Mild traumatic brain injury during infancy:

Executive function and behavioural outcomes 24 months post-injury

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Abstract

Traumatic brain injury (TBI) is a leading cause of death and disability for children and young people worldwide. Research has found that children in infancy and early childhood are at the highest risk of sustaining a TBI; and that mild TBI accounts for a large majority of these injuries. Unfortunately, there is limited research regarding the effects of TBI in this age group; and population-based studies are undertaken rarely. Most of the paediatric TBI research also focuses on school-aged children; and thus the effects of TBI sustained in infancy are not yet well understood. The main aim of this study was to investigate whether preschool children who have sustained a mild TBI would perform differently to healthy children in executive function (EF), with a particular focus on working memory and inhibitory control. A secondary aim was to investigate whether preschool children who have sustained a mild TBI would differ to healthy children in behavioural/emotional functioning.

The investigation involved a population-based sample of 24 children who sustained a mild TBI between the ages of 0-2 years old. 24 children who had not had a TBI were also recruited as an age-matched comparison group. Assessments involved both parents and their children; and were conducted approximately 24 months post-injury. Parents completed the Behaviour Rating Inventory of Executive Function – Preschool Version (BRIEF-P); and the Behaviour Assessment System for Children, Second Edition (BASC-2). Children were also assessed using performance-based measures of EF such as the Delayed Alternation task - which measures working memory; and the Colour-Object Interference task - which measures inhibitory control.

Results showed that children with and without mild TBI were characterised by similar EF abilities, including working memory and EF behaviours. In contrast, more children in the injury group (22.7% of the TBI sample) had clinically significant internalising behaviour problems (anxiety, depression and somatisation) as rated by their parents. These results indicate the need for children who have had a mild TBI to be screened for possible behavioural/emotional difficulties; and for interventions to be implemented as needed. Additional support for parents/caregivers may also be necessary. While no differences were observed between the two groups in EF at the time of assessment, it is recommended that longer-term studies are conducted.

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Introduction and Literature Summary

Traumatic brain injury (TBI) is a frequently occurring neurological condition; and a leading cause of death and disability for children and young people worldwide. TBI is a major public health issue and can have an impact not only on the individual; but also families and the community. Mild TBI accounts for the majority of TBI in New Zealand (NZ), and is an injury that is frequently misunderstood. After a TBI, children of all ages can experience deficits in areas including: internalising and externalising behaviour, social functioning, academic performance, intellectual function and executive function. Pre-school-aged children (under 5 years) are a particularly vulnerable population, as this is a period of unique and rapid development. Unfortunately, this age group has received limited attention in paediatric traumatic brain injury research. As part of addressing this neglected area of study, the focus of this investigation will be on the impact of mild TBI in pre-schoolers.

Traumatic Brain Injury (TBI)

Definition. The World Health Organization (WHO) performed a systematic review to produce a working definition for TBI; and further applied this definition specifically for mild TBI. The 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 criteria for clinical identification of TBI include: confusion or disorientation, loss of consciousness, post-traumatic amnesia, and/or other transient neurological abnormalities. The Centers for Disease Control and Prevention in the US (2003) also provides a definition for TBI, and suggest that signs of neurological/neuropsychological dysfunction can be used for a diagnosis. These

include: seizures acutely following the head injury; and in very young children - irritability, lethargy, or vomiting. In older children and adults, symptoms can include: headache, dizziness, irritability, fatigue or poor concentration (National Center for Injury Prevention and Control, 2003).

Two types of TBI can be identified: closed head injury and penetrating head injury. A closed head injury is more common and occurs when a force to the head does not penetrate the dura. A penetrating head injury refers to injuries resulting in penetration of the skull, dura, and brain tissue (Ayoub et al., 2003).

TBI severity can be classified into categories of mild, moderate or severe. The severity of brain injury is measured internationally using the Glasgow Coma Scale (GCS); which is scored on a scale ranging from 3-15 (Teasdale & Jennett, 1974). Categories in the scale include Eye Opening, Motor Response, Verbal Response, Confused and Oriented. In adults and older children, the duration of post-traumatic amnesia (PTA) is another measure of head injury severity. PTA is described as a period of confusion, disorientation, and impaired memory immediately after a head injury. The duration and depth of loss of consciousness (LOC) is also used.

Lower scores on the GCS represent greater injury severity: scores of 8 or less represent severe TBI; GCS scores of 9-12 are moderate TBI; and GCS scores of 13-15 generally represent mild TBI. Mild TBI may be categorised further into the categories of: high risk (GCS of 13-15 with risk factors of coagulopathy, drug or alcohol consumption, previous neurosurgical procedures, pre-trauma epilepsy, or age over 60 years); medium risk (GCS of 15 with loss of consciousness, amnesia, vomiting, and/or diffuse headache); or low risk (GCS of 15 on admission

but without a history of LOC, amnesia, vomiting, or diffuse headache) (Servadei, Teasdale, & Merry, 2001).

Using the GCS to measure TBI severity is difficult with particular populations, including: the hearing impaired, individuals who are intoxicated, and patients who do not speak English. It is also problematic to use in pre-verbal individuals such as infants and toddlers (Harrahill, 1996). In effect, a GCS score in the moderate range for an infant or toddler may indicate a more severe injury than in a verbal child. A modified version of the GCS has been developed for pre-verbal paediatric populations but this has not seen much use, and has received little formal study at this time (Holmes, Palchak, MacFarlane, & Kuppermann, 2005).

Prevalence and epidemiology. TBI is one of the most frequently occurring neurological conditions in the world, yet epidemiological studies on TBI are rarely undertaken. In addition, incidence rates of TBI as reported in the literature have varied greatly due to differences in methodology. This can include variations in: the definitions of TBI used; criteria for diagnosis; sources of information; and methods of case ascertainment. It is also purported that the number of mild TBI that occur in the population has been underestimated, as many epidemiological studies have focussed on TBI patients seeking medical care at hospitals. This is problematic as most TBIs are mild, and medical treatment following mild TBI may not be sought. Many studies from the last decade have also focussed on administrative data sets to collect information (Krause & Chu, 2005). This approach can pose disadvantages also, as there is limited control over the quality of the data collected and there is the possibility of having missing items or records.

As summarised by Kraus and Chu (2005), epidemiological studies on TBI based in the United States have reported rates from as low as 92 per 100,000 person-year; to as high as 618 per 100,000 person-year. Overall, they concluded that the average rate of hospitalised brain injuries for TBI is approximately 120 per 100,000 person-year. In terms of New Zealand data on the incidence of TBI; Barker-Collo, Wilde, and Feigin (2008) used morbidity data from the National Health Information Service to examine TBI-related hospital discharges from 1997/1998 to 2003/2004. They found that that the overall age adjusted hospital-based incidence of traumatic head injury in New Zealand in 2003/2004 was 342 per 100,000 person-year. Another NZ study used prospective longitudinal methodology to examine a large birth cohort of 1265 children; and found an average incidence rate of 1750 per 100, 000 person-year. It was reported in this study that over 30% of the cohort sustained a TBI by the time they had reached 25 years of age (McKinlay et al., 2008).

The BIONIC (Brain Injury Outcomes New Zealand In the Community) study was the first population-based study to investigate TBI incidence across the spectrum of severity; in all age groups, in a geographical region, with urban and rural populations (Feigin et al., 2013; Theadom et al., 2012). Findings showed that the total incidence of TBI per 100,000 person-years was 790 (749 cases of mild TBI and 41 cases of moderate to severe TBI). These findings suggested that the incidence of TBI - particularly mild TBI - is much greater than some of the previous estimations.

Research has suggested that certain populations are at greater risk of sustaining a TBI. In NZ, it has been identified that the Māori population has a greater risk of sustaining a TBI compared to Europeans; and the total incidence of

TBI was significantly higher in Māori compared to all other ethnic groups. (Barker-Collo et al., 2008; Feigin et al., 2013). It is noted, however, that individuals of lower socio-economic status are also at higher risk of TBI, and that ethnic minorities may be related to being within a lower socio-economic environment. For example, data from the 1985-1987 National Health Interview Survey in the United States revealed that rates of injury were higher in families with the lowest socio-economic status (Collins, 1990).

Higher rates of TBI are also seen amongst children and young persons. In the United States, data from the CDC shows that 473,947 children aged 0 to 14 years visit the emergency department due to TBI (Faul, Xu, Wald, & Coronado, 2010). Data gathered in NZ are also consistent with these findings. Feigin et al. (2013) found that TBI was most common in two age groups: children between 0-4 years and those aged 15-34 years. In children aged 0-4 years, it was estimated that the incidence of TBI was 1262 per 100, 000 person-years for mild TBI; and 38 per 100,000 person-years for moderate to severe TBI.

Gender differences in TBI incidence are also evident. Data from NZ and overseas has consistently found that males are at higher risk of having a TBI compared to females (Corso, Finkelstein, Miller, Fiebelkorn, & Zaloshnja, 2006; Faul et al., 2010; Kraus & Chu, 2005; McKinlay et al., 2008). One United States report suggests that young males (0 to 4 years) have the highest rates for TBI-related emergency department visits, hospitalizations, and deaths combined (National Center for Injury Prevention and Control, 2003).

TBI can be sustained in various ways; and different rates for mechanisms of injury have been presented in the literature. A study in the United States (years 2000-2006) found that falls were the main mechanism of injury (35.2%). This is

followed by unknown/other mechanisms (21%); motor vehicle/traffic incidents (17.3%); being struck by/against (16.5%); and assaults (10%) (Faul et al., 2010). In terms of NZ data, Feigin et al. (2013) found that across all cases of TBI, the most common causes of injury were falls (38%), exposure to mechanical forces (21%), transport accidents (20%), and assaults (17%). Similar results were found overseas. Specifically in preschool children (0-4 years), Feigin et al. (2013) found that falls were the most common mechanism of injury (987 per 100,000 person-years), followed by exposure to a mechanical force (199 per 100,000).

TBI also has significant impact in terms of economic burden. In the US, it has been estimated that mild TBI alone cost the nation nearly $17 billion each year (National Center for Injury Prevention and Control, 2003). Overall, the prevalence and impact of TBI highlights that it is a major public health issue in NZ and worldwide; and can have detrimental consequences at an individual and societal level.

Long-term Consequences of Mild Traumatic Brain Injury in Children

Children and young persons are at higher risk of sustaining a TBI compared to the general population; but it is recognised that mild TBI is a particularly significant issue in preschool children. The data presented by Feigin et al. (2013) showed that the incidence of mild TBI was significantly greater in children aged 0–4 years compared to all other age groups.

Interestingly, early research proposed that brain damage acquired at a younger age may result in better outcomes; with the assertion that plasticity of the developing brain can enable healthy tissue to assume the functions of damaged tissue. This theory of early plasticity became referred to by some as the Kennard (1936) principle; based on early results that infant monkeys suffered less severe

behavioural consequences following cortical lesions. The opposing view to the 'early plasticity' theory is the 'early vulnerability' hypothesis. This hypothesis is based on a premise that the developing brain undergoes distinct stages of development, where different skills are gained at different times. Maturation of cortical matter is rapid during these critical stages of cognitive development; and it is defended that cerebral regions damaged at these critical stages can be permanently impaired (Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2005).

The early vulnerability perspective has been supported by some findings in paediatric TBI research, where results have suggested that young children may in fact suffer from more adverse consequences compared to older children/adults who have TBI of similar severity (Anderson et al., 2005; Anderson et al., 2010; Anderson, Morse, Catroppa, Haritou, & Rosenfeld, 2004). Children sustaining brain damage at under the age of 2 years are said to be at particularly high risk of poor outcomes, with many cognitive skills being established at this age (Anderson et al., 2010). This highlights the importance of understanding TBI sustained during infancy, as these children are not only at higher risk of sustaining TBI but may also be more susceptible to lasting impairments.

Research attempting to understand the effects of TBI on children can be wrought with many challenges. One important issue is that while observed impairments in existing skills acquired from TBI in childhood may diminish; the injury may still affect the child's development of new skills. Children may 'grow into' their deficits, with the impairments only becoming evident a long period after the injury (Taylor & Alden, 1997). This suggestion highlights the need for paediatric TBI studies that look at longer-term outcomes, in order to fully consider how TBI affects the developing brain.

A further concern in current long-term studies on paediatric TBI is that studies have focussed predominantly on school-aged children - with limited studies on the pre-school population (Anderson et al., 2006). In addition, many of the studies that do investigate pre-school children have included school-aged children in the analysis. McKinlay (2009) suggests that this requires further consideration in TBI research; as "wide age ranges are often assessed without regard to the differential impact that head injury may have on skill acquisition and consolidation at their differing stages of development" (pg. 15).

Research on the impact of severe TBI in childhood is well established compared to moderate and mild injuries; and severe TBI is generally known to have detrimental short- and long-term effects on many areas of functioning. However, there remains uncertainty and controversy regarding the long-term effects of mild TBI. The research that will be presented below shows that while some studies have found negative consequences for children after mild TBI, others have suggested that mild injuries do not lead to impairments.

Overall, evidence suggests that TBI can have an impact on a number of domains such as internalising and externalising behaviour, cognitive functioning, and executive functions (EF) (including: working memory, flexibility and inhibitory control). The main focus of this paper will be on the long-term impact of mild TBI on the development of EF in preschool children. The definition, assessment and significance of EF in the preschool population will be discussed in the following section.

The remainder of this section will summarise some of the key findings from paediatric TBI research, with a particular focus on studies assessing long-term outcomes. Research on school aged children has been included due to the

lack of studies on preschool children. Information on older children will be summarised first, followed by a discussion of outcomes in early childhood. The impact of sustaining a TBI in childhood on behaviour and cognitive function will be explored; followed by an emphasis on EF.

Behaviour. Children with TBI can experience internalising and externalising behaviour problems. Internalising behaviour problems refer to intrapersonal behaviour difficulties such as anxiety and depression; while externalising problems refer to interpersonal difficulties such as aggression towards others and hyperactivity (Gimpel & Holland, 2003).

Studies on behavioural outcomes from childhood TBI have commonly included only school-aged children and/or do not include mild injuries. For example, Taylor et al. (2002) investigated longitudinal outcomes in 189 school-aged children (6-12 years at injury) up to 4 years post TBI, including: 53 children with severe TBI, 56 with moderate TBI, and 80 with orthopaedic injuries (OI). Results showed that at least a subset of children with severe TBI experienced more behaviour problems as rated by parents compared to children with OI.

Schwartz et al. (2003) included some participants out of this same group of children, and found that the prevalence of elevated behaviour problem ratings on the CBCL were higher in one or both TBI groups compared to the OI group at 6 months, 12 months and 4 years post-injury. For example, the prevalence of caseness (i.e., whether or not a subject has the condition of interest) was 36% of children in the severe TBI group, 22% of the moderate TBI group, and 10% of the OI group at the 4 year follow-up. Predictors for poorer outcomes in this study included more severe injuries, lower socio-economic status, and pre-injury behavioural difficulties.

Thaler, Mayfield, Reynolds, Hadland, and Allen (2012) investigated the impact of moderate to severe TBI on 25 school-aged children compared to 25 matched control children. Children had a mean age of 12.7 years and were assessed over a three year period using teacher forms of the BASC-2. It was found that teachers reported greater levels of externalising problems in the TBI group compared to controls and the BASC-2 standardisation sample; as reflected by higher scores on the Externalising Problems scale. A high percentage of the TBI group also fell within the at-risk and clinically elevated range, while matched controls mostly fell within the expected range (except on the Anxiety subscale). Smaller differences were seen in terms of internalising behaviour problems between the two groups.

Studies which have included children with mild TBI in their investigation often have not found impairments. Fletcher, Ewing-Cobbs, Miner, Levin, and Eisenberg (1990) studied the behavioural adjustment of 45 children who sustained mild, moderate, and severe TBI using the Child Behaviour Checklist (CBCL) and the Vineland Adaptive Behaviour Scales (VABS). Compared to standard scores for these measures, it was found that up to 12 months post injury, children with severe TBI had significantly more adaptive behaviour problems and engaged in fewer social activities. Children with mild to moderate TBI were not significantly different to the standardisation sample.

Light et al. (1998) conducted a study which found similar results. The participants were 119 school children with mild TBI; 114 children with other injuries and 106 control children – all aged between 8-16 years old. Assessments were conducted at baseline and at 1-year post injury. No differences were found between the TBI and control group behavioural functioning as measured by the

CBCL, suggesting that mild TBI did not increase the probability of new behavioural problems.

In contrast; Andrews, Rose, and Johnson (1998) studied 54 children (8 mild TBI, 9 moderate TBI, 10 severe TBI, 27 controls) with a mean age of 12.5 years. They found that this population had significantly higher levels of maladaptive behaviour, loneliness, aggressive or antisocial behaviour, and lower levels of adaptive behaviour and self-esteem compared to children in the control group; approximately 1.4-1.5 years post TBI. Interestingly, this study found that there were no differences in performance between the three TBI severity groups in these areas. Impairments were evident even following mild TBI, and did not appear to be worse with increased severity.

Peterson et al. (2013) examined 130 children aged 12-17 years who were hospitalised overnight for complicated mild to severe TBI. Children were assessed up to 6 months post-injury using parent forms of the CBCL. It was found that 22% to 26% of the TBI sample demonstrated clinically elevated internalising problems at follow-up. Findings showed that parental psychiatric symptoms predicted internalising symptoms in adolescents.

Focussing specifically on the preschool population, the evidence also points towards a higher risk of behaviour problems post-TBI. Findings have suggested that these impairments can be long-term; with some studies reporting that symptoms can persist into adolescence. Chapman et al. (2010) investigated children aged 3-7 years at injury who had sustained severe and moderate TBI; and compared them to children with OI. Assessments were conducted at intervals up to 18 months post injury, and revealed that children who sustained a severe TBI developed more externalising behaviour problems up to the 18-month follow-up.

Deficient social competence also appeared at the final follow-up time period as measured by the Preschool and Kindergarten Behaviour Scales (PKBS-II), which suggested a potential pattern of emerging deficits.

