a control group, no difference was observed in the reading skills of the TBI and Control groups in this investigation. The severity of injury was, however, not clearly specified by Barnes et al. (1999), with the only injury information available being that children were recruited via admission to hospital. This does suggest that their study contained a more severe TBI group, as very few of the children in the current study required admission to hospital. This difference in TBI severity groups may explain the differences between their results and this study.

The moderate effect sizes found for mathematics and writing highlights the need for additional research to examine these differences further. Ewing-Cobbs et al. (1998) found that while children with severe TBI scored within the average range, these test performances did not accurately reflect the difficulties many of these children experienced within the classroom setting. This emphasises the need to explore other measures of academic functioning, such as the use for special educational assistance, to see how standardised academics tests relate to everyday school functioning.

**Characteristics of TBI children with three of more measures in the clinically significant range.** Further analyses were undertaken to explore the differences between children with TBI who were in the clinically significant range across three or more measures, from the remaining TBI children. One third of the TBI group had scores in the clinically significant range for at least three measures, compared to only two of the Control group. This TBI subgroup had significantly lower SES scores, were more likely to identify as Maori, and to come from a single parent home. These children were also more likely to have a parent receiving treatment for depression (marginally significant difference). All of these demographic variables have been linked to more negative outcomes and recovery after childhood TBI (e.g., Crowe et al., 2012; Taylor et al., 2002; Tompkins et al., 1990; Yeates et al., 2010) These variables are also considered risk factors associated with an increased risk of problems transitioning to school.

While the sample group was too small for any in-depth statistical analyses to examine potential predictors of TBI, these results do tentatively suggest that children with overall poorer outcomes after TBI may come from more disadvantaged family environments. These findings highlight the importance of

examining other factors, such as family functioning and parental mental health, when exploring outcomes after early childhood TBI.

**Relationship between parent and teacher reports.** Correlations between parent and teacher ratings of the child's behaviour, social competence and EF were explored to compare the parent and teacher perceptions of the child's functioning. Due to the low return rate of teacher reports, along with the comparable mean scores across the two groups, correlations were undertaken with all children combined. Measures of externalising and internalising behaviours, along with pro-social behaviour showed the greatest correlations. While not statistically significant, they showed moderate agreement between parent and teacher ratings for these behaviours. Only small positive correlations were found across the remaining measures.

These findings are comparable with past research that found only moderate correlations between teacher and parent reports of behaviour (Achenbach, McConaughy, & Howell, 1987). One suggestion for this difference is that behaviours observed in the classroom environment may differ from what parents see at home. In this study, parents with children with TBI appeared to rate their children as slightly poorer functioning than the teachers did. This may reflect a bias in parent report, based on the parents viewing their children's behaviour more negatively in light of the TBI. On the other hand, the teachers were not necessarily aware that the children with TBI had sustained the injury, as all children were injured before they started school.

### **Clinical Implications**

While no clear significant differences were found between the TBI and Control groups, the high number of children who had experienced a TBI with

clinically elevated externalising behaviour, peer problems, and overall difficulties in social functioning highlight the potential for difficulties for some children after TBI. Externalising problem behaviours, such as hyperactivity and aggression, can disrupt a child's functioning within the classroom environment. This can have a detrimental impact on not only their learning, but also impact on others around them (Raver & Knitzer, 2002). Children with externalising behaviours can be difficult to teach and are more likely to have poor teacher-child relationships, which can both lead to lower academic performance (Graziano et al., 2007; Ladd, 1990).

The potential for behavioural problems to negatively influence both the child's transition to school, and later school success, emphasises the importance of understanding the impact of TBI on preschool children. The current findings highlight the importance of further investigating behavioural difficulties after early childhood TBI - to examine factors associated with poorer outcomes after injury. Identifying preschool children with TBI – who are at risk for behavioural difficulties – before they start school, can allow for interventions and supports to be put in place early. The preschool years are considered an ideal period for interventions, particularly for areas of behavioural and social competence (Bierman & Erath, 2006). Early intervention may help minimise difficulties as children transition into formal schooling.

