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**The consequences of paediatric mild traumatic brain injury  
(mTBI) on executive functioning**

A thesis

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of the requirements for the degree

of

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## ABSTRACT

Traumatic Brain Injury (TBI) is one of the most common causes of death and disability in children and adults under 35 years of age, and is a major health concern worldwide (Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2001; Babikian & Asarnow, 2009; Feigin, et al., 2013; Langlois, 2005). It is estimated 10 million people are effected worldwide annually (Hyder, Wunderlich, Puvanachandra, Gururaj, & Kobusingye, 2007), and it is projected that TBI will be the third largest cause of global disease burden by 2020 (The Lancet Neurology, 2010). Symptoms of TBI can persist across cognitive, behavioural, emotional, and social domains, regardless of age; pre-school children being particularly vulnerable, due to rapid development of the brain within the first years of life.

The main purpose of this study (aim 1) was to determine whether mild traumatic brain injury (mTBI) injury in pre-school children had an effect on their normal cognitive development, specifically executive functioning (EF) and the sub domains of inhibitory control and working memory 24 months post injury compared with an age-matched control group. Behavioural functioning was also examined in terms of its relationship to EF (aim 2), specifically addressing both internalising and externalising behaviours and adaptability. Lastly factors that may contribute or be predictive of risk of injury were explored (aim 3), specifically age/maturation of the brain or stage of development, and both parental/environmental factors.

Forty four children participated in this population-based study; twenty two were pre-schoolers aged two years of age at the date of injury, and were assessed 24 months post injury and were aged between 4 years – 4 year 11 months. This group was matched by age, gender, and geographical region with a TBI free control group (n=22).

Both the parent-rated Behaviour Rating Inventory of Executive Functioning (BRIEF-P) and the performance based Colour Object Interference and Day & Night tasks (COI & D&N) measures of executive functioning were used to determine any differences between the groups in terms of inhibitory control and working memory. Further parent-rated measures the Behavioural Assessment System for Children (BASC-2) and a screening test (SDQ) were