While the aforementioned study did not find significant behavioural deficits in relation to moderate injuries, other studies have observed behavioural consequences even for mild injuries in the pre-school period. For instance, McKinlay, Grace, Horwood, Fergusson, and MacFarlane (2010) studied 76 children who sustained a mild TBI at the age of <5 years of age and 839 controls from a NZ birth cohort; assessed when they were 14-16 years of age. Results showed that children who had been hospitalized for mild TBI at the age of 5 years or under were significantly more likely to show symptoms of: attention deficit/hyperactivity disorder, conduct disorder/ oppositional defiant disorder, substance abuse, and mood disorder.

In contrast, some studies have found no differences in ratings for pre-school behaviour for children post-TBI at all, even after severe injuries. For example, Wetherington, Hooper, Keenan, Nocera, and Runyan (2010) studied children who were under the age of 2 at the time of injury, followed up at 3 years old (31 mild TBI, 20 moderate/severe TBI, and 31 comparison group). Using the CBCL, it was found that pre-schoolers who suffered a TBI did not differ in behaviour to the comparison group. However, the authors suggested that it may be premature to infer that pre-schoolers do not suffer behavioural dysfunction after TBI as these deficits may not yet be apparent. Longer-term studies were recommended.

As presented, the detrimental effect of TBI on behaviour when sustained in childhood is clear, particularly for severe injuries. There is very little in the

literature on behavioural outcomes post-TBI in preschool, and so far results have been mixed for young children sustaining only mild injuries. Other areas affected by TBI in childhood will be explored in the following sections.

Cognitive. Cognitive function is another important area of which may be vulnerable to long-term impairments post-TBI. Again, the research on the effects of severe TBI on cognitive function is well-established. For example, a study by Gerrard-Morris et al. (2010) assessed cognitive performance of children aged 3-6 years at injury, up to 18 months post-TBI and found that severe TBI was associated with generalized cognitive deficiencies as measured by the General Conceptual Ability score on the Differential Ability Scales. Another study investigated intellectual outcomes 5 years post TBI, in children aged between 2-7 years (Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2009). In this study, 54 children who had a TBI were compared with 16 children in a control group. Results indicated that severe TBI had a significant long-term impact on IQ: children with severe TBI obtained the lowest IQ scores; and scored at least 1 standard deviation below the mean. Children with mild-moderate TBI, however, did not perform significantly differently from the comparison group.

Anderson, Godfrey, Rosenfeld, and Catroppa (2012) also investigated cognitive function and recovery for the same group of children 10 years post-TBI and concluded that children who sustained severe TBI experienced global and persisting intellectual deficits, while children with less severe TBI appeared to have normal intellectual functioning.

Keenan, Hooper, Wetherington, Nocera, and Runyan (2007), conducted a study to investigate the effects of TBI on cognitive functioning specifically in preschool. Assessments occurred at 1 and 2 years post-TBI and included: a TBI

group of 112 children who sustained their injury prior to 2 years of age; and 31 children in a comparison group. In contrast to the previously mentioned study children with only mild TBI were found to have cognitive deficits, scoring below normal on composite scores of the Mullen Scales of Early Learning.

In summary, TBI may adversely impact a number of areas including internalising and externalising behaviour, and overall cognitive functioning. The evidence has shown that school-aged and preschool children are at risk of such impairments, particularly for severe injuries. However, the research available appears to provide inconsistent evidence for impairments following mild TBI.

Executive Functioning (EF) and mild TBI in Pre-school Children

Defining EF in children and infants. In the literature, there is a lack of consensus regarding the definition of EF; with not one specific operational definition available. One definition of EF proposed by Lezak (1982) describes EF as the mental capacities necessary for formulating goals, planning how to achieve them, and carrying out the plans effectively. Similarly, Anderson (2008) summarises EF as a broad term which encompasses a range of high-level cognitive processes involved in goal-oriented behaviour. Many conceptual models and clinical frameworks have been proposed in an attempt to describe the many processes related to the term. In fact, there continues to be debate regarding what processes constitute EF. The differences in the conceptual models proposed in the literature are mainly due to variations in underlying rationale (Anderson, 2008).

Unitary models were early attempts to conceptualise EF, and included well-known models such as: the 'supervisory attentional system' (SAS) (Norman & Shallice, 1986); and the 'central executive' (Baddeley, 1996). Further research

indicated that such models were too simplistic, and work has shifted towards integrating both unitary and componential models (Garon, Bryson, & Smith, 2008). Using structural equation modelling and confirmatory factor analysis (CFA), Miyake et al. (2000) proposed that a model with three correlated latent factors, which are: working memory, inhibition, and shifting – leading to the perspective of the unity and diversity of executive function. Based on these findings, the diversity of EF, at least in older children and adults, is now generally accepted (Wiebe et al., 2011).

Similar to the adult literature on EF, there is no consensus on the definition of EF specifically in children and infants. Anderson, Jacobs, and Anderson (2008) suggest that for definitions of EF to be relevant across various ages and stages of development; frameworks of EF need to account for developmental processes. There are currently few models that conceptualise EF using this approach. There is debate in the literature as to whether EF is to be conceptualised in as a single cognitive process or in a multifactorial way, when considering very young children.

Anderson (2002) proposed a model of the executive control system based on factor analytic studies and current neuropsychological knowledge; which is influenced by developmental neuropsychology research. EF is conceptualised by Anderson's (2002) model as an overall control system, consisting of four separate domains: attentional control, cognitive flexibility, goal setting and information processing. It is suggested that the executive control system is a conceptual framework rather than a theoretical model, and provides a structure for the assessment of EF. This framework is depicted in *Figure 1* below.

The domain of attentional control is depicted in this model to include: selective attention, self-regulation, self-monitoring and inhibition. It is suggested that impairments in attentional control would result in behavioural manifestations such as impulsivity, lapses in attention, inappropriate responding and lack of self-control.

The domain of cognitive flexibility includes divided attention, working memory, conceptual transfer and feedback utilization; and is considered a principal component of EF. Individuals who have impairments in the domain of cognitive flexibility are usually thought to be rigid, ritualistic, have difficulty manipulating information, and exhibit perseverative behaviour.

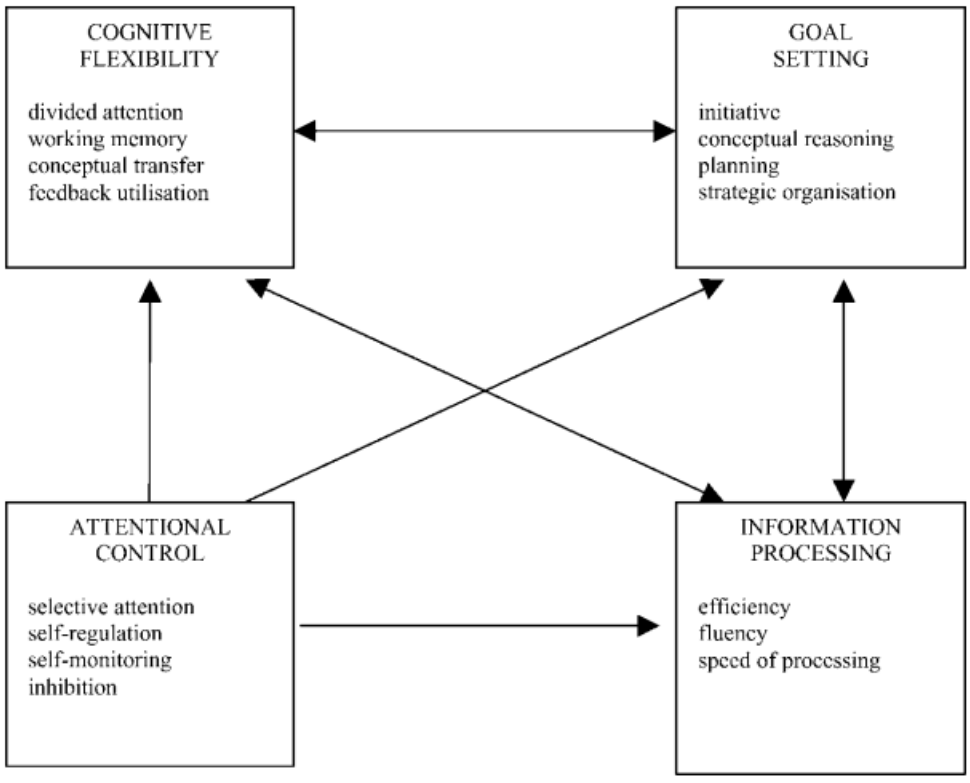

Figure 1. Framework for the Executive Control System - Anderson's (2002) proposed model for executive function in children.

The goal setting domain includes: initiative, conceptual reasoning, planning, and strategic organization. Impairments in goal setting is thought to be associated with deficiencies such as poor problem-solving ability, poor conceptual reasoning, difficulty starting tasks and difficulty with devising a method for completing tasks.

The final executive domain as suggested by this framework is information processing, which includes: efficiency, fluency and speed of processing. It is suggested that there is a bidirectional relationship between the information processing domain and the other domains of EF as presented in this model. Impairments in this domain can result in slow reaction times, hesitation and reduced productivity (Anderson, 2002).

In summary, attempts at age-appropriate definitions of EF are quite recent in the literature and defining EF in the context of very young children remains a challenge for researchers. Age-appropriate definitions that account for developmental processes are necessary in order to conceptualise EF accurately, and requires an understanding of the developmental trajectory of EF in young children. The following section will attempt to describe the development of EF from infancy throughout the preschool period, as well as factors that contribute to EF development in children.

EF and development. The frontal regions of the brain - particularly the prefrontal cortex (dorsolateral and orbitofrontal) - are thought to play a significant role in executive function (Fuster, 2002). There is research suggesting that the level of maturational advances or growth spurts in the development of the frontal lobes correspond with gains in abilities related to EF (Diamond, 2002). It should be noted that EF and the frontal lobes are not synonymous; and that frontal lobes

act as part of a broader system involving other areas of the brain. However - in simple terms - the prefrontal cortex is considered to be a primary mediator for this process (Anderson, Anderson, Jacobs, & Smith, 2008).

EF in young children did not receive much attention the past, as the frontal lobes were thought to be largely inactive during this period. However, more recent evidence showed that EF skills can be present from as early as 12 months of age; with observations of emerging skills in working memory and inhibitory control (Diamond, 2002). De Luca and Leventer (2008) summarised that the first signs of working memory and inhibition systems are observable at 7-8 months of age, with improvements to these skills seen at age 2 years. It is suggested that EF skills show most dramatic improvement around the ages of 3-5 years old (Carlson, 2005), with gains in inhibitory control, sustained attention, and improved cognitive flexibility. At 5 years old, the beginnings of goal-directed behaviour and planning are evident, as well as gains in working memory and strategy formation.

Various factors can affect the development of EF in childhood. Examples of factors that can have a significant impact include parenting and the family environment. Schroeder and Kelley (2009) found that family organisation, parental support, and appropriate limit setting by parents are associated with higher levels of executive functioning in children. Family organisation was associated with better abilities to plan-organise, inhibit, shift and monitor thoughts and behaviours, organise materials and retain information in working memory; and parental support was positively associated with the children's ability to plan/organise, inhibit thoughts and behaviours, and working memory abilities.

The frequency and intensity of maternal positive affect observed during a parent-child interaction has also been positively correlated with global executive

function performance (Kraybill & Bell, 2013). In contrast, psychosocial deprivation in early life was found to be associated with impaired inhibitory control in children assessed at 8 years of age (McDermott et al., 2013). Parental mental health can also have an impact on EF development. For instance, Hughes, Roman, Hart, and Ensor (2013) found that higher levels of exposure to maternal depression for children aged between 2-6 years predicted poorer EF at age 6 years; with reductions in depressive symptoms also predicting improvements at age 6.

Other factors such as lower socio-economic status (SES) have also been identified as predictors of EF in children without TBI. For instance, children's performance on an aggregate battery of EF tasks (including tasks measuring working memory, set shifting and inhibitory control) was found to be predicted by chronic exposure to poverty and environmental hazards associated with poverty (Raver, Blair, & Willoughby, 2013). Similarly, Clearfield and Niman (2012) found that high-SES infants assessed at 6, 9 and 12 months of age showed typical developmental trajectory for a measure of EF; while low-SES infants showed a delayed pattern. Sarsour et al. (2011) also found SES to be a predictor for EF, but additionally suggested that parental responsivity, enrichment activities and family companionship mediated the association between family SES and child inhibitory control and working memory.

Similar to these results, it has also been found that children who had parents with a higher education level performed better on measures of EF (Ardila, Rosselli, Matute, & Guajardo, 2005). These researchers suggested that parents with a higher education level may provide a more stimulating environment for their child due to a differing values system.

Sustaining a traumatic brain injury can also significantly affect EF development in children, which will be explored in subsequent sections. In terms of environmental factors, associations have been revealed between lower socio-economic status and increased risk of long-term EF impairment across a number of domains at 30 months post-TBI (Anderson et al., 2004). It is also suggested that favourable family environments may promote cognitive development similarly in children with TBI and in children without brain injuries (Gerrard-Morris et al., 2010). TBI characteristics such as injury severity and age at injury can also affect EF development. For example, Nadebaum, Anderson, and Catroppa (2007) conducted a study including 54 children who had sustained a TBI between the ages of 2-7 years of age (mild = 12, moderate = 24, severe= 18) and found that more severe injuries were associated with much poorer EF outcomes compared to milder injuries.

The age at which the TBI is sustained may also be of significance in the development of EF; as poorer outcomes for younger children compared to older children who have sustained a TBI of the same severity have been observed in other areas of functioning (Anderson et al., 2010; Anderson et al., 2004; Taylor & Alden, 1997). The numerous factors that can influence the development of EF suggest that there are likely to be complex interactions across these domains, impacting the outcomes for a child post-TBI.

Consequences of executive dysfunction. Executive dysfunction can have debilitating consequences; and impaired EF can affect many aspects of a child's current and future functioning. Understanding and accurately assessing EF in children is therefore critical. It is indicated that young children with impaired EF can have disadvantageous behavioural presentations: severe impulsivity, inability

to maintain attention, inability to inhibit behaviours, and difficulty focussing attention from one activity to another (Diamond, 2013). In fact, there is research associating impaired EF with a number of developmental psychopathologies such as: attention-deficit hyperactivity disorder and autism (Pennington & Ozonoff, 1996); externalising behaviour problems (Schoemaker, Mulder, Deković, & Matthys, 2013); and poorer social functioning (McQuade, Murray-Close, Shoulberg, & Hoza, 2013). Academic performance may also be affected by impaired EF (Fulton, Yeates, Taylor, Walz, & Wade, 2012).

EF difficulties can persist into adulthood, and can contribute to serious consequences for the individual. A longitudinal prospective study was conducted by Moffitt et al. (2011), using a birth cohort of children from the Dunedin Multidisciplinary Health and Development Study. It was identified that EF - particularly lower levels of inhibitory control - was a predictor for: physical health, substance dependence, personal finances, and criminal offending outcomes. Executive dysfunction has also been associated with the frequency and severity of violent offending (Hancock, Tapscott, & Hoaken, 2010).

It is evident that healthy development of EF can significantly contribute to more positive outcomes for children. Considering the various effects of poor EF on the child's present and future functioning; an understanding of EF and how individual, environmental and injury factors affect development is essential. In order to identify children with impairments in this area, the availability of accurate and reliable methods of assessment is essential. This brings us to the challenge of measuring EF in the preschool period.

Assessment of EF in preschool children. The measurement of EF remains a difficult area, both in adults and young children. There are particular

challenges to the assessment of EF in children as young as preschool age, one of them being the lack of a consensus on the definition of EF as discussed above. Another issue is the lack of validated standardized assessments suitable for this younger population. Furthermore, it is argued that measuring EF in very young children involves the assessment of multiple skills simultaneously, including skills which may not develop at the same rate (Gelman, 2008). A number of EF tasks that have been used with pre-schoolers in the literature will be described.

There are EF tasks used with adults that have been modified for use with young children - enabling them to follow less complex instructions and complete more simple tasks. One example of an EF task adapted from adult research is the TRAILS-P, developed by Espy and Cwik (2004), with the aim of assessing pre-school children's ability to shift cognitive set. It is based on the adult Trail Making test, and utilises a child-friendly story book format.

The TRAILS-P task involves four conditions. In Condition A (control), the children are instructed to identify dogs in order of size using a stamp. In Condition B (switch) pictures of like-sized bones are introduced and children were asked to match them to the dogs (flexibly switch among the like-sized stimuli). Condition C assessed the effects of reversal on performance, and involved instructing the child to stamp the dogs in order of size while ignoring the bones. Finally, Condition D assessed the effects of distraction on performance by mixing cat stimuli with the dogs and bones as distractors and instructing the child to alternate stamping dogs and matching bones while ignoring the cats. The development of the TRAILS-P involved administration to 103 normally developing children aged between 2 and 6 years. Evidence of discriminant validity and convergent validity with other standardized psychometric tasks

designed to measure EF is required before TRAILS-P can see widespread use in this age group. However, TRAILS-P task performance varied with task demands and age and appears to have good psychometric properties (Espy & Cwik, 2004).

The Shape School (Espy, 1997) is another EF task which uses a child-friendly storybook format. It is proposed by the developers as an effective tool in measuring EF in children aged around 3-6 years old, and may be useful for children who have atypical developmental patterns (Espy, Bull, Martin, & Stroup, 2006). The Shape School also involves four Conditions: A, B, C and D. In Condition A, children are instructed to name figure colours. Condition B involves naming colours only of happy-faced figures, while inhibiting naming sad-faced figures (response suppression). Condition C required children to name the colours of hatless figures, and then name shapes of hatted figures (context-controlled selection). Finally, Condition D required children to name colours of happy-faced, hatless figures; inhibit naming of sad/frustrated-faced, hatless figures; name shapes of happy-faced, hatted figures; and inhibit naming of sad/frustrated-faced, hatted figures (concurrent context-controlled selection). Shape School performance was related to performance on other tests that purport to measure EF such as the Statue and Visual Attention subtest of the NEPSY; and Digit Span. Task sensitivity to differing executive demand was also demonstrated. The authors suggested that more research is required to improve task parameters.