A high proportion of the TBI group had elevated levels of social difficulties, as rated by their parents. This finding highlights the need to investigate this area further, to better understand the impact of TBI on social competence at this young age. Research on social competence after early childhood TBI remains lacking. Literature on normal development highlights the

importance of social competence for a child as they transition to school and have to interact with more people from outside their home environment (Pianta & Rimm-Kaufman, 2006). Understanding further the impact that TBI has on this age group is essential.

### **Limitations and Strengths**

One main limitation of the current study was the small sample size, which limited the power to identify significant differences. While several medium or large effect sizes were found, the between group differences did not reach statistical significance. Due to the low number of children in the TBI group ( $n = 15$ ), all TBI children were grouped together, making comparisons across injury severity categories impossible. A larger sample size would have allowed for an investigation on the impact of injury severity on outcomes, in particular for the proposed categories of mTBI (i.e. high-, medium- or low-risk mTBI). This small sample size also limited the statistical analyses that could be carried out, especially the inability to carry out regression analysis to examine predictors of outcome after TBI

Another potential limitation of the current study was the use of an uninjured control group. Research remains divided over the use of uninjured versus injured control groups as a comparison for TBI participants, as it is argued that children who sustain TBI are not representative of the general population. An orthopaedic control group is considered by some to be more psychosocially and demographically similar to TBI participants. This can take into account factors associated with an injury, such as hospitalisation (Goldstrohm & Arffa, 2005; Mathias, Dennington, Bowden, & Bigler, 2013; Taylor et al., 2008).

Nearly all of the TBI children in the current study sustained mild TBI, with most children being recruited via sources other than hospital admission. As a result, a vast majority of TBI group did not require hospitalisation. In this case, McKinlay (2010) suggests that an orthopaedic control group may have more stress and pain related to their injury and hospitalisation than mTBI children, which in turn may bias the results. Mathias et al. (2013) found that with careful recruitment (e.g. matching participants for age and gender characteristics) a community control group was as effective as an injured control.

While the control group in the current study was matched to the TBI group in relation to gender and age, there was a significantly larger SES mean score associated with the control group.

Assessment of young children can be challenging, with many factors outside of the TBI potentially impacting on the child's performance. Factors such as shyness, tiredness or distractibility may negatively affect performance-based measures of child functioning, such as cognitive or academic tests of ability (Wrightson et al., 1995). To try and alleviate these potential problems in the current study, child assessments were split into two or three sessions to try and avoid fatigue or boredom. Time was also spent building rapport, especially for children that appeared to be shy or uncomfortable initially.

A further issue with research on preschool-aged children is the lack of information on the academic ability of children before their TBI. As a result, it was not possible to estimate the cognitive or academic functioning of the children pre-injury; this limited the ability to investigate how these domains may have changed as a result of the TBI. A lack of pre-morbid information, in general, was also a concern of the current study. With little information available on pre-

morbid functioning, particularly for behaviour, it was difficult to determine if any difference between TBI and control group was a result of the TBI, or if differences were present before the injury.

Difficulties can also arise when it comes to classifying TBI severity in young children. Preschool-age children are often unable to explain what happened, or what they are experiencing, after their injury. As a result, TBI classification in young children is reliant on the parent's subjective report of the incident. This may lead to either over- or under-diagnosing incidences of TBI, especially for instances of mTBI. Wrightson et al. (1995) found in their study that parents often did not witness the accident and a majority (60%) of the parents were unable to say if their child had lost consciousness.

While limitations were present in the current study, there were also several strengths associated with the methodology used. This study was population-based and looked at every instance of TBI across the region of interest. Unlike most research on TBI, no children were excluded based on pre-morbid developmental or behavioural functioning problems. While this made comparisons across other studies more difficult, it means the results are more generalizable to the general population as the sample was a representative of all cases of TBI.

Another strength of this study was the recruitment of TBI participants across a wide range of sources, resulting in comprehensive sample of TBI children. Most studies rely on recruitment of participants through hospital admissions or databases. These fail to capture the experience of people who sustain milder forms of TBI and are not admitted to hospital, or who may not seek medical attention.

This investigation also used multiple informants to assess the child's functioning across several contexts. The use of several informants can reduce the chance of reporting bias (Anderson, Le Brocque, et al., 2012). It can also help provide a comprehensive picture of the functional abilities of the children, in both their home and school environment. Self-rated reports of behaviour allowed an understanding of the children's personal experiences and self-perceived functioning.