Another method of assessment is the Stroop task, which is believed to place demands on cognitive flexibility, resistance to interference, and inhibitory capacity. The classic Stroop task (Stroop, 1935) requires individuals to name colours in which a word is printed in, while refraining from reading the word itself. The Stroop effect relies on the learned tendency of readers to focus on the

word, while paying less attention to other features like the word's colour. When instructed to name the colour of the ink in which a word is printed, the strong tendency to attend to what word is must be inhibited. A variation of this task was developed by Prevor and Diamond (2005)which is suitable for preschool children, using a colour-object version which does not require the ability to read. This task was developed by presenting four sets of line drawings to 168 children who were aged 3.5–6.5 years old. Each set of line drawings varied: Set A consisted of drawings of 12 familiar objects strongly associated with a particular colour, outlined in their characteristic colour (e.g., a brown bear). Set B consisted of those same 12 objects, drawn in a non-canonical colour (e.g., a blue bear). Set C contained drawings of 11 familiar objects not associated with any particular colour, outlined in a colour (neutral). Set D included line drawings of 11 abstract shapes, each outlined in one of the six colours already used. Children were asked to say the colour in which each object was drawn (the colour identification condition) and half were asked to say what the object was (object-naming condition). It was found that children had a predominant tendency to name the object even when instructed to name the colour. Children also responded faster and more accurately at naming colour when the form could not be named (abstract shape) than when it could. Prevor and Diamond (2005) suggest that this Stroop task represent the existence of colour–object interference among preschoolers; and may be useful tool in measuring EF with further research.

Another performance-based task which can be used to measure EF in pre-school children is the Delayed Alternation task – presumed to rely on working memory (Espy, Kaufmann, McDiarmid, & Glisky, 1999). In the Delayed Alternation task, children are instructed to search for a hidden reward out of two

locations. If the response was correct, the child received a reward; and if the response was incorrect, the child received no reinforcement. If the subject searched from the correct location, the reward would be hidden in the other location on the subsequent trial, which the subject would search for after a specified time period. Children had to alternate their responses (win-shift strategy) and search on the side opposite to the one that they had previously gained reinforcement.

As well as direct assessment of the child, the use of behaviour rating scales can also aid as a measure of EF. One such scale is the Behaviour Rating Inventory of Executive Function Pre-school Version (BRIEF-P) (Gioia, Espy, & Isquith, 2002).The BRIEF-P is a standardised rating scale which measures behavioural manifestations of EF in pre-school children, within the context of their everyday environments. The BRIEF-P is widely used and is suitable for children aged 2 years to 5 years 11 months. The BRIEF-P subscales are: Inhibit; Shift; Emotional Control; Working Memory; and Plan/Organize, and can be completed by the child's parent and/or teacher. These are but a few measures of EF that have been used with preschool children, both in TBI and non-TBI populations. The following section will summarise research on EF outcomes after TBI sustained in childhood.

Research on TBI and effects on EF. Only a small number of research studies have investigated the effects of mild TBI on EF development in young children. Similar to outcome studies in other areas of functioning, studies assessing EF have included both school-aged and pre-school children. Some studies have investigated the impact of TBI on EF, but have not included mild TBI. For example, Ganesalingam et al. (2011) studied children aged 3.0 to 6.11

years at time of injury; which included 23 participants with severe TBI, 64 with moderate TBI, and 119 with OI assessed at 3 and 6 months post injury. EF was measure using neuropsychological tests such as the Delayed Alternation task and Shape School, as well as parent rated behaviour on the BRIEF-P and Child Behaviour Questionnaire. The assessment also included use of the Adaptive Behaviour Assessment System, Preschool and Kindergarten Behaviour Scales, and Home and Community Social Behaviour Scales to measure social competence. It was found that children with severe TBI performed significantly lower on neuropsychological tests, ratings of social competence and ratings of EF compared to children with OI. Effects or children with moderate TBI were less distinct.

Chapman and colleagues (2010) also investigated EF in children aged 3 to 7 years at the time of injury up to 18 months post-injury; including severe TBI, moderate TBI and OI. It was found that EF skills as measured by parent ratings on the BRIEF-P were more impaired in the severe TBI group compared to the OI group, persisting up to 18 months. No significant differences were found between the moderate TBI group and OI group.

While the aforementioned studies only investigated moderate-severe TBI, there are also a small number of studies which have included children with mild TBI. Crowe, Catroppa, Babl, and Anderson (2012), investigated EF outcomes of children with TBI sustained prior to 3 years of age; assessed 3-4 years post-injury. A group of 55 children (19 mild TBI, 16 moderate-severe TBI, and 20 control participants) were assessed using measures of attentional control and information processing; and parent rated EF using the BRIEF. This study found that the mild TBI group performed below the control group on a measure of inhibitory control

(Statue subtest of the NEPSY-II), but no significant group differences were reported on measures of information processing or parent ratings of their child's EF.

Nadebaum and colleagues (2007) investigated EF outcomes in children 5 years post-injury and included 54 children who had sustained a TBI between the ages of 2-7 years of age (mild = 12, moderate = 24, severe= 18); and 17 children in a control group. Their results suggested that unlike children who sustained severe TBI, children with mild to moderate TBI showed intact EF in measures of: attentional control, cognitive flexibility, goal setting and information processing; and parent ratings of their child's EF as measured by the BRIEF. However, the authors suggested further longitudinal research to follow-up these children when EF skills are fully matured.

Children from the same group were also investigated by Catroppa, Anderson, Morse, Haritou, & Rosenfeld (2007). The researchers assessed attentional skills 5 years post-TBI in 70 children (54 TBI and 16 controls). Overall, it was found that children who had severe TBI had deficits in attentional processing and speed of processing; which persisted up to 5 years after the time of injury. The children's performance in measures of attention, information processing and shifting/inhibitory control supported a dose-response relationship; while mild TBI did not affect performance.

Another study was by Beauchamp et al. (2011) who assessed EF in a sample of 19 children with mild to severe TBI - 10 years post injury. It was found that these children performed within age expectations on tests of: attentional control, cognitive flexibility, goal setting, information processing; while children

with severe injuries had poorer performance on goal setting and processing speed tasks.

Overall, much of the research presented suggests that preschoolers who sustain a TBI can suffer deficits in EF. This is particularly true for moderate to severe injuries, while the results are less clear for mild TBI. Some studies have reported EF impairments in children who have sustained an injury while others report no significant differences compared to control or orthopaedic groups.

It is evident that the number of studies involving EF post-TBI in preschool children is limited. These studies on effects of TBI on EF have also included a range of ages in the analysis - comprising of both pre-school and school-aged children. As suggested earlier, this is a factor that may require consideration in future research (McKinlay, 2009). In addition, there are few longitudinal studies which investigate EF outcomes post-TBI in preschool children.

In summary, it is clear from a review of the literature that TBI can have detrimental effects on many areas of functioning. TBI can result in difficulties such as internalising and externalising behaviour problems, impaired cognitive functioning, and impaired EF. While the effects of severe TBI are clear, the evidence for impairments from mild TBI are inconsistent – and for the preschool population – the number of studies are still particularly limited.

More studies are required in order to understand how factors such as TBI in early life can affect development, particularly the effects on EF for the preschool population. Understanding EF development after TBI in children is important due to the implications of executive dysfunction, such as impairments in: academic performance, behaviour, physical health, social functioning, and mental health. Understanding the relationship between factors that contribute to

the development of EF, and which buffer the effects of TBI in children are also important; as this will have potential benefits for the development and implementation of interventions for this population.

While EF is the main topic of investigation, it is also clear from the literature summary that understanding the effects of mild TBI on behaviour will also provide essential information. Unfortunately, with the research focussed on injuries of greater severity and older children, the effects of mild TBI on preschool development have been largely neglected. This poses many challenges for the management and treatment of children suffering from mild TBI.

This study sought to address this by investigating the long-term effects of mild TBI sustained in infancy on EF and behavioural outcomes. Using various methods, a population-based sample of children who were 0-2 at the date of injury were assessed approximately 24 months post TBI (current age 2-4 years). The investigation had several aims and hypotheses:

Aim 1. To investigate whether preschool children who have sustained a mild TBI would perform differently to healthy children in EF tasks, with a particular focus on: working memory, inhibitory control, and behavioural manifestations of EF in the context of everyday environments. It was hypothesised that children who have sustained a mild TBI would have poorer inhibitory control, working memory; as well as more behavioural difficulties related to executive dysfunction 24-months post-injury.

Aim 2. To investigate whether preschool children who have sustained a mild TBI would differ to healthy children in behavioural/emotional functioning (externalising behaviour, internalising behaviour, other behavioural symptoms

and adaptive skills) as rated by parents. It was hypothesised that children with mild TBI would experience more behavioural/emotional difficulties.

Aim 3. To investigate the relationship between parental/environmental factors and performance on measures of EF and behaviour. It was hypothesised that higher quality parent-child interaction (characterised by higher ratings on the Positive Affect, Supportive Presence and Facilitation of Self-Regulation scales; and low ratings on the Intrusiveness and Negative Affect scales); lower levels of anxiety and depression; and higher SES would be associated with better performance on EF-related measures and measures of behavioural/emotional difficulties.

Method

Participants

The study consisted of two groups: The mild TBI group and an age-matched cohort of children who have not had a TBI as the control group.

Mild traumatic brain injury group. Participants from the mild TBI group were recruited from the Brain Injury Outcomes New Zealand in the Community (BIONIC) study. BIONIC was a large population-based epidemiological study of traumatic brain injury undertaken during 2010-11. Further details from this study are available in articles published by Feigin et al. (2013) and Theadom et al. (2012). BIONIC study participants sustained TBIs between 1 March 2010 and 28 February 2011. All participants of the study resided within the Hamilton city area or Waikato District, which is a geographical area that contains a population structure that is representative of the NZ population (Statistics New Zealand, 2006).

TBI was defined using the WHO criteria as described in the introduction (Carroll et al., 2004). For inclusion in the study, individuals needed to have experienced one or more of the following symptoms: (a) confusion or disorientation (b) loss of consciousness and/or (c) post-traumatic amnesia. As all participants were children, other medical or behavioural changes immediately after the injury were also required for inclusion. These were changes such as: vomiting, lethargy, persistent crying, being very quiet (out of character), irritable, refusing food, sleepiness, seizures, disorientation, unequal pupil size, headache, complaining and/or described as being ‘out of sorts’. Mild TBI was defined as a Glasgow coma scale (GCS) score of 13–15. GCS scores were recorded at the scene of the injury when possible, at admission to hospital/medical service, or

both. Individuals' worst GCS score, as recorded in the medical notes within the first 4 weeks of injury was also recorded when available, to capture change in scores during admission. If GCS scores were not available, patients were classified as mild TBI, as GCS could not be assigned retrospectively. Mild TBI were further classified into high risk (GCS of 13-15 with risk factors of coagulopathy, drug or alcohol consumption, previous neurosurgical procedures, pre-trauma epilepsy, or age over 60 years); medium risk (GCS of 15 with loss of consciousness, amnesia, vomiting, and/or diffuse headache); or low risk (GCS of 15 on admission but without a history of LOC, amnesia, vomiting, or diffuse headache).

At the conclusion of the final BIONIC assessment, participants were asked whether they were willing to be contacted for any future studies. Parents who consented to this and had children who were 0 to 15 years old at the age of injury were invited to participate in COBIC (Consequences of Brain Injury in Childhood). COBIC is a longitudinal study on TBI in children which conducts a longer-term follow up on children from BIONIC; and also recruited a matched cohort of children who have not had a TBI. The current study includes children from COBIC who were 0-2 at the age of injury, followed up at approximately 24 months post-injury (follow-up age of 2-4 years). *Figure 2* summarises the number of children contacted and recruited for the study, as well as the number of children who completed a full assessment at 24 months.

Age-matched control group. A group of children were recruited as a comparison group for the study. These participants were recruited via flyers and posters distributed through local kindergartens and childcare centres (see Appendix C). Requests were also made for recruited TBI and control participants

to distribute pamphlets to friends who had children of a similar age. Children who had ever had a head injury were excluded from this group. The following question was used to identify such children: “has your child ever hit their head so hard that you sought medical attention, or wanted to seek medical attention?” Any uncertainty regarding this criterion was clarified by asking further questions about the injury. Children who did not reside within the specified geographical area were also excluded from the study. Children in the control group were matched by age and gender, but no other exclusion criteria were applied (see Appendix D for eligibility checklist).

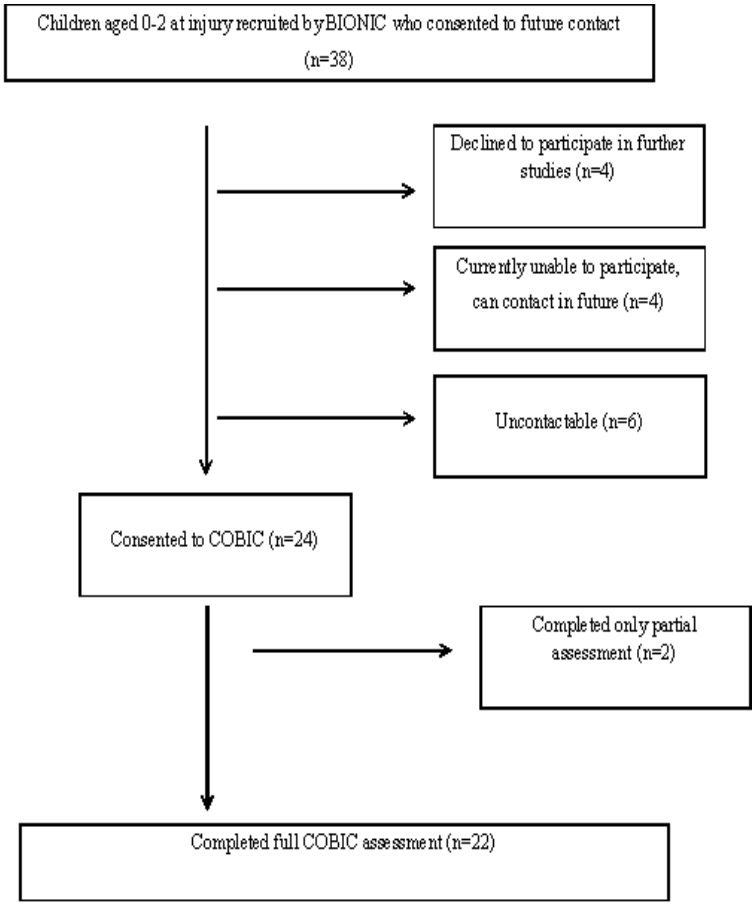

Figure 2. Flow chart summarising the recruitment and assessment completion of children in the TBI group

Sample characteristics. Consent was obtained for a total of 48 children to partake in the study. 24 children were in the mild TBI group and 24 children were in the age-matched control group. The sample characteristics for the 48 participants are included in Table 1. Analyses were conducted to determine whether there were any significant differences between the TBI and control groups in demographics. Overall, the two groups had comparable demographics apart from family SES. As presented in Table 1, no significant differences were found for age at assessment; and there was also no difference in the male: female

ratio between the two groups. Fisher's exact tests (FET) comparing parent and child ethnicity showed no differences in frequencies between the two groups.

The occupation of the main income earner in the household was coded using the Australia and New Zealand Standard Coding of Occupations; and codes were further translated into scores on the Australian Socioeconomic Index 2006 (AUSE106) (further details are in the Materials section below). A comparison of these scores revealed that the control group had a higher mean SES compared to the TBI a group t (44) = -2.25, p= 0.029.

All of the children in both groups were biological children of parents who completed the assessment; and all children were conceived naturally. The most common health problems for both the TBI and control groups were: ear problems (i.e. infections, glue ear), asthma and eczema. One child in the control group had an existing language disorder diagnosis.

Table 1.

Participant characteristics at time of assessment

Demographic	Group				Significance of difference (X^2, FET or t, p)
	TBI (*n*=24)		Control (*n* =24)		
Child Gender					
Males, *n* (%)	17	(70.8)	16	(66.7)	X^2 (1) = 0.97, p = 0.76
Parent Gender					
Males, *n* (%)	1	(95.5)	2	(8.3)	
Females, *n* (%)	21	(4.5)	22	(91.7)	
Age at assessment - years, *M (SD)*	3.40	(0.53)	3.41	(0.46)	t(46) = -.12, p= 0.91
Region					X^2 (1) = 0.95, p = 0.33
Urban , *n (%)*	19	(79.2)	16	(66.7)	
Rural, *n (%)*	5	(20.8)	8	(33.3)	
Parent Ethnicity					
NZ European, *n* (%)	17	(70.8)	19	(79.2)	p= 0.50, FET
Māori, *n* (%)	4	(16.7)	2	(8.3)	p=0.33, FET
Other, *n* (%)	3	(12.5)	3	(12.5)	p=0.50, FET
Child Ethnicity					
NZ European	16	(66.7)	19	(79.2)	X^2 (1) = 0.95, p = 0.33
Māori, *n* (%)	4	(16.7)	3	(12.5)	p = 0.50, FET
Pasifika, *n* (%)	-	-	-	-	
NZ and other, *n* (%)	4	(16.7)	2	(8.3)	p=0.33, FET
Socioeconomic status, *M (SD)*[a]	53.06	(21.02)	66.63	(19.88)	t(44) = -2.25,p= 0.03

Note: $X^{2\ =}$ Chi-square statistic; FET = Fisher's exact test

TBI characteristics. Group injury characteristics of the TBI group are presented in Table 2 below. In terms of injury severity, most of the children were in the mild, low risk category (37.5%). The majority of children in the sample sustained their TBI at a private residence (83.3%); and the most common mechanism of injury was having a fall (83.3%). Most of the children were at leisure/play when the injury was sustained (75.0%). For the majority of participants, the recorded incident was the first TBI ever sustained by the child (75.0%). Just over half of the TBI group were recruited through Waikato Hospital. Consistent with previous research, the majority of children who sustained a TBI were male (70.8%).

Table 2

Traumatic brain injury group characteristics

Variables	TBI (*n*=24)
Age at injury - years, *M (SD)*	1.29 (0.47)
Time since injury at date of assessment (y), *M (SD)*	2.19 (0.15)
Mild TBI classification, *n* (%)	
Mild (unspecified)	3 (12.5)
Mild, low risk	9 (37.5)
Mild, medium risk	7 (29.2)
Mild, high risk	5 (20.8)
Place of Injury, *n* (%)	
Private house/compound	20 (83.3)
Recreational area	1 (4.2)
School	1 (4.2)
Other	2 (8.3)
Mechanism of Injury, *n* (%)	
Fall	20 (83.3)
Exposure to mechanical force	3 (12.5)
Assault	1 (4.2)
Activity at Time of Injury	
Leisure/Play	18 (75.0)
Travelling	1 (4.2)
Other	5 (20.8)
Number of TBI	
First	18 (75.0)
Second	2 (8.3)
Third	2 (8.3)
4 or More	2 (8.3)
Case Located	
Waikato Hospital	13 (54.2)
General Practitioner	4 (16.7)
Accident and Medical Clinic	3 (12.5)
Accident Compensation Corporation	4 (16.7)

Materials

The assessments involved completion of a questionnaire including parent-rated measures, child cognitive assessment, performance-based measures completed by the child, and observation. Not all children completed all assessment components due to parents opting out after only partial assessments (based on time constraints/other commitments). Some children (in both groups) were unable to be engaged in the task adequately to conduct an accurate assessment. In addition, some tasks were suitable only for a particular age range.

General Questionnaire. The child's parent completed a questionnaire which included child history; general information about parent and child; and standardised rating scales.

Child History. This section of the questionnaire asked questions regarding the child's health history and development. Information gathered included: disability; any current health problems or conditions; use of prescriptions medications and over-the-counter medicines; hospital admissions; prenatal information (i.e. maternal health, use of prescription drugs, gestation period, method of childbirth, use of pain relief during birth, and birth complications); information about child in first few years of life (i.e. breastfeeding, health and development); current behaviour at school and at home; and the family composition.

General Parent/Family Information and Socio-economic Status (SES). This section gathered general information regarding parent and child ethnicity; occupation and income; level of education; and marital status. The occupation of the main income earner in the household was used and coded using the Australia and New Zealand Standard Coding of Occupations; which is accessible from the

Australian Bureau of Statistics (ABS). These codes were further translated into scores on the Australian Socioeconomic Index 2006 (AUSE106) (McMillan, Beavis, & Jones, 2009); which is a system that converts data coded in accordance with the official occupational classifications of the ABS into occupational status scores. AUSE106 scores range from 0-100 (higher scores reflected higher SES). In situations where the participant was not currently in paid employment, SES codes from AUSE106 were estimated using the participant's level of education.

Hospital Anxiety and Depression Scale (HADS). The HADS is a 14-item self-report measure developed by Zigmond and Snaith (1983) which was used in this study to assess parent/caregiver levels of anxiety and depression. Items in the HADS include: 7 statements relating to symptoms commonly associated with anxiety; and 7 statements relating to symptoms commonly associated with depression. The informant rated each statement on a four point (0–3) response category, relating to how much of the time each statement has applied to them in the last week. Examples of questions for the Anxiety scale include: "I get a sort of frightened feeling as if something awful is about to happen" and "Worrying thoughts go through my mind". Examples of statements for the Depression scale include: "I still enjoy the things I used to enjoy" and "I look forward with enjoyment to things".

HADS scores range from 0 to 21 for anxiety and 0 to 21 for depression, with higher scores on each subscale reflecting greater probability of mood or anxiety disorder. A score of 0 to 7 for either subscale could be regarded as being in the normal range. Scores of 8 to 10 of either subscale was considered suggestive of the presence of a respective mood disorder, and scores of 11 or

higher was considered an indication of the probable presence of the respective disorder. The HADS takes approximately 5 minutes or less to administer.

The HADS performs adequately in assessing caseness and severity of anxiety and depressive disorders in psychiatric/primary patients and the general population, and has sensitivity and specificity of approximately 0.80 for both the Anxiety and Depression scales. Correlation ranging from 0.49 to 0.83 can be found between the HADS and similar questionnaires such as: the Beck Depression Inventory, State-Trait Anxiety Inventory, Clinical Anxiety Scale, and the Symptom Checklist 90 Scale (Anxiety and Depression subscales) (Bjelland, Dahl, Haug, & Neckelmann, 2002).

Parent Ratings of Child Behaviour. As well as collecting general demographic information, questionnaires designed to assess child behaviour based on parent ratings were also used. This included:

Behaviour Rating Inventory of Executive Function Preschool Version (BRIEF-P). The BRIEF-P was completed by the parent as part of the parent questionnaire. The BRIEF-P (Gioia, Espy, & Isquith, 2003) is a standardized rating scale which measures behavioural manifestations of executive function in preschool children, within the context of their everyday environments. On a 3-point Likert scale format (i.e. “Never”, “Sometimes”, or “Often”), parents rated how often specific behaviours have been problematic for the child over the past 6 months, relative to other children of the same age. The BRIEF-P takes approximately 10-15 minutes to administer. The BRIEF-P is suitable for children aged 2 years to 5 years 11 months. The BRIEF-P T scores have a mean of 50 and a standard deviation of 10. Higher T-scores reflect greater EF difficulties, with T-scores at or above 65 considered clinically significant.

The measure consists of 63 items which form the following domains: Inhibit (16 items), Shift (10 items), Emotional Control (10 items), Working Memory (17 items), and Plan/Organize (10 items). These scales are summarized in three overlapping indexes: Inhibitory Self-Control (Inhibit and Emotional Control), Flexibility (Shift and Emotional Control), and Emergent Metacognition (Working Memory and Plan/Organize); and form an overall composite score named the Global Executive Composite. The BRIEF-P also has two validity scales (Inconsistency and Negativity); which are designed to measure inconsistent and/or excessively negative responses. The scale composition of the BRIEF-P is summarised in Table 3 below.

Gioia et al. (2003) report high internal consistency reliability (.80-.95 for the parent sample and .90-.97 for the teacher sample); and moderate test-retest reliability (.78-.90 for the parent sample and .64-.94 for the teacher sample). Parent and teacher ratings had only modest inter-rater agreement ratings across the scales, indexes, and composite score, with an overall mean correlation of .19. This is as expected by the authors, as they note that expectations and opportunities for the performance of behaviours differ across home and school settings. The BRIEF-P was selected as it is sensitive to deficits in executive functioning in children with traumatic brain injury (V. Anderson, Anderson, Northam, Jacobs, & Mikiewicz, 2002; Nadebaum et al., 2007). The BRIEF-P was scored using software provided by the test developers.

Table 3

Scale composition of the BRIEF-P

	Composite Index	Clinical scale	Area assessed	Item Example
Global Executive Composite (GEC)	Inhibitory Self Control Index (ISCI)	Inhibit (IS)	Inhibitory control (i.e. ability to inhibit/resist an impulse)	"Gets easily side-tracked during activities"
		Emotional Control	Ability to modulate emotions	"Overreacts to small problems"
	Flexibility Index (FI)	Shift	Ability to move freely from one situation/activity to another	"Has trouble changing activities"
	Emergent Metacognition Index (EMI)	Working Memory (WM)	Capacity to hold information in mind	"Has trouble with tasks that have more than one step"
		Plan/Organise	Ability to manage current and future-oriented task demands.	"Has trouble following established routines for sleeping, eating or play activities"

Behavioural Assessment System for Children, Second Edition (BASC-2). The BASC-2 is a rating scale designed to assess emotional and behavioural difficulties/disorders. The BASC-2 is multidimensional and is designed to measure a range of both adaptive and problematic behaviour. The BASC-2 has different versions that can be used to assess a wide age range of children, from 2:00 to 21:11 years. The preschool version of the BASC-2 contains 134 items. There are different BASC-2 formats available: the parent rating scales (PRS), teacher rating scales (TRS) and the self-report of personality (SRP). The SRP is only suitable for children 6:00 years or over and was not used in this study.

Responses to items in the BASC-2 are in a 4-point Likert format, where respondents select: "Never", "Sometimes", "Often" or "Always" to a series of statements. Respondents are asked to mark the response that best describes how the child has behaved over the past month. The BASC-2 takes approximately 10-20 minutes to complete. The BASC-2 has 12 scales: Hyperactivity, Aggression, Anxiety, Depression, Somatization, Atypicality, Withdrawal, Attention Problems, Adaptability, Social Skills, Activities of Daily Living and Functional Communication. The twelve scales form four composite scores: Externalising Problems, Internalising problems, Behavioural Symptoms Index and Adaptive Skills. The scale composition of the BASC-2 is summarised in Table 4 below.

Higher scores on the BASC-2 clinical scales reflect greater problems in these areas, while high scores on the adaptive scale reflect greater adaptive skills. T-scores between 60-69 on the clinical scales indicate that the child is 'At-Risk' for developing difficulties in these areas, while a T-score of 70 or above is considered to be in the Clinically Significant range. For the adaptive scale, a score

of 30 or below is considered clinically significant. BASC-2 ASSIST Plus software was used to score completed questionnaires.

Table 4

Scale composition of the BASC-2

Composites	Scales	Item Examples
Externalising Problems (Clinical)	Hyperactivity Aggression	"Needs too much supervision" "Bullies others"
Internalising Problems (Clinical)	Anxiety Depression Somatization	"Is afraid of dying" "Is easily upset" "Complains of pain"
Behavioural Symptoms Index (Clinical)	Atypicality Withdrawal Attention Problems	"Acts strangely" "Refuses to join group activities" "Has a short attention span"
Adaptive Skills (Adaptive)	Adaptability Social Skills Activities of Daily Living Functional Communication	"Recovers quickly after a setback" "Encourages others to do their best" "Needs help tying shoes" "Answers telephone properly"

Cognitive assessment.

The Wechsler Preschool and Primary Scale of Intelligence – Third Edition (WPPSI-III), Australian Standardised Edition. The WPPSI-III is a clinical instrument used to assess intellectual ability in children aged 2 years 6 months through 7 years 3 months (2:6 to 7:3). The test is separated into age bands with the younger age band covering from 2:6 to 3:11 and the older from 4:0 to 7:3. The younger age band includes 5 subtests which are: Receptive Vocabulary,

Information, Block Design, Object Assembly and Picture Naming. These subtests yield three main composite scores which are: Verbal IQ (VIQ), Performance IQ (PIQ) and Full Scale IQ (FSIQ). The WPPSI-III scale composition for the 2:6 to 3:11 age group is presented in Table 5 below, including task examples.

For children aged 4:0 to 7:3, a short form of the WPPSI-III was used for research efficiency. The short-form was obtained from Sattler and Dumont (2004) and included only four subtests: Information, Matrix Reasoning, Picture Completion and Symbol Search. The sum of scaled scores obtained from this short form were calculated and converted to an estimated FSIQ using table B-16 (p. 354). This short form combination used for this study have reliability and validity coefficients of rxx = .948 and r=.921. The WPPSI-III in general has good reliability, with internal consistency reliability coefficients across all the groups ranging from .94 to .96 (Sattler & Dumont, 2004).

Composite scores (IQ scores) for both age bands have a mean of 100 and a standard deviation of 15. Composite scores below 70 are considered Extremely Low, 70-79 is Borderline, 80-89 is Low Average, 90-109 is Average, 110-119 is High Average, 120-129 is Superior, and a score of 130+ is categorised as Very Superior.

Table 5

WPPSI-III Scale Composition for 2:6 to 3:11 age group

Subtest	Composite	Task
Receptive Vocabulary (Core)	VIQ, FSIQ	Examiner names a word and the child points to a picture from a set. E.g. "Show me the basketball"
Information (Core)	VIQ, FSIQ	Child answers questions posed by examiner. E.g. "How old are you?"
Block Design (Core)	PIQ, FSIQ	Child uses blocks to copy a design
Object Assembly (Core)	PIQ, FSIQ	Child puts puzzle together
Picture Naming **(**Supplemental)	VIQ (substitute)	Names object in a picture

Performance-Based Measures of EF.

Delayed-Alternation Task **-** Delayed alternation (DA) is a measure of working memory useful in evaluating executive functioning. The design selected for this investigation was adapted from a DA task developed by Espy et al. (1999). In each trial, the child was instructed to search for a hidden reward, out of two hiding places. If the response was correct, the child received a reward; and if the response was incorrect, the child received no reinforcement. Children had to alternate their responses (win-shift strategy) and search on the side opposite to the one that they had previously gained reinforcement.

The apparatus used was a beige, wooden testing board which was 43 cm by 20 cm. The board had with three shallow wells, which were 2.5cm in diameter and less than 1cm deep. The two lateral wells which were 21.5cm apart were used, and the centre well was not used. Two plastic, white cups were inverted and used to cover the lateral wells. Treats such as raisins, Tic Tac and M&M's were used as rewards for the task, depending on child and parent preference.

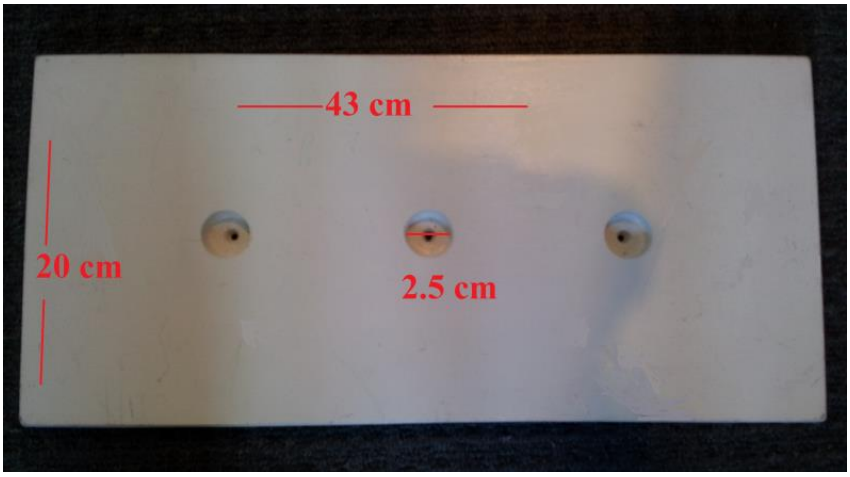

Figure 3. Testing board used for the Delayed Alternation task

For this task, the wooden board was hidden out of the child's sight (sunder a table). The reward was always hidden in the right-hand well for the first trial. After correct retrieval, the reward was hidden in the alternate well. Whether the reward is shifted from one lateral well to the other depends upon the child's performance. For maximal correct responding, the child was to alternate retrieval from right to left wells for each trial. If the child disrupted the alternation by searching on the same side, the reward was hidden at the same location until correct retrieval occurred. A total of 20 trials were administered regardless of the child's performance. The script below was used to explain the instructions:

"Now we are going to play a hiding game. You will need to look for the

[treat]. I'm going to hide the [treat] then you find it…Where is the [treat]?"

"Yes, good looking. You can eat the [treat]" OR "No; the [treat] is not in there"

The dependent measures scored for the task were number correct, number of consecutive correct (DACORR) trials in the longest run of alternations (DACRUN), and number of trials in the longest perseverative run (DAPRUN).

The Stroop Colour-Object Interference Task. Stroop tasks are believed to place demands on inhibitory capacity, as described in the literature summary. The classic Stroop task requires individuals to name colours in which a word is printed in, while inhibiting reading the word. The "Stroop effect" occurs when occurs when automatic word reading interferes with the processing of the word colour, when the word and ink colour are incongruent (e.g. the word "purple" printed in yellow).

The task used in this investigation was adapted from the colour-object Stroop designed by Prevor and Diamond (2005), with modifications made to suit the study. Prevor and Diamond's (2005) adaptation of the classic Stroop does not require the ability to read, and is therefore suitable for use with preschool aged children. For this particular study, the stimuli used were 48 line drawings, each of which was displayed on laminated A5 sized white paper. Each line drawing was digitally produced in red, yellow, green, orange, brown or blue, and was oriented horizontally on each card. The drawings included were an apple, orange, tree, teddy bear, water, lemon, love heart, whale, horse, carrot, frog, and 12 abstract shapes. Examples of drawings used for each set are presented in *Figure 4* below.

The cards were divided into four sets, presented in the order of Set A, Set B, Set C and Set D. The cards in Set A were 12 drawings of familiar objects that were strongly associated with a particular colour, which are all drawn in their non-canonical colour (incongruent). For example: blue apple and a red teddy bear. The cards in Set B were the same 12 drawings in their canonical colour (congruent), For example: red apple and brown teddy bear. Sets A and B set were used to assess if children experience interference when colour-naming (as indicated by longer response times and poorer accuracy) whenever a nameable object was present. They were also used to compare whether there were differences in accuracy and response time when objects were presented in congruent or incongruent colours.

Set C were a set of 12 unique abstract shapes with all six colours presented twice. This set was used as a baseline and to determine if children were faster and more accurate at identifying the colour of a stimulus when is unable to be named. This also enabled the researcher to observe whether the child was familiar with the colour without object-naming interference. Set D consisted of the 12 common items, which were drawn in a neutral colour (black). This set was used as a baseline, and to determine if children were familiar with what the objects were.

The procedure for this task involved a within-subjects design. All children above the age of 3 were asked to name the colour in which each object was drawn in Set A, Set B and Set C. Children were then asked to name the items outlined in black in Set D. There were no breaks between each set. To ensure that each child understood the instructions, a trial was given at the beginning of the task. The task was video-taped by the experimenter for accurate analysis. Response times were calculated from when the child first viewed the stimulus to the time of responding.

When a child self-corrected their response, the first answer given was the one recorded.

Figure 4. Examples of stimuli for Stroop Colour-Object Interference Task (Row 1= Sets A, Row 2 = Set B, Row 3= Set C, and Row 4 = Set D).