### **Future Studies**

The focus of the current study was on overall functioning across various measures, with less attention paid to specific areas within each domain. Further in-depth research within each domain, to examine if there are any subtle differences seen within specific areas of functioning, would be beneficial. Donders and Warschausky (2007) suggest that focusing on specific skills, rather than global measures, is especially important for long-term follow-up. These subtle differences may be missed by concentrating on overall levels of functioning.

As a result of the young age at injury, these children with TBI were still relatively young at time of assessment. Trenchard, Rust, and Bunton (2013) suggest that 24 month follow-up is not long enough to provide a true indication of long term outcomes after childhood TBI. Longitudinal research that follows these children later into childhood or adolescents is required to see if outcomes change over time.

Due to the young age of the participants, variables associated with the family environment are proposed to impact on outcomes and recovery after TBI. For young children, a majority of their experiences and interactions happen in their family and home environment. Information on parent-child relationships,

along with family function, would be beneficial as these factors can play an important role both in a child's transition to school and during their recovery from TBI. Further research on the family and social environment is necessary to understand variables that may place a child at risk of poorer outcome after TBI.

### **Conclusions**

In conclusion, the hypothesis that children with TBI would have an increase in behavioural difficulties from 12 to 24 months was not supported by the current results. Children's behavioural difficulties decreased in all areas, with a significant decrease in internalising behaviours. While adaptive abilities decreased over this period, The TBI group was still rated as having better adaptive functioning than the control group, at 24 months post-TBI. Cognitive functioning of the TBI group remained stable from 12 to 24 months, with scores within the average range.

The results failed to support the hypothesis of significantly lower functioning for the TBI group than a community control group, at 24 months post-TBI. The TBI and Control group were found to have comparable mean scores across the domains of: behavioural and adaptive functioning; social competence; EF; cognitive and intellectual functioning; and academic performance. The TBI group was found to have a lower estimated FSIQ, which was marginally significant.

While no significant group differences were observed, a high proportion of the TBI group had elevated levels of externalising behaviour, peer problems, and overall social difficulties. These findings highlight the importance of further investigating behavioural and social outcomes after early childhood TBI, due to the negative impact difficulties in these areas can have on a child's transition to

school and later school outcomes. Early identification of children experiencing social or behaviour difficulties may allow for interventions to be set up to support the child before, and during, the school transition.

Significant gaps still exist in the research on early childhood TBI, particularly for mTBI. Understanding family and social factors that may impact on recovery and outcomes after TBI is also essential, to help identify children more at risk of aversive outcomes after TBI. Further longitudinal research on the impact of TBI during this age is recommended.

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## Appendices

## Appendix A: Classification of Mild TBI

Table 24

*Severity ratings used in the BIONIC study to classify mild TBI*

Category	Definition	GCS	PTA	Clinical findings <sup>a</sup>	Neurological deficits <sup>b</sup>	Skull fracture	Risk factors <sup>c</sup>
Mild	Low risk	15	< 24 hours	Absent	Absent	Absent	Absent
	Medium risk	15	< 24 hours	Present	Absent	Absent	Absent
	High risk	15	< 24 hours	Present/ Absent	Present/ Absent	Present/ Absent	Present/ Absent
	High risk	14	< 24 hours	May or may not be associated with other clinical or radiological findings.			
	High risk	13	< 24 hours	May or may not be associated with other clinical or radiological findings.			

*Note:* <sup>a</sup>Clinical findings: loss of consciousness, amnesia, vomiting, diffuse headache

<sup>b</sup>Neurological Deficits: impaired vision/hearing/speech, balance/walking difficulties, weakness

<sup>c</sup>Risk factor: Coagulopathy, drug or alcohol consumption, previous neurological procedures, pretrauma epilepsy, and age over 60 years

## Appendix B: Parent Information Sheet



### The Consequences of Brain Injury In Childhood (COBIC) Parent (Proxy) Information Sheet - Preschool Children

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#### Who are we?

We are a team of people who work in universities and health care services in New Zealand. We would like to help children and teenagers who have had a head injury and to find out information that will make treatment better. For us to find out how head injury affects children and teenagers, we need to talk to those who have had a head injury and to those who haven't.