Fruit Stroop Task. This task is also a variant of the classic Stroop task as described above; and was used as an alternative to the Stroop Colour-Object Interference task for children who were under 3 years of age. Similar versions of this task have been used in previous studies investigating EF in young children (Evans & Lee, 2013; Kochanska, Murray, & Harlan, 2000). This task involved the use of nine fruit pictures. Each fruit picture was digitally produced and oriented horizontally on laminated, white A4 paper. The first three cards were coloured pictures of a large apple, a large orange and a large banana, which were oriented horizontally on the page. The next three sets were significantly smaller coloured pictures of the same three fruit. The remaining three cards were pictures of the

three large fruit, with pictures of the small fruit embedded within them on a white background. *Figure 5* shows examples of the stimuli used.

The task began with a practice trial: pictures of the large orange, large apple and large banana were presented to the child starting from the right. Below these items, the corresponding small fruit were presented in the same order. The fruit pictures were then introduced to the child:

"I have a BIG ORANGE (big voice) and a LITTLE ORANGE (little voice).

A BIG APPLE (big voice) and a LITTLE APPLE (little voice)

And a BIG BANANA (big voice) and a LITTLE BANANA (little voice)"

The row of small fruit was then removed from the child's view, and the child was asked to point to the orange, apple and banana individually. Children were required to correctly identify all three fruit to continue with the Stroop trials.

During the Stroop trials, the embedded fruit cards were placed in front of the child (in the order of orange, apple and banana starting from the right). Without providing any verbal feedback, the child was asked to point to the "little apple", "little banana", and "little orange" in this order. The child's response was recorded using a checklist.

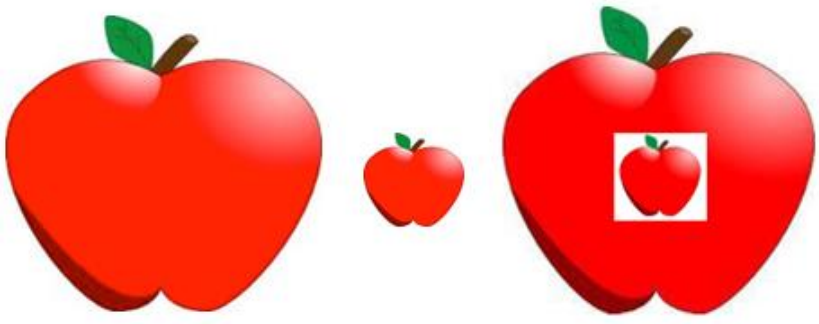

Figure 5. Example of stimuli used in the Fruit Stroop Task: big fruit, little fruit and embedded fruit (from left to right).

Observation of Parent-Child Interaction.

The assessment included an observation of how the parent interacted with their child during a series of tasks. The parent is firstly informed that the purpose of the task is to observe their child solving problems with the support of a familiar person. Parents were then introduced to the three activities, and were provided instructions for each activity. Parents were asked to assist and interact with their child how they typically would, when looking at new toys at home. Parents were provided with three black canvas bags, each with a different activity for the parent and their child to complete. The three activities, the materials used, and the activity instructions are summarised in Table 6 below. These interactions were video recorded for later analysis, and were coded by individuals who were blind to the participants' experimental group. Training was completed by individuals prior to scoring the observation, and inter-rater reliability was above r=0.80.

Table 6

Materials and instructions for activities observed in the parent-child interaction.

Activity	Materials	Instructions
1	Wooden puzzle board in two: one for children aged less than 2 years 6 months and one for older children.	Complete a wooden puzzle.
2	Magnetic letter board and loose magnetic letters. Magnetic letters were glued to the board to form the word "BEARS".	Copy the word "BEARS" using the loose magnetic letters
3	A Duplo block model; a picture of the Duplo block model; and loose Duplo blocks	Use the remaining Lego blocks to copy the provided model

The parent-child interaction was coded using a number of categories, based on existing coding schemes which have been developed and used previously (Belsky, R., Sligo, Woodward, & Silva, 2005; Chase-Lansdale, Brooks-Gunn, & Zamsky, 1994; Clark, Woodward, Horwood, & Moor, 2008; Network, 1999). This coding protocol adapted for this study has been used in previous studies (Clark et al., 2008). Descriptions of each category are summarised but not described in detail. Each category is scored for each of the three tasks; and the scores for all three tasks were then summarised into one average rating for that category. The parent-related categories that were rated

include: Positive Affect (towards the child), Negative Affect (towards the child), Supportive Presence, Facilitates Self-Regulation, and Intrusiveness/Over Controlling. Child-related categories that were rated include: Positive Affect, Negative Affect, Activity Level, Child Persistence, Dependence, and Quality of Task Transition. A score for Interactional Synchrony is also rated, and each of these categories is scored on a scale of 1 to 5 for each task.

Positive Affect (toward the child). This was used as a measure of the overall quality of the parent's positive expressions toward their child during the task. Displays of positive affect include: smiles, chuckles, lilt in voice, beaming, good humouredness, expressions of affection (kissing, hugging, touching), exclamations, clapping, and playfulness in voice; but does not include inappropriate/sarcastic laughter. Higher scores on this category reflect more intense and frequent displays of positive affect.

Negative Affect (towards the child). This category reflected the frequency and intensity of negative affective behaviours of the parent towards the child, including: expressions of disapproval, tense body, negative voice, abruptness, tense facial expression, raised eyebrows, screaming, sharpness, curtness, anger, annoyance, and irritability. Higher scores reflected higher frequencies and intensity of negative affect.

Supportive Presence. This category is an assessment of the parent's expression of positive regard and emotional support to their child. This includes: providing encouragement with emotional regard, a secure base, physical closeness for support, reassurance, and acknowledging accomplishments. The lowest score on this scale indicates the parent's failure to be supportive to the child; by either

being aloof, unavailable or hostile. Higher scores indicate that the parent established themselves as being supportive and encouraging of the child.

Facilitates Self-Regulation. This category is an assessment of the extent to which a parent scaffolds each task to enable the child to a) control their emotions and behaviour; and b) actively and positively engage in the task. This includes: explaining rules and instructions clearly, preventing actions as needed in a clear and supportive manner, provision of rationales that offer information or appeal to consequences in order to obtain compliance, provision of well-timed and non-intrusive directions, manipulation of items which improve the child's chances of success, and provision of well-timed interventions preventing their child from becoming over-aroused and/or disorganized. Higher scores on this scale indicate more frequent and salient facilitative behaviour displayed by the parent.

Intrusive/Over-controlling. This category is an assessment of the extent to which parental behaviour is ill-timed, intrusive and excessively controlling relative to the child's behaviours. The parent's behaviour may disrupt the child's goals or lack empathy and synchrony towards the child's feelings and actions. This includes behaviours such as: providing instructions in a dictatorial fashion, directing play in a way that does not allow the child to explore (telling child what to play with and in what way), provision of constant verbal directions leaving the child with little opportunity for autonomous functioning, or intrusive manipulation of materials to force the child to behave in a certain manner. High scores reflect that instances of intrusiveness during the parent-child interaction are frequent or salient.

Child Positive Affect. This category is an assessment of the overall quality of positive expressions/responses displayed by the child during the

session. Displays of positive affect by the child include behaviours such as: smiles, laughter, lilt in voice, beaming, good humouredness, clapping, animation, and positive exclamations. Higher ratings reflect more frequent and intense displays of positive affect.

Child Negative Affect. This category is an assessment of the intensity and frequency of unhappiness, sadness, and hurt expressed by the child during each task. Displays of negative affect include: frowns, whining, negative facial expressions, sulking, pouting, crying and edginess. Higher ratings reflect more intense and frequent displays of negative affect by the child.

Activity Level. This scale assesses how physically active the child is during the observation. This includes behaviours such as: frequent movements, shifting positions, constantly moving a body part, constantly in motion while completing a task, and restlessness. The rating considers speed, frequency, intensity, involvement and negative reactions to enforced non-activity. Higher ratings indicate that the child was more highly and intensely active.

Child Persistence. This scale is a measure of the extent to which the child was problem-oriented in session, or whether they displayed little effort in the task. Higher ratings indicate that the child was more persistent during the task. More behaviours such as avoiding the task, lack of concentration on the task, and loss of interest would result in lower ratings; whereas behaviours such as longer periods of concentrated problem-solving and lack of diversionary tactics would result in higher ratings.

Interactional Synchrony. This scale was rated to assess the parent-child synchrony during the task, and refers to the balance and coordination of the pair. This includes: responsiveness, interconnectedness, engagement, mutual focus,

reciprocity and harmony. Higher ratings indicate better interactional synchrony. Examples of behaviours that could lead to lower ratings can be: when one partner is instructing the other to follow (not reciprocal) or one partner ignores/misses cues. Higher ratings would be granted when behaviours such as: shared affect, eye contact, responsiveness by both partners, physical closeness are observed.

Procedure

This study was part the Consequences of Brain Injury in Childhood (COBIC) study at the University of Waikato (in collaboration with AUT). The COBIC study was approved by the Northern Y Ethics Committee (Ref NTY/11/02/016) and the School of Psychology Ethics Committee, University of Waikato. Data for the present study was collected by a University of Waikato Masters student. A research assistant was also involved in collecting some parent data in collaboration with the student.

Families that were part of BIONIC - and agreed to be contacted for any future studies - were invited to take part. An information sheet and a pamphlet were sent to each potential participant, as well as a letter explaining the purpose of contact (see Appendix A for information sheet). After a period of approximately one week, participants were contacted by phone to provide more information and to inquire about their interest in participating. For parents who provided verbal consent, an appointment was made to gain written consent and to complete the assessment (see Appendix B for consent form). Parents were provided with the option of being seen in their homes or at another mutually convenient location, but all participants in this study preferred to be assessed at home. The same

process was employed for parents of non-TBI participants who responded to advertisements.

At the assessment, parents were provided with a parent questionnaire. Parents were able to complete these independently, or to have the questions read to them by the researcher. The children were assessed by a table in a quiet space while parents completed the questionnaire, usually in a separate area. The duration of the full assessment was approximately two hours per child, but parents had the option of undertaking two shorter sessions if needed. A $20 voucher was provided for families who completed the full assessment.

Analysis

The data for this study was analysed using IBM SPSS Statistics 20 software. Independent *t*-tests were used to compare the two group means on the performance based-measures of EF (Delayed Alternation and Colour-Object Interference tasks) and parent-rated behaviour related to EF (BRIEF-P). Cohen's *d* effect sizes were also calculated for each comparison.

In terms of non-parametric tests, the Mann-Whitney U-test was used to compare the difference between the two groups in ordinal data (parent-child interaction ratings, HADS scores). Chi-square analyses were used to analyse differences in the frequency of children in each group who scored in the clinically significant range for each of the BRIEF-P and BASC-2 composite scales. Where there were very small observed or expected frequencies, Fisher's exact tests (FET) were used.

Correlations between parental/environmental variables and measures of EF and behaviour were also undertaken, as regression analyses could not be

conducted due to the smaller sample size. Where the variables were on an interval scale, (SES, BRIEF-P and BASC-2 T-scores) Pearson's correlations were conducted. Spearman's rho correlations were conducted if one or both variables were on an ordinal scale (parent-child interaction ratings, HADS scores).

Results

Statistical analyses were conducted to explore the hypotheses, and these results are presented in six parts. Part 1 presents results from measures which were used to investigate sample characteristics. This includes parent mental health, quality of the parent-child interaction and child cognitive functioning. Part 2 presents results for TBI and control group performance on performance-based measures of EF. Part 3 presents results for measures of parent-rated EF and behaviour (BRIEF-P and BASC 2). Part 4 of this section compares the number of children in each group who are above clinical cut-off scores for measures of parent-rated EF and behaviour (BRIEF-P and BASC-2). Part 5 of the results explores the relationships between parental/environmental factors and measures of EF and behaviour. The final section of the results includes post-hoc analyses of the data.

Part 1: Other Sample Characteristics

Parent-specific sample characteristics. As explored in the literature review, parental factors such as mental health and interaction with their child can affect EF outcomes. To examine whether there were any differences in parental mental health between the two groups, scores on the Depression and Anxiety scales of the HADS were analysed using a Mann-Whitney U-test. These results are presented in Table 7. The findings indicate that there were no statistically significant group differences between TBI and control group in Anxiety and Depression scale scores.

Individuals who score above 11 on either of the HADS scales are considered meet criteria for ‘caseness’ of possible depression or anxiety disorder. Results from Fisher’s exact test presented in Table 8 shows that the frequency of

parents who met criteria for 'caseness' on the HADS were not statistically different.

Table 7

Comparison of group means for parent scores on the Depression and Anxiety scales of the HADS.

	TBI (*n*=22)		Control (*n*=24)			
HADS	Median	IQR	Median	IQR	U	p
Anxiety	5.5	5	4	4	234.00	0.51
Depression	2.5	6.25	2	3	243.00	0.65

Note: HADS = Hospital Anxiety and Depression Scale.

Table 8

Parents who met criteria for HADS anxiety/depression 'caseness'.

	TBI (*n*=22)		Control (*n*=24)		FET
HADS	Normal N(%)	Case N(%)	Normal N(%)	Case N(%)	p
Anxiety	19 (86.4)	3 (13.6)	21 (87.5)	3 (12.5)	0.62
Depression	20 (90.9)	2 (9.1)	24 (100)	-	0.22

Note: FET = Fisher's exact test. HADS = Hospital Anxiety and Depression Scale.

Ratings from the parent-child interaction were also analysed to examine whether there were any differences in the quality of the parent-child interaction between the two groups. A Mann-Whitney U-test was used to compare ratings, which presented in Table 9. As shown, there were no significant differences found between the two groups in the categories related to the parent including: Parent

Positive Affect, Parent Negative Affect, Supportive Presence, Facilitation of Self-regulation, Intrusiveness and the parent-child Interactional Synchrony.

Table 9

Comparison of parent-related ratings between the TBI and control group for the parent-child interaction task.

Parent-Child Interaction	TBI (*n*=22)		Control (*n*=23)		*p*
	Median	IQR	Median	IQR	
Positive Affect	4	1	4	1	0.91
Negative Affect	1	0	1	0	0.34
Supportive Presence	5	1	5	1	0.99
Facilitation of Self-Regulation	4	1	4	0	0.72
Intrusiveness	1	2	2	1	0.27
Interactional Synchrony	3	1	4	1	0.60

Note: IQR = Interquartile range

Other child characteristics. The WPPSI-III was used to assess estimated IQ in both groups as a controlling variable. The full WPPSI was used for children ages 2:6 to 3:11 years, while a short form of the WPPSI was used for children aged over 4:0 years. Table 10 shows the number of children who completed each version of the WPPSI-III. One child from each group was below the age of 2:6 years and thus did not complete the WPPSI-III. One participant in the TBI group who was within the age range did not complete the WPPSI-III, as the child was unable to be adequately engaged in the task.

Table 10

Number of children who completed cognitive assessments

Cognitive Assessment	TBI (n=22)	Control (n = 23)
WPPSI-III (2:6 to 3:11years)	19	20
WPPSI-III short form (4:0 to 7:3 years)	3	3
Children under 2:6 years of age	1	1
Did not complete assessment (other)	1	0

Note: WPPSI = Weschler Preschool and Primary Scale of Intelligence – III.

The distribution of estimated FSIQ scores is presented in *Figure 6* below. The TBI group had a lower mean estimated IQ (*M*= 105.00, *SD*=13.27) compared to the control group (*M*= 110.83, *SD*=11.33). However, an independent *t*-test revealed that the difference between the groups was not statistically significant (*t* (43) = -1.59, *p*=0.12). Cohen's value (d = .48) suggested a moderate effect.

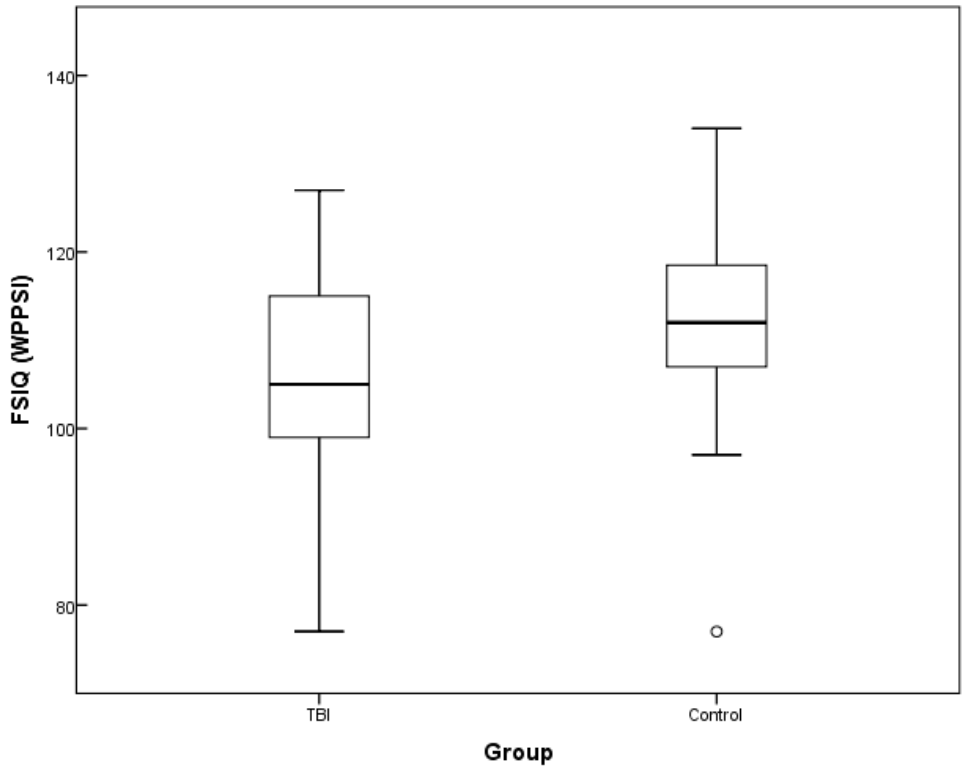

Figure 6. Distribution of estimated FSIQ scores on the WPPSI-III for the TBI and control group.

Note: WPPSI = Weschler Preschool and Primary Scale of Intelligence – III; FSIQ = Full scale IQ.

WPPSI-III scores fit into different descriptive categories. Composite scores below 70 are considered Extremely Low, 70-79 is Borderline, 80-89 is Low Average, 90-109 is Average, 110-119 is High Average, 120-129 is Superior, and a score of 130+ is categorised as Very Superior. Table 11 shows the number of children who fall into each descriptive category for the WPPSI-III. No children were in the Extremely Low range (below 70) so this was not included in the table. The frequency of children in each category is similar, but no children in the control group scored in the Low Average category, compared to 2 children in the TBI group. The TBI group's mean was within the Average range for the WPPSI-III, while the control group mean is in the High Average range.

Table 11

Number of children in each descriptive category on the WPPSI-III.

WPPSI-III Descriptive Categories	TBI (n =22) n (%)	Control (n=23) n (%)
Borderline (70-79)	1 (4.5)	1 (4.3)
Low average (80-89)	2 (9.1)	0 (0.0)
Average (90-109)	10 (45.5)	9 (39.1)
High average (110-119)	6 (27.3)	8 (34.8)
Superior (120-129)	3 (13.6)	4 (17.4)
Very superior (130+)	0 (0.0)	1 (4.3)

Note: WPPSI = Weschler Preschool and Primary Scale of Intelligence – III.

Part 2: Group Comparisons for Performance-Based Measures of EF

Delayed Alternation task. To investigate whether children in the TBI and control groups differed in terms of their performance on this objective measure of working memory, group means for 1) differences in the number of correct responses (DACORR), 2) longest consecutive run of correct responses (DACRUN), and 3) longest perseverative run (DAPRUN) were analysed. These findings are presented in Table 12. The means for all of the dependent variables were similar between the TBI and control group, and independent *t*-tests revealed that the differences in the two group means did not reach statistical significance. Further, Cohen's *d* suggests a small effect.

Table 12

TBI and control group performance on the Delayed Alternation task.

Delayed Alternation task	TBI (n =22) Mean, (SD)	Control (n=22) Mean, (SD)	*t*	df	p	*d*
DACORR	14.00 (8.00)	13.0 (3.13)	.49	42	.62	0.15
DACRUN	4.27 (2.96)	5.14 (4.27)	-.78	42	.44	-0.24
DACORR	2.00 (0.98)	1.77 (1.19)	.69	42	.49	0.21

Note: DACORR = number of correct responses, DACRUN = longest consecutive run of correct responses, DAPRUN = longest perseverative run.

Colour-object interference task. Out of children who were 3 years of age or over (TBI group n=20; control group n= 20); only 19 children in total (TBI group n= 8; control group n= 11) were able to be included in the analysis for this task. One child in the TBI group did not complete it as the parent opted out after a partial assessment (due to time constraints). For the remaining 20 children, the task was attempted but not able to be scored as the children did not have adequate knowledge of colours for the task to be valid.

To examine whether there was a Stroop effect, the mean reaction times (for correct responses) and accuracy for Sets A, B, C and D were compared. As described by Prevor and Diamond (2005), differences that would be observed if there was a Stroop effect include: faster and more accurate responding to naming objects rather than colour; and slower and less accurate responding for incongruent stimuli than for congruent/neutral stimuli. Table 13 shows the mean reaction times for each test condition for the two groups combined. A repeated-measures ANOVA was used to compare means for each test condition. The

results showed that the testing condition significantly affected accuracy $F(3, 54) = 2.68$, $p < .05$ and response time $F(3, 54) = 2.87$, $p < .05$.

As sphericity was not violated, a Tukey's post hoc test was conducted. The results showed that children responded significantly slower on the incongruent (Set A) and compared to the object naming (Set D) condition ($p=0.01$); and also marginally slower on the congruent (Set B) colour-naming trials compared to the object naming (Set D) condition ($p=0.05$). No difference was found for response time on the neutral colour-naming (Set C) compared to any other condition. The accuracy of responding was only significantly different between the incongruent colour-naming (Set A) condition and the object naming (Set D) condition ($p=.02$).

Although results from comparisons of each test condition did not fully replicate those of Prevor and Diamond (2005); mean response times (seconds) and accuracy (percentage correct) for each test condition were compared between the two experimental groups. As presented in Table 13 below, there were no significant differences found in response time or accuracy between the TBI and control group for any of the test conditions.

Table 13

Comparison of TBI and control group on reaction time and accuracy for the colour-object interference task

Set	Dependent Variable	Group		Independent *t*-test			
		TBI (n=8)	Control (n=11)				
		Mean (SD)	Mean (SD)	*t*	df	p	d
A	Time (s)	3.05 (0.68)	3.15 (0.86)	-0.25	17.00	0.81	-0.12
	% Correct	82.29 (15.06)	87.12 (13.62)	-0.73	17.00	0.48	-0.36
B	Time (s)	2.73 (0.38)	3.02 (0.93)	-0.84	17.00	0.41	-0.41
	% Correct	87.50 (16.67)	86.36 (18.74)	0.14	17.00	0.89	0.07
C	Time (s)	2.75 (0.88)	3.03 (1.28)	-0.53	17.00	0.60	-0.26
	% Correct	88.54 (10.85)	90.15 (8.99)	-0.35	17.00	0.73	-0.17
D	Time (s)	2.36 (0.50)	2.46 (0.65)	-3.72	17.00	0.72	-1.83
	% Correct	95.83 (8.91)	93.94 (8.41)	0.47	17.00	0.64	0.23

Note: Set A = incongruent colour-naming; Set B = congruent colour-naming; Set C = neutral colour-naming; Set D = object naming.

Fruit Stroop task. Out of the sample only 6 children (3 TBI; 3 control group) in total were below the age of 3 years (and therefore suitable for this test). All three of the TBI children failed the identification practice trials, where the children asked to point to the apple, the orange and the banana. The task was therefore discontinued before proceeding to the Stroop trials. The three children from the control group successfully completed the identification practice trial and correctly identified all of the items in the Stroop trials. No other data was collected; and as there are no meaningful comparisons are able to be made from this information, there was no further analysis.

Part 3: Comparison of TBI and Control Groups for Parent-Rated Behaviour

To investigate differences between the two groups in EF in the context of everyday environments, the main composite scores for the BRIEF-P (as well as the Working Memory (WM) and Inhibit (IH) subscales) were analysed. As presented in Table 14, the TBI group had higher mean scores across all of the BRIEF-P composite scales, which suggests greater EF difficulties. Independent *t*-test analyses showed that the difference in scores between the two groups were not statistically significant. However, the difference between the two groups for the Emergent Metacognition Index (EMI) (composed of the Working Memory and Plan/Organize scales) showed a trend towards significance ($p= 0.09$), with the TBI group showing greater difficulties. All of the group means for the BRIEF-P were within the normal range.

To examine whether there were any differences between the TBI and control groups in behavioural/emotional functioning as rated by parents; composite T-scores from the BASC-2 parent reports were analysed. As shown in

Table 15, the TBI group had slightly higher means for all of the BASC-2 clinical scales (indicating more behavioural/emotional problems) and a lower score on the Adaptive Skills scale (suggesting less adaptive behaviour). While the differences between the two groups were not found to be statistically significant for any of the BASC-2 scales, the difference between the two groups on the Internalising Problems scale showed a trend towards significance ($p = 0.09$), with more internalising problems evident for the TBI group. Group means were also within the normal range for behaviour as determined by the BASC-2 cut-off scores.

Table 14

Comparison of T-scores for parent ratings of the BRIEF-P for the TBI and Control Groups

BRIEF-P	Group				Independent *t*-test			
	TBI (*n*=22)		Control (*n*=24)					
	Mean	(Std. Dev)	Mean	(Std. Dev)	*t*	df	p	d
Scale								
IH	55.77	(12.59)	53.75	(12.72)	0.54	44.00	0.59	0.16
WM	60.09	(8.91)	54.79	(12.74)	1.62	44.00	0.11	0.49
Index								
ISCI	52.91	(12.17)	52.38	(11.34)	0.15	44.00	0.88	0.05
FI	53.37	(12.29)	48.71	(8.38)	1.51	44.00	0.14	0.46
EMI	59.18	(9.32)	53.58	(12.50)	1.71	44.00	0.09	0.52
GEC	57.32	(11.72)	52.58	(10.18)	1.47	44.00	0.15	0.44

Note: BRIEF-P = Behavior Rating Inventory of Executive Function–Preschool; IH = Inhibit; SH = Shift; EC= Emotional Control; WM = Working Memory; P/O= Plan/Organize; ISCI = Inhibitory Self-Control Index; FI = Flexibility Index; EMI = Emergent Metacognition Index; GEC = Global Executive Composite.

Table 15

Comparison of T-scores for parent ratings of BASC-2 for the TBI and Control Groups

BASC-2	Group				Independent *t*-test			
	TBI (*n*=22)		Control (*n*=24)					
	Mean	(Std. Dev)	Mean	(Std. Dev)	*t*	df	p	d
Ext	52.86	(14.36)	50.17	(10.29)	0.74	44.00	0.47	0.22
Int	54.27	(12.33)	48.96	(7.78)	1.73	35.00	0.09	0.52
Adapt	52.70	(8.70)	57.13	(10.77)	-1.53	44.00	0.13	-0.46
BSI	52.60	(12.29)	49.24	(9.64)	1.02	44.00	0.31	0.31

Note: BASC-2 = Behavioural Assessment System for Children – 2nd Edition; Int = Internalising Problems; Ext = Externalising Problems; Adapt = Adaptive Skills; BSI = Behavioural Symptoms Index.

Part 4: Clinical Cut-Off Scores for Parent Behaviour Questionnaires

For the BRIEF-P, and the BASC-2, children's scores were categorised into either the 'Normal' or 'Clinical' range as determined by test cut-off scores. The BRIEF-P T-scores have a mean of 50 and a standard deviation of 10, with T-scores at or above 65 considered clinically significant. The BASC-2 T-scores also have a mean of 50 and a standard deviation of 10. A T-score of 70 or more on the BASC-2 clinical scales (Externalising, Internalising and Behavioural Symptoms Index) indicates clinically significant behaviour problems on, while T-scores in the 60-69 range show that the child is 'at risk' of developing a clinically significant problem. For the Adaptability scale, lower scores are indicative of more difficulty in adaptive skills. A T-score of 30 or below on this scale indicates clinical significance, while children with T-scores in the 31-40 range are 'at risk'.

The percentage of children in the TBI and control groups with BRIEF-P scores in the clinically significant range is presented in *Figure 7*. A higher percentage of children in the TBI group were in the clinically significant range for the FI, EMI and the GEC; while the control group had a higher percentage of children in the clinical range for the ISCI.

The percentage of children in the TBI and control groups with BASC-2 scores in the clinically significant range is presented in *Figure 8*, where it is shown that a higher percentage of children in the TBI scored in the clinical range for Internalising and Externalising scales; while the percentage of children in the clinical range for the BSI and Adaptive scales were very similar. It can also be seen from this figure that no children in the control group were in the clinical range for the Internalising behaviour scale, compared to 22.7% of children in the TBI group.

As there were very small expected or observed frequencies, Fisher's exact tests were used to analyse whether the differences in the percentage of children above clinical cut-offs between the groups were statistically significant. No significant differences were found for any of the BRIEF-P scales. In terms of the BASC-2, no significant differences were found between the two groups on the Externalising scale, BSI or the Adaptive Index. However, a statistically significant difference was found between the TBI and the control group for the Internalising behaviour problems scale, with a significantly greater proportion of the TBI group scoring above the clinical cut-off (FET, p=.019).

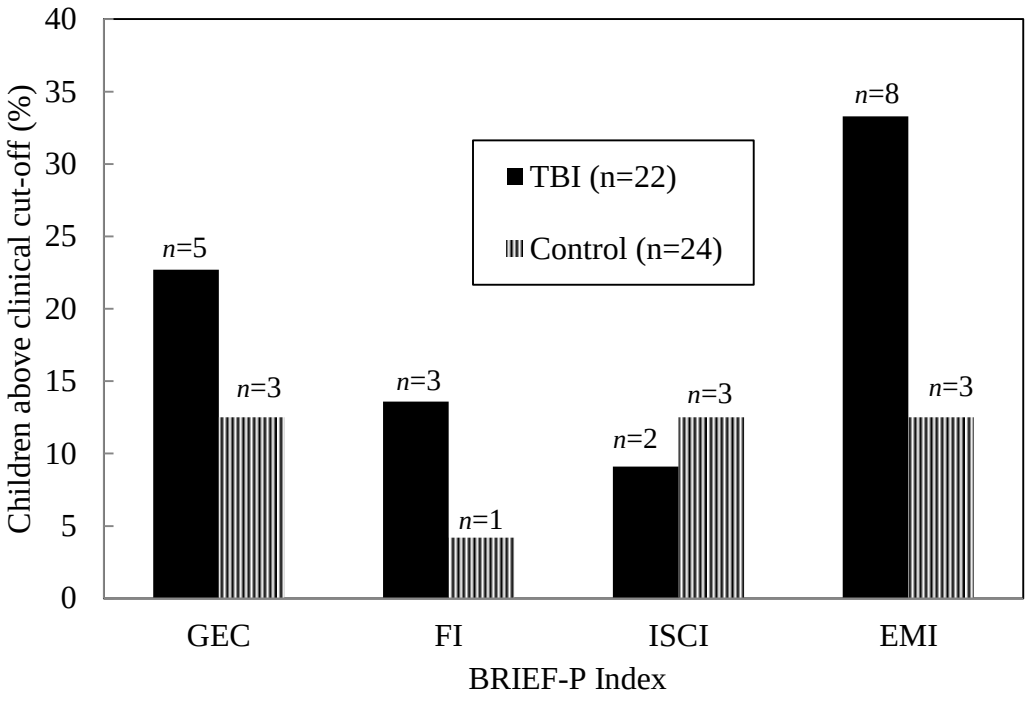

Figure 7. Percentage of children in the TBI and control groups with BRIEF-P scores in the clinically significant range.

Note: BRIEF-P = Behaviour Rating Inventory of Executive Function–Preschool; IH = Inhibit; SH = Shift; EC= Emotional Control; WM = Working Memory; P/O= Plan/Organize; ISCI = Inhibitory Self-Control Index;FI = Flexibility Index; EMI = Emergent Metacognition Index; GEC = Global Executive Composite.

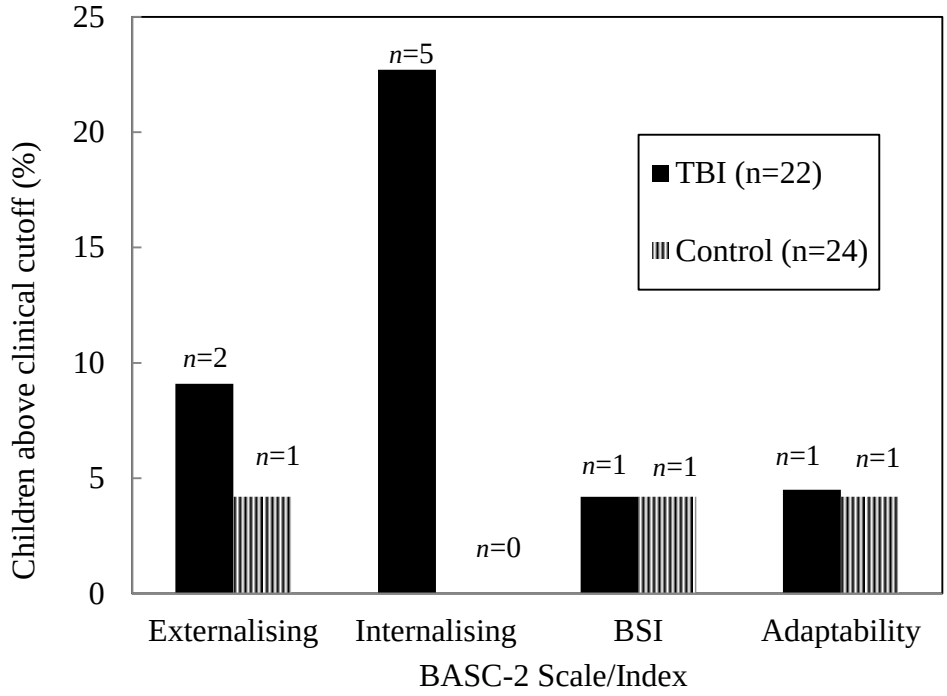

Figure 8. Percentage of children in the TBI and control groups with BASC-2 composite scores in the clinically significant range.

Note: BASC-2 = Behavioural Assessment System for Children – 2nd Edition; BSI = Behavioural Symptoms Index.

Part 5: Parental/Environmental Factors

EF behaviours and parental mental health. Spearman's rho correlation analyses were conducted between behavioural measures of EF and parental factors (mental health and the quality of the parent-child interaction) to investigate if there was a relationship between these variables. As shown in Table 16, there were significant positive correlations found between all of the BRIEF-P composite scales and the HADS Anxiety and Depression scales for the TBI group (parents of children in the TBI group with higher levels of anxiety and depression were associated with children who had worse EF scores). Table 16 also shows that for the TBI group, the Anxiety scale had significant positive correlations with the

Internalising Problems, Externalising Problems and Behavioural Symptoms indices of the BASC-2 (parents who had higher scores on the HADS Anxiety and Depression scales were associated with children who had worse behavioural symptom scores). For the control group, the same table shows that there were no significant correlations between the HADS scales and any of the BRIEF-P or BASC -2 composite scales.

Performance-based EF and parental mental health. As parental factors were significantly correlated with parent ratings of behaviour, Spearman's rho correlation analyses were conducted between scores on measures of parental mental health and an objective measure of EF (Delayed Alternation). The Colour-Object Interference task was not used for this analysis due to its questionable validity. As shown in Table 17, a positive significant correlation was found between longest correct run on the DA task and the Anxiety scale for the TBI group (parents who had higher levels of anxiety were associated with children had better working memory performance). No other significant correlations were observed.