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#### An invitation

The aim of this study is to examine the long term effects of head injury in children and adolescents. You are being invited to take in this research study because you represent a child who:

- 1) had a head injury (brain injury) between March 2010 and February 2011,

#### OR

- 2) you are volunteering your child to become part of the non-injured comparison group.

This study is coordinated by the School of Psychology, University of Waikato, Hamilton, in collaboration with the National Institute for Stroke and Applied Neurosciences, AUT University, Auckland.

Your participation is entirely voluntary (your choice). You do not have to take part in this study. If you choose not to take part, any care or treatment that your child is currently receiving will not be affected. If you do agree to take part, you/ your child are free to withdraw from the study at any time, without having to give a reason. Withdrawing at any time will in no way affect your or your child's future health care. To help you make your decision please read this information brochure. You may take as much time as you like to consider whether or not to take part.

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#### What are the aims of this study?

The main aim of the study is to find out about the long-term effects of head injury during childhood or adolescence (under 16 years of age). We will be looking at how children and adolescents recover, 1, 2 and 3 years after their injury, and compare them to children and teenagers of a similar age who have not had a head injury.

The study aims to find out what the effects of the head injury (if any) are on:

- Social behaviour
- Memory and other cognitive functioning
- Quality of life
- The families of people with head injury

We hope this study will be of long-term benefit to New Zealanders in identifying the effects of head injury, and we hope it will eventually lead to improved care and help for children with head injury.

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#### Who can take part in this study?

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We need two groups of children / adolescents to take part in this study - those who have had a head injury and those who haven't. You and your child can take part in this study if:

- a) You took part in the BIONIC (Brain Injury Outcomes New Zealand in the Community) study and your child was under 16 years of age when they had a head injury. This means your child had a head injury between 1<sup>st</sup> March 2010 and 28<sup>th</sup> February 2011.

OR

- b) Your child is between 1- 16 years of age, has not had a head injury and would be willing to be part of the comparison group.

We are asking for your consent (as their parent/proxy) for your child to take part. We will talk to your child directly and we would also like to ask you some questions about your child's behavior and wellbeing as well finding out about your general health. We will explain the study to your child so that they can ask any questions they might have and we will obtain their assent to take part.

In addition, we would like to ask your child's pre-school teacher to take part so that we can find out if a head injury affects a child's behavior at school. We will ask you if you would like to nominate a teacher to answer some questions.

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#### How many people will be in the study?

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We estimate about 690 children will be involved in this study.

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#### What happens if I do decide to take part?

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If you decide you/ your child would like to take part, your participation would be for two years only. In total there will be three assessments - at the start of the study, and then in 1 year and 2 years time. Each assessment will take place over 2 sessions of approximately 90 minutes each. This is about half a day of your time over 2 years.

The researcher will ring you and ask you some questions over the phone. They will then arrange a time to meet with you and your child face-to-face to complete the assessment. This meeting can be at your home, at the University or other suitable place. Each assessment will include answering some questions about any illnesses or injuries your child may have had. In addition, you will be asked questions about your child's behavior and mood, as well as questions relating to your health and wellbeing.

Most children find these tasks enjoyable. Feedback about the assessments is not routinely given. All researchers who will be asking

these questions and working with your child will have been specially trained for this project. These assessments can be conducted over more than 2 sessions if you would prefer.

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#### What will my child have to do?

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We would also like to carry out some activities with your child which can be done at home. These activities will help us to monitor your child's progress and enable us to see if head injuries affect their ability to pay attention, the way they think and how they play with a familiar person. We have found previously that children find these activities enjoyable and the activities will be suitable for the age of your child. The activities will last for a total of 1.5 hours (depending upon the age of your child) and we will do these over several sessions. You are welcome to stay with your child during these activities.

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#### What is the time-span for the study?

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The study is expected to start on 1 March 2011 and will continue until 31 October 2014.

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#### How will the study affect me?

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Taking part in this study will take some of your time and require you to answer a series of questions and for your child to complete some activities. There are no known risks caused by this study. Your (or your child's) usual medical care will not be affected in any way by participating in the study, or withdrawing from the study at any stage. Your (and your child's) participation in this study will be stopped should any harmful effects appear or if the doctor feels it is not in your best interests to continue. Similarly your doctor may at any time provide you (or your child) with any other treatment he/she considers necessary.