Table 16

Spearman's rho correlations between parental factors and composite scores on the BRIEF-P and BASC-2 for the TBI and control group

	TBI (n=22)		Control (n=24)	
Measure	HADS Anxiety	HADS Depression	HADS Anxiety	HADS Depression
<u>BRIEF-P</u>				
Flexibility I	**.73****	**.69****	.30	.24
Inhibitory Self-Control I	**.72****	**.66****	.35	.06
Emergent Metacognition I	**.67****	**.53***	.34	.34
Global Executive Composite	**.80****	**.69****	.38	.32
<u>BASC-2</u>				
Externalising Prob	**.45***	**.50***	.28	-.06
Internalising Prob	**.75****	**.52***	-.19	-.32
Behavioural Symptoms I	**.71****	**.58****	.36	-.00
Adaptive Skills	-.22	-.27	-.29	-.25

Note: BRIEF-P = Behavior Rating Inventory of Executive Function–Preschool; BASC-2 = Behavioural Assessment System for Children – 2nd Edition. I = Index. *Correlation is significant at the 0.01 level;**Correlation is significant at the 0.05 level.

Table 17

Spearman's rho correlations between HADS scores and scores on the DA task for the TBI and control group.

Measure	HADS Anxiety		HADS Depression	
	TBI (n=21)	Control (n=22)	TBI (n=21)	Control (n=22)
DACORR	.40	.09	.01	-.15
DACRUN	**.46***	-.13	-.12	-.14
DAPRUN	-.22	-.15	-.00	-.09

Note: HADS = Hospital Anxiety and Depression Scale; DA = Delayed Alternation task; DACORR = number correct; DACRUN: longest correct run; DAPRUN: longest perseverative run

*Correlation is significant at the 0.01 level; **Correlation is significant at the 0.05 level.

EF, behaviour, and the parent-child interaction. To explore whether the parents' interaction with their child was related to scores on measures of EF and behaviour, aspects of the parent-child interaction were also correlated with composite scales of the BRIEF-P and BASC-2. Spearman's rho results for the TBI group are shown in Table 18; and control group in Table 19. The TBI group correlations found a significant positive correlation between the parents' Supportive Presence and the BASC-2 Internalising scale. This indicated that higher levels of support from the parent were associated with higher levels of child internalising problems. Facilitation of Self-Regulation was also found to have a positive correlation with the Global Executive Composite of the BRIEF-P and the Behavioural Symptoms Index of the BASC-2. This indicates that better

facilitation from the parents was associated with more EF difficulties and behavioural problems in the child. These correlations were of moderate strength.

Table 19 shows that of the control group correlations, a significant positive correlation was found between the Supportive Presence scale and the Externalising Problems scale. This indicates that higher levels of supportive presence from the parent during this task were related to greater behavioural problems in the control group children. The Interactional Synchrony scale was also found to be negatively correlated with the Flexibility Index and the Inhibitory Self-Control Index of the BRIEF-P, indicating that better quality interactional synchrony between parent and child was related to less EF impairment in flexibility and inhibitory control. All correlations were of moderate strength.

Table 18

Spearman's rho correlations between parent-rated behaviour and parent-child interaction ratings for the TBI group.

Measure	Positive Affect	Negative Affect	Supportive	Facilitation	Intrusiveness	Interactional Synchrony
BRIEF-P						
Flexibility Index	0.07	0.06	0.33	0.40	-0.03	0.16
Inhibitory Self-Control I	0.14	0.10	0.32	0.29	-0.02	0.09
Emergent Metacognition I	-0.01	0.10	0.16	0.36	0.03	0.08
Global Executive Composite	0.11	0.06	0.27	**.50***	-0.06	0.22
BASC-2						
Externalising Prob.	-0.04	0.29	0.18	0.28	0.25	0.15
Internalising Prob.	0.00	0.13	**.47***	0.39	0.01	0.28
Behavioural Symptoms I	-0.03	0.17	0.22	**.48***	0.02	0.23
Adaptive Skills	0.02	-0.10	-0.08	-0.12	-0.32	0.19

Note: BRIEF-P = Behaviour Rating Inventory of Executive Function–Preschool; I = Index; BASC-2 = Behavioural Assessment System for Children – 2nd Edition.

*Correlation is significant at the 0.01 level; **Correlation is significant at the 0.05 level

Table 19

Spearman's rho correlations between parent-rated behaviour and parent-child interaction ratings for the control group.

Measure	Positive Affect	Negative Affect	Supportive	Facilitation	Intrusiveness	Interactional Synchrony
BRIEF-P						
Flexibility Index	-0.08	-0.16	0.23	-0.07	0.2	**-.44***
Inhibitory Self-Control I	0.08	-0.04	0.38	0.11	0.24	**-.42***
Emergent Metacognition I	-0.21	0.18	0.1	-0.02	0.29	-0.34
Global Executive Composite	-0.03	-0.05	0.27	0.01	0.34	-0.37
BASC-2						
Externalising Prob.	0.26	0.13	**.50***	0.15	0.07	-0.25
Internalising Prob.	0.11	-0.12	0.3	-0.26	0.14	-0.01
Behavioural Symptoms I	0.06	0.09	0.36	0.14	0.05	-0.38
Adaptive Skills	-0.1	-0.35	-0.19	-0.27	0.16	0.23

Note: BRIEF-P = Behaviour Rating Inventory of Executive Function–Preschool; I = Index; BASC-2 = Behavioural Assessment System for Children – 2nd Edition.

*Correlation is significant at the 0.01 level; **Correlation is significant at the 0.05 level

Socio-economic Status. Correlation analyses between SES and measures of EF and behaviour were conducted. Table 20 shows that no significant correlations were found between SES and performance on the BRIEF-P, BASC-2 or Delayed Alternation task. Again, the Colour-Object Interference task was not included due to the uncertainty of its validity.

Table 20

Pearson's correlations (r) between SES and measures of EF and behaviour for the TBI and control groups.

Measure	SES	
	TBI	Control
BRIEF-P	(n=22)	(n=24)
Flexibility Index	.010	-.12
Inhibitory Self-Control Index	-.19	-.16
Emergent Metacognition Index	-.35	-.26
Global Executive Composite	-.15	-.20
BASC-2	(n=22)	(n=24)
Internalising Problems	-.17	-.22
Externalising Problems	.01	-.28
Behavioural Symptoms Index	-.06	-.30
Adaptive Skills	-.02	.24
Delayed Alternation	(n=21)	(n=22)
DACORR	.09	-.27
DACRUN	.12	-.19
DAPRUN	-.014	.14

Note: BRIEF-P = Behaviour Rating Inventory of Executive Function–Preschool; BASC-2 = Behavioural Assessment System for Children – 2nd Edition. DACORR = number correct; DACRUN: longest correct run; DAPRUN: longest perseverative run.*Correlation is significant at the 0.01 level; **Correlation is significant at the 0.05 level.

Part 6: Post-Hoc Analyses

Performance-Based Measures and Parent-Rated Measures of Working Memory. A Pearson's correlation analysis was conducted between the Delayed Alternation task, Working Memory subscale of the BRIEF-P, and composites of the BRIEF-P which include the WM scale (Emergent Metacognition Index and Global Executive Composite); to see if there was a relationship in scores for these two measures. Table 21 shows that there were no significant correlations found between performance-based measures of working memory and behaviour rated EF related to working memory; for either the TBI or control group.

Table 21

Pearson's r correlations between DA task and BRIEF-P composites for the TBI and control group.

Measure	DACORR		DACRUN		DAPRUN	
BRIEF-P	TBI	Control	TBI	Control	TBI	Control
Working Memory	0.03	-0.35	0.06	-0.24	0.05	0.26
Emergent Metacgonition	0.09	-0.40	0.13	-0.34	0.06	0.31
Global Executive	0.01	-0.36	0.00	-0.29	0.14	0.18

Note: BRIEF-P = Behaviour Rating Inventory of Executive Function–Preschool: DACORR = number correct; DACRUN: longest correct run; DAPRUN: longest perseverative run.*Correlation is significant at the 0.01 level;**Correlation is significant at the 0.05 level.

Summary of Results

Sample characteristics including parental mental health, quality of the parent-child interaction and child overall cognitive functioning were measured using the HADS, observation of the parent-child interaction and the WPPSI-III. No significant differences were found between the two groups in parent levels of anxiety and depression; or the quality of the parent-child interaction. There were also no statistically significant differences were found between the TBI and control group in estimated IQ.

The BRIEF-P was used as a measure of EF behaviours in the context of the child's everyday environment. It was found that there were no statistically significant differences between the two groups for any of the indexes or composite scales of the BRIEF-P. There was also no statistical significance in the proportion of children who were experiencing clinically significant EF difficulties between the two groups (for any of the composite scales).

The Delayed Alternation task was used as a performance-based measure of working memory. No significant differences were found between the two groups in task performance for any of the dependent variables (number of correct responses, longest run of correct responding and the longest perseverative run).

The colour-object interference task was used as a performance-based measure of inhibitory control. Only 8 children in the TBI group and 11 children in the control group could complete this task as some children did not have adequate knowledge of colours for the test to be valid. The data obtained did not replicate the findings of Prevor and Diamond (2005); and thus a Stroop effect was not fully observed. No significant difference was found between the TBI and control group for response time and accuracy for any of the trials. The Fruit Stroop task was

another objective measure of inhibitory control used for children under the age of 3. However, as all the children in the TBI group were unable to pass the trial stage, results from this test were unable to be used meaningfully.

The BASC-2 was used as a measure of behavioural and emotional difficulties as rated by parents. No significant group difference was found. However, significantly more children in the TBI group (22.7% of the TBI sample) were experiencing clinically significant internalising behaviour problems compared to the control group.

The relationships between EF/behaviour and parental and environmental factors were also explored. For the TBI group, there were significant positive correlations found between all of the BRIEF-P composite scales and the Anxiety and Depression scales of the HADS (higher levels of parental anxiety and depression were associated with more behavioural/emotional disturbance in TBI group children). The HADS Anxiety scale also had significant positive correlations with the Internalising Problems, Externalising Problems, and Behavioural Symptoms indices of the BASC-2 for the TBI group (parental anxiety and depression was associated with worse behavioural symptom scores in TBI group children). Finally, a significant positive correlation was found between the longest correct run on the DA task and the HADS Anxiety scale (parents who had higher HADS-A scores were associated with children who performed longer correct runs on the DA task). For the Control group, the Anxiety and Depression scales of the HADS did not significantly correlate with any of the BASC-2 or BRIEF-P scores.

Ratings from the parent-child interaction observation were also correlated EF and behavioural assessment scores for each group. The TBI group correlations

found a significant positive correlation between the parents' Supportive Presence and the BASC-2 Internalising scale (higher levels of support from the parent were associated with higher levels of child internalising problems). Facilitation of Self-Regulation was also found to have a positive correlation with the Global Executive Composite of the BRIEF-P and the Behavioural Symptoms Index of the BASC-2 (better facilitation from the parents was associated with more EF difficulties and behavioural problems in the child). For the Control group, a significant positive correlation was found between the Supportive Presence scale and the Externalising Problems scale (higher levels of supportive presence from the parent during this task were related to greater behavioural problems in children). The Interactional Synchrony scale was also found to be negatively correlated with the Flexibility Index and the Inhibitory Self-Control Index of the BRIEF-P (better quality interactional synchrony between parent and child was related to less EF impairment in flexibility and inhibitory control).

A post-hoc analysis investigating the relationship between scores on performance-based measures of EF and scores on parent rated EF was also conducted. No significant correlation was found between the Delayed Alternation task; and the Working Memory subscale of the BRIEF-P. Performance on the Delayed Alternation task also did not correlate with scores on any composite scales of the BRIEF-P which include the WM scale (Emergent Metacognition Index and Global Executive Composite).

Discussion

This study investigated EF and behavioural outcomes from mild traumatic brain injury in preschool, 24 months post-injury. The first aim of the study was to establish if children in the mild TBI group were experiencing more EF difficulties than their age-matched control counterparts 24 months post-injury; with a particular focus on working memory and inhibitory control. The second aim was to observe whether there were any differences in behavioural/emotional functioning between the two groups. A final aim was to examine the relationship between parental/environmental factors; and the children's performance on measures of EF and behaviour.

It was hypothesised that due to the vulnerability of the developing brain at this young age; children who sustained a mild TBI would have poorer performance on executive tasks and more behavioural/emotional problems compared to children in the control group. It was also hypothesised that factors such as the quality of the parent-child interaction, parental mental health and SES would be related to performance on EF tasks and behaviour. Specifically, it was predicted that: higher quality parent-child interaction (characterised by higher ratings on the Positive Affect, Supportive Presence, Facilitation of Self-Regulation and Interactional Synchrony scales; and low ratings on the Intrusiveness and Negative Affect scales); lower levels of anxiety and depression; and higher SES would be associated with better performance on EF tasks and less behavioural/emotional difficulties.

To investigate these issues, the BRIEF-P was used as a measure of EF behaviours in the context of everyday environments. Performance based measures such as the Delayed Alternation task (measuring working memory), Colour-

Object Interference task, and the Fruit Stroop (both measuring inhibitory control) were also used to measure specific components of EF. In addition, the behavioural and emotional functioning of children in the two groups was examined using the Behavioural Assessment System for Children – Second Edition (BASC-2).

Executive Function and Behavioural Outcomes

As summarised in the previous section, the overall findings revealed that at 24-months post-injury; children who have sustained a mild TBI showed comparable EF performance to healthy control children in measures of working memory, inhibitory control, and executive function behaviours. In contrast to this however, more children in the mild TBI group (22.7% of the TBI sample) had clinically significant internalising behaviour problems (anxiety, depression and somatisation) as rated by their parents.

The finding that children did not suffer from impaired EF after mild TBI in infancy appear to be consistent with findings by Nadebaum et al. (2007), who also detected no differences in EF behaviours children who sustained mild TBI, 5 years post-injury. Similarly, Crowe and colleagues' (2012) results revealed no difference in EF behaviours between control children and children who have sustained a mild-severe TBI. However, Crowe et al. (2012) did find that children with mild TBI performed below the control group on a performance-based measure of inhibitory control. This is inconsistent with the current findings as no deficits were observed.

It is clear that the results do not support the hypothesis that children with mild TBI are more likely to suffer from EF difficulties. However, an important issue to explore in light of these findings is that while there does not yet appear to

be any impairment in EF for this sample of children; the assessment was conducted only 24 months post-injury. Due to developmental factors, longitudinal studies are still necessary to investigate differences when EF abilities have fully matured. Preschool children have few established skills and thus the impact of mild TBI may appear to be minimal. When considering the possibility of children 'growing into' deficits (McKinlay et al., 2010; Taylor & Alden, 1997); a longer period of follow up post-injury would provide more information. Longitudinal studies that have investigated the effect of TBI on EF when sustained in preschool are currently very rare, and it is perhaps too early to infer that children who sustain a mild TBI in infancy do not suffer any EF impairments.

There are currently still very few studies that investigate the effects of TBI on EF in preschool-aged children in general, and results so far have been variable. The limited number of investigations to date; inconsistent findings so far; and the difficulty in assessing EF in this age group all make it difficult to conclude that mild TBI sustained in the preschool period does not result in impaired EF.

The higher frequency of children with mild TBI experiencing clinically significant internalising behaviour problems is an interesting finding. Although their study was conducted with school-aged children and with TBI varying in severity from complicated mild-severe; these results are very similar to findings by Peterson and colleagues (2013), who found that 22% to 26% of the TBI sample was in the clinically significant range for internalising problems (on the CBCL). Also in school-aged children, Andrews and colleagues (1998) found significantly higher levels of maladaptive behaviour, loneliness, aggressive or antisocial behaviour; and lower levels of adaptive behaviour and self-esteem compared to children in the control group; approximately 1.4-1.5 years after their injury.

McKinlay et al.'s (2010) study on preschool children found that the TBI group were significantly more likely to show symptoms of: attention deficit/hyperactivity disorder, conduct disorder/ oppositional defiant disorder, substance abuse, and mood disorder compared to the control group when assessed at 14-16 years of age.

While these studies support the result that children who have sustained a mild TBI can experience behavioural/emotional difficulties; the study by McKinlay et al. (2010) and Andrews et al. (1998) is dissimilar to the current study in that no differences between the two groups were found in terms of other behavioural symptoms. Specifically, McKinlay et al. (2010) observed increased externalising behaviour problems after preschool mild TBI, and suggested that these skills may be more vulnerable to early brain injury. Increased externalising behaviour problems, however, were not observed with the TBI group in the current study.

There is also other research contradicting findings of long-term behavioural/emotional consequences after mild TBI in childhood (both in older children and in preschool children). Fletcher et al. (1990), Light et al. (1998) and Wetherington et al. (2010) detected no differences between the mild TBI and the comparison group in behavioural functioning. It may be noted however, that follow-up assessments by Fletcher et al. (1990), Light et al. (1998) and Wetherington et al. (2010) were conducted only one year after their injury. The studies by Andrews et al. (1998) and McKinlay et al. (2010) and the current study, however, assessed children after a longer time period from the date of injury; which may have allowed more time for deficits to emerge and become observable.

The higher proportion of children in this study experiencing clinically relevant internalising behaviour problems highlights an issue with only considering group differences in paediatric traumatic brain injury research. While differences may not be observed with the mild TBI group as a whole, this does not reflect an absence of EF and behavioural problems in every child who has sustained a mild TBI. For various reasons, a subset of children may be at higher risk of developing clinical behavioural problems. For example, three out of the five children who were above clinical cut-offs on the Internalising Problems scale of the BASC-2 were Māori. This is notable as there are only four children in the TBI sample in total who were identified as Māori. In addition, all five of the children had SES scores below 50 (range 0-100) on the AUSEI06. Although there is clearly insufficient information here to make any statements regarding ethnicity and SES as risk factors for the development of internalising behaviour problems post-TBI; it is an indication of the need to explore such factors in research.

As well as the limited research on EF in preschool, there are significant discrepancies in the research on behavioural outcomes after mild TBI in this age group. The number of studies that focus on preschool children is currently limited; and the variations in the quality and methods of assessment across the studies make it difficult to draw conclusions. Overall, it is proposed from the results that the higher probability of developing EF impairments and clinically relevant behavioural/emotional problems post preschool TBI may require additional attention in research; particularly longitudinal studies and studies which focus specifically on this age group.

A further issue that will be discussed is the difficulties in using neuropsychological measures to assess EF in preschool children. This is an issue

commonly deliberated in the literature, both in TBI and non-TBI populations. Difficulty with the performance-based measures of EF in this age group was a particular issue, specifically the Colour-Object Interference task. Only a small proportion of children from each group were able to complete this; predominantly due to children having inadequate knowledge of colours. It has been suggested that a challenge in measuring EF in this age group is that assessments typically require measurement of multiple skills simultaneously, which may not develop at the same rate. In the case of this study, many of the children were not yet able to correctly name all of the colours used in the colour-object interference task, which made the data void. In addition - for children who could complete the task - the data did not replicate the findings of Prevor and Diamond (2005) in that the expected Stroop effects were not fully observed. While object-naming was found to be dominant compared to colour-naming as predicted, there were no differences observed between any of the colour naming conditions (incongruent, congruent and neutral). Regardless of this, analyses were conducted and showed no significant differences in accuracy or response time between the two groups. However, with the very small (and possibly biased) sample; it is difficult to conclude that the children in the TBI group performed no differently than the control group in this measure of inhibitory control.

Due to the lack of other standardized measures for measuring EF and the difficulty in using these; the study relied heavily on parent report. There are also several issues to consider when interpreting this type of data. It has been suggested that parents may be reluctant to report problems post-TBI in parent questionnaires, with one reason being feelings of guilt for their child sustaining the injury (Crowe et al., 2012; Wetherington et al., 2010). In addition, many

parents may not be fully informed or experienced in child development, which can affect ratings provided (Wetherington et al., 2010). It is possible that this contributed to the lack of differences found between the TBI and control group means for the behavioural measures (both for EF and behavioural/emotional problems); particularly since the children were at a very young age at the time of injury. Variations in the measures of behaviour used in the different studies presented may also be an explanation for inconsistencies in the literature.

Correlations between a performance-based measures of working memory (DA) and parent-rated measures (BRIEF-P) were also conducted as a post-hoc analysis, to examine the relationship between these two types of EF assessments. It was found that there was no correlation between scores on the Delayed Alternation task (purported to measure working memory) or the Working Memory subscale of the parent-rated BRIEF-P (including composites that are comprised from the Working Memory scale). As the two groups did not differ in performance on the BRIEF-P or Delayed Alternation task, it is difficult to ascertain whether the BRIEF-P is more sensitive to real-world manifestations of EF impairment compared to the DA task or vice versa. However, this finding may denote the need to consider the ecological validity of common neuropsychological tasks used to assess EF in children.

Parental/Environmental Factors

As well as analysing differences in performance on measures of EF and behaviour; the relationship between different measures and parental factors were also considered. In the current study, the investigation of parental and other environmental factors included assessment of: parental mental health, observation

of the parent-child interaction; and collection of relevant parental demographic information (parent education level and occupation - used to determine SES). Correlation analyses between these variables and measures of EF were conducted to explore any relationships. The results showed that for the TBI group, parental mental health (as measured by the Depression and Anxiety scales of the HADS) had a significant positive correlation across all of the BRIEF-P composite scales and all clinical scales on the BASC-2. These positive correlations indicate that parents with higher levels of anxiety and depression were associated with children who had more EF difficulties and behavioural problems. Although there were no significant differences between the TBI and control groups in BRIEF-P, BASC-2 or HADS scores; no significant correlations were found between these any of these measures for the control group.

It is commonly suggested in the literature that parents who have higher levels of anxiety/ depression may be more likely to give poorer ratings of their child's behaviour on questionnaires. However, this does not explain why such moderate-high positive correlations are observed with the TBI group and not with the control group. A possible explanation for this is that children who have had a TBI may be more susceptible to adverse environmental conditions such as maternal anxiety, depression, and negative parenting; while children free from brain injury are more robust to these effects. Similar findings have been observed in other paediatric populations with neurological insult, such as children born very preterm (Treyvaud et al., 2010). Another important consideration is the possible bi-directionality of this relationship between parent and child. It may be that children who have had a TBI are characterised by greater behavioural difficulties after injury; which in turn has a detrimental effect on parental mental health.

Another possibility is that responses by parents in the TBI group were biased in that they are aware of their child having sustained a brain injury. Parents may therefore experience more concern in regards to increased severity of symptoms. It is also worth considering the possibility that TBI group families are experiencing more overall family stress; which is contributing to problems in both parents and children (for instance, the TBI group had lower SES compared to the control group).

Hughes and colleagues (2013) presented research identifying that children's exposure to their mother's depressive symptoms result in poorer EF functioning in the long-term. As there is no parental mental health information available from before time of assessment and no regression analyses are able to be completed with the small sample; it is not possible to speculate whether more severe symptoms of anxiety/depression has led to more EF and behavioural difficulties in these children. However, significant positive correlations found only for the TBI group is an interesting result and may indicate the need for further investigation, as well as signifying the need for seeking information from multiple sources when conducting this type of research.

To further explore the relationship between parental mental health and EF performance, scores on the Depression and Anxiety scales of the HADS were correlated with scores on the Delayed Alternation task (considered an objective measure of EF). Due to the positive association between parental depression/anxiety and child behaviour/EF difficulties, it was expected that higher levels of parental anxiety and depression would be related to poorer performance on the DA task. However, there was a significant positive correlation found between the longest correct run (DACRUN) and the parent Anxiety scale for the

TBI group; which indicates that higher levels of anxiety were associated with more correct responding on the DA task. It is uncertain why this result was found, and it is possible that this was a spurious statistical anomaly due to the number of correlation analyses conducted.

Ratings from the parent-child interaction observation were also correlated with measures of EF and behaviour. A significant moderate correlation was found between the Supportive Presence and Facilitation of Self-Regulation scales and some composite scores of the BRIEF-P and BASC-2. This was an unusual and unexpected finding, as it was it was anticipated that a better quality interaction with the parent would be associated with less behavioural difficulties in the child. This is therefore inconsistent to previous research as presented in the literature summary (Kraybill & Bell, 2013; McDermott et al., 2013; Sarsour et al., 2011; Schroeder & Kelley, 2009). A possible explanation may simply be that children who had more EF and/or behavioural difficulties were finding the activities in the parent-child interaction more challenging; and thus parents were providing them with more frequent support and scaffolding during the observation. This would affect the ratings, which is based on frequency and quality of these behaviours from the parent.

Another interesting finding from the correlation analyses was a moderate negative correlation between the parent-child Interactional Synchrony and Flexibility and Inhibitory Self-Control indexes of the BRIEF-P (for the control group only). This indicates that better levels of interactional synchrony between parent and child were associated with less EF difficulties in the children, particularly in areas such as cognitive flexibility and inhibitory control. This is consistent with previous research. For example, parent–child dyadic synchrony in

toddlerhood has been associated with self-control/self-regulation (Feldman, Greenbaum, & Yirmiya, 1999; Lindsey, 2009). However, it is unknown why these correlations were not evident with the TBI group.

Socio-economic status was discussed in the literature summary as a predictor of EF skills and child behaviour. Contrary to expectations, no significant correlations were found between SES and measures of EF and behaviour for both the TBI and control groups. As presented in the literature summary the development of EF in children has related to the family's SES; with research suggesting that lower SES is associated with poorer EF skills (Anderson et al., 2004; Clearfield & Niman, 2012; Raver et al., 2013; Sarsour et al., 2011). The findings of Sarsour et al. (2011) identified that parental responsivity, enrichment activities and family companionship mediated the association between family SES and EF. It is possible that this was the case for the families involved in the current study. Another possible explanation is that SES was calculated using Australian codes. While Australian and New Zealand codes are assumed to be similar, it is possible that the SES scores obtained may be less accurate than if codes specific to the New Zealand population were used.

Clinical Implications

The findings from this study contradict suggestions that there are little or no long-term consequences suffered from mild TBI sustained in childhood. As revealed by the evidence, children with mild TBI should indeed receive significant attention in research and in practice. The number of children suffering from internalising behaviour problems in the mild TBI group has significant implications. Internalising problems measured by the BASC-2 include symptoms

of anxiety, depression and somatization. As summarised by Wenar and Kerig (2006), these symptoms in children can be detrimental and can present in many forms. In preschool children, a loss of pleasure in activities may be observed. Children may also exhibit symptoms such as excessive anxiety about separating from their caregiver, and express vague somatic complaints. Depressive symptoms in preschoolers can also be associated with developmental backsliding, such as loss of skill in cognition and language. Other symptoms include excessive irritability and sleep-related problems. Untreated, these preschool internalising problems may persist and further affect school performance, peer relationships, and functioning in other areas of life.

With these issues considered, the screening/assessment of these concerns in children who have had a TBI may be beneficial in order to detect behavioural/emotional difficulties as early as possible. Screening should also identify not only children who are experiencing clinically significant behavioural/emotional disturbance but also children who are at risk for developing clinically relevant problems. Children who are identified as suffering from behavioural/emotional difficulties should receive support and treatment accordingly.

Furthermore, behavioural and emotional challenges such as these are not only problematic for the child, but are also likely to be a source of distress for parents and the whole family. As presented in the results, the correlation analyses showed greater behaviour difficulties in children to be associated with higher levels of parental anxiety/depression. One suggestion made for this was that children who have had a TBI may be more susceptible to adverse environmental conditions such as maternal anxiety and depression. Another possibility is the bi-

directionality of this relationship. For example: children who have had a TBI may be characterised by greater behavioural difficulties after injury; which in turn has a detrimental effect on parental mental health. Parental mental health difficulties may then further impact on the child's normal development. This highlights the possible need for providing support for parents of children who have sustained a TBI.

Limitations and Strengths

The study and its findings should be considered in light of its strengths and limitations. The study sample size was comparable to similar studies on paediatric TBI. It is noted however that the small number meant that regression analyses were unable to be conducted. The size of the group may have also limited the ability to detect any subtle differences between the TBI and control group.

Control participants were recruited by word-of-mouth or distributing fliers through childcare centres. Parents agreed to participate in the study on a volunteer basis. This means that only children who went to particular childcare centres or had parents who heard about the study from others were able to take part. The sample of children in the control group may therefore not be representative of the general population.

In the fliers distributed, parents were also offered feedback on their child's cognitive functioning as part of their participation in the study. There is a possibility that this resulted in a biased sample by attracting parents who had concerns about their child's development and or/behaviour; or parents who had an interest in having their child assessed for 'giftedness'. Furthermore, not all TBI

children who were invited to participate in the study consented to participate, which may have also biased the sample.

The importance of accounting for injury factors in TBI research has been emphasised in the literature, with one of the recommendations being the use of orthopaedic injury control groups for comparison. The current study did not use an orthopaedic injury group. However, in light of the non-significant findings between the TBI and control group means, the inclusion of an OI group may have provided very little advantage in this case. Furthermore, just under half of the mild TBI group were not located from hospitals and did not require hospitalisation. Children that were hospitalised are also unlikely to have required frequent follow-ups (as would be expected with children in an OI group); questioning whether such comparison groups are appropriate for children who have had mild TBI.

The children included in this study were within a limited age range. This is considered a strength for the study, as the current research on children sustaining TBI at this age is very uncommon. Including only this age group allows a greater ability to consider the developmental stage of individuals when interpreting results, as recommended in the literature (McKinlay, 2009). The small age range was also very advantageous in that children were able to use the same versions of particular tests (such as the BRIEF-P, and BASC-2). This allowed for simpler and more accurate comparison of scores.

Another further strength of the study is that it is population-based. It included both rural and urban populations, and located cases of mild TBI from various sources. This included not only children who went to seek medical care from hospitals; but also located cases from: general practices, accident and

medical clinics and the Accident Compensation Corporation (ACC) database. Population-based studies on TBI incidence and outcomes are relatively uncommon, particularly studies focussing on this younger age group.

Future Studies

There are areas of research not explored in this paper that may provide valuable information about outcomes from mild TBI in preschool. As previously mentioned, longitudinal research on preschool children post-TBI are rare. Longitudinal data will not only provide information on deficits that may emerge over time that can be associated with mild TBI; but may also inform us about factors that contribute to good or poor outcome in children who are suffering from clinically significant difficulties.

This study relied predominantly on comparing parent ratings of their child's behaviour. While performance-based measures of EF were utilised, some had questionable validity. Developing a good combination of both performance-based and parent-rated measures may aid in getting a full picture of EF in this age group. Future studies could utilise tests such the NEPSY-III (Korkman, Kirk, & Kemp, 2007), TRAILS-P (Espy & Cwik, 2004) and Shape School (Espy et al., 2006), which are tests that have been applied by other researchers. Re-assessing this same group of children at a later date will also allow the use of other available neuropsychological assessments which are suitable only for older children. Future studies with additional resources may utilise clinical interviewing and direct observation of children to comprehensively assess behaviour/emotional difficulties experienced by the mild TBI group, considering the number of children who exceed clinical cut-offs.

Collecting data from multiple sources is recommended, and will allow a broader analysis of outcomes post-TBI in preschool. Information from more than one source will provide a more robust examination of children's functioning across different contexts. This could include an integration of parent, teacher and examiner reports. Teacher reports were used but not analysed for this paper due to the low response rate, but would be a useful addition to the current information. The children in this study will be entering into a school environment in between 12-24 months from the time of assessment. As the school environment places more demands on children cognitively, behaviourally and socially, it will be important to investigate the longer-term effects of mild TBI on school performance and social functioning.

Finally, as significantly more children with mild TBI are experiencing internalising behaviour problems, it may be interesting to investigate how these symptoms develop over time. It will also be interesting to investigate which factors contribute to good or poor outcome in these children; which can provide important information for the development and implementation of interventions in the future.

Conclusions

In conclusion, the hypothesis that the TBI group would experience more difficulties with EF compared to the control group was not supported by the results. No group differences were found in either parent ratings of EF-related behaviour or performance-based measures. However, difficulties in assessing EF in preschool children were highlighted.

While no differences in performance were found between the two groups in EF, results supported the hypothesis that children who have sustained a TBI in preschool may experience more behavioural/emotional problems. The results suggested that there are more children in the TBI group who are experiencing clinically significant difficulties compared to the general population of preschool children; particularly in relation to internalising behaviours such as anxiety, depression and somatization. This indicates that children who have sustained mild TBI may need to be screened for possible behavioural/emotional difficulties and be provided with interventions accordingly. It is also suggested that parents of children with mild TBI may require additional support. The results indicate that impairments from injury can occur long-term after a mild TBI - in this case up to 24 months post-injury.

It has been emphasised that the research on long-term outcomes from mild TBI in preschool children is presently insufficient. Further studies are recommended, which should focus on longitudinal data and incorporate information from a number of sources.

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Appendices

APPENDIX A: Parent Information Sheet

The Consequences of Brain Injury In Childhood (COBIC)

Parent (Proxy) Information Sheet - Preschool Children

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.

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.

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.

Who can take part in this study?

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 1st March 2010 and 28th 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.

How many people will be in the study?

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

What happens if I do decide to take part?

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 1 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.

What will my child have to do?

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.

What is the time-span for the study?

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

How will the study affect me?

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.

Compensation

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

Confidentiality

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 16th 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.

Your rights

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.

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.

Finally

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

Study Investigators

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 B: 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.

APPENDIX C: Control Participant Flyer

School of

Psychology

The

To find out more about the effects of brain injury on child development, researchers from the University of Waikato are currently looking for children aged 2 years - 3 years 11 months who have not had a head injury to take part in our research study.

You would be asked to take part in an assessment which involves filling out questionnaires, and fun tasks for your child.

Your child will be offered a $20 voucher and certificate at the end of the full assessment and this may take one to two visits. You will also receive some general feedback about your child's cognitive functioning.

To find out more, please email Setareh Zareie at COBIC@waikato.ac.nz or ring 07 8384466 ext 8082

APPENDIX D: Control Eligibility Checklist

The Consequences of Brain Injury In Childhood (COBIC)

FORM CE: Case Ascertainment/Eligibility - For ALL Participants (Phone)

Information to be obtained from phone or face to face

Registration Number ☐☐☐☐☐☐ Participant initials ☐☐☐☐

Date of birth: ☐☐ ☐☐ ☐☐

1. General Questions – Section 1

Q#	Label	Field format
1.1	NIH Number	
1.2	Gender	Male Female
1.3	Date of Birth	ddmmyyy
1.4.1	TBI between 1 March 2010 and 28 Feb 2011 and registered in BIONIC?	Yes – go to 1.4.4 No – go to 1.4.2
1.4.2	TBI free since birth?	Yes – go to 1.4.3 No – ineligible for study, go to 1.4.5
1.4.3	Are they age/gender matched to TBI participant?	Yes – go to 1.4.4 No – ineligible for study, go to 1.4.5
1.4.4	Are they a resident of Hamilton /Waikato District	Yes - go to 1.5 No – ineligible for the study, go to 1.4.5
1.4.5	Can we keep your contact details for future studies?	Yes - stop here, sign and date form No - stop here, sign and date form
1.5	Area of Residence	Resident of Hamilton

		Resident of Waikato
1.6	Ethnicity (tick one on each line) New Zealand European Maori Samoan Cook Island Maori Tongan Niuean Chinese Indian Other (such as Dutch, Japanese, Tokelauan)	 Yes/No Yes/No Yes/No Yes/No Yes/No Yes/No Yes/No Yes/No Yes/No
1.6.1	If other, please specify	Text

Study Researcher to complete

	Label	**Field format**
	Signature	Text
	Printed name	Text
	Date	ddmm20yy

Now complete Contact details form (CC) if eligible or if happy for future contact.