This study will be of benefit to the wider population. There is no guarantee that you will benefit directly from being involved in this study. However, if your child has had a head injury, you will be given an opportunity to discuss this with a researcher. The results obtained from your participation may help others with this condition in the future.

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#### Compensation

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An age appropriate gift or voucher (\$20) will be provided to you / your child after completion of each of the interviews (3 gifts or \$60 in total).

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#### Confidentiality

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The study files and all other information that you provide will remain strictly confidential, unless there is an immediate risk of serious harm to yourselves or others. No material that could personally identify you (or your child) will be used in any reports on this study. Upon completion of the study your records will be stored for at least 10 year after your child's 16<sup>th</sup> birthday in a secure place at the University of Waikato. All computer records will be password protected. All future

use of the information collected will be strictly controlled in accordance with the Privacy Act.

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### Your rights

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If you have any queries or concerns about your rights as a participant in this study, you may wish to contact a Health and Disability Advocate at the Health Advocates Trust,

Telephone: **0800 555 050**, email: [advocacy@hdc.org.nz](mailto:advocacy@hdc.org.nz).

Or Te Puna Oranga (Waikato DHB Maori Health Unit), Hockin Building, Level 1, Pembroke wSt, P.O.Box 934, Hamilton. Ph: (07) 834 3644. Fax: (07) 834 3619.

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### Finally

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This study has received Ethical Approval from the Northern Region Y Ethics Committee Ref NTY/11/02/2016). If you would like some more information about the study please feel free to contact the researchers:

Dr Nicola Starkey, Senior Lecturer, Department of Psychology, University of Waikato, Hamilton, on 07 8384466 ext 6472 or email; [nstarkey@waikato.ac.nz](mailto:nstarkey@waikato.ac.nz)

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### Study Investigators

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The principal investigator for this study is: **Dr Nicola Starkey (contact detail above)**

*Please keep this brochure for your information. Thank you for reading about this study*

## Appendix C: Parent Consent Form



### **The Consequences of Brain Injury In Childhood (COBIC) Parent (Proxy) Consent Form – Preschool Children**

The form and the accompanying information sheet outline what the study involves and requests your consent to be part of the study.

- 1) I have read and I understand the information sheet (Version 1 dated 07/09/2011) for parent (proxy) participants taking part in the Consequences of Brain Injury in Childhood (COBIC) Study
- 2) I have had the opportunity to discuss this study with the research team and I am satisfied with the answers I have been given.
- 3) I have had the opportunity to use whānau support or a friend to help me ask questions and understand the study.
- 4) I understand that taking part in this study is voluntary (my choice), and that I (or my child) may withdraw from the study at any time, and this will in no way affect my (or my child's) continuing health care in any way.
- 5) I understand the compensation provisions for this study.
- 6) I have had time to consider whether to take part in the study.
- 7) I know who to contact if I have any questions about the study.
- 8) I understand that my participation in this study is confidential and that no material that could identify me (or my child) will be used in any reports on this study.
- 9) I understand the limits of confidentiality
- 10) I agree to an approved auditor appointed by either the ethics committee, or the regulatory authority or their approved representative, and approved by the Northern Region Y Ethics Committee reviewing my relevant medical records for the sole purpose of checking the accuracy of the information recorded for the study.

- 11) I give my approval for information regarding a head injury of the child I am representing to be obtained from his/her medical records.
- 12) I understand that the GP of the child I represent may be informed about their involvement in this study.
- 13) I am willing for the research team to film my child playing with a familiar person and completing the assessments.  
Yes / No

I wish to receive a copy of the results. I understand that there may be a significant delay between data collection and the publication of the study results. Yes / No

I am a representative of \_\_\_\_\_ (the participant), being a person who is lawfully acting on the participant's behalf or in his or her interests. My relationship to the participant is \_\_\_\_\_. I agree to health information about the participant being disclosed for the purposes of this research. I also agree to participate in this research.

Signature  
(or representative) ..... Signature of  
witness.....

Date: ..... Name of  
witness.....

Project explained by ..... Project role  
.....

Signature ..... Date  
.....

*Note: A copy of the consent form to be retained by participant and a copy to be placed in the case record file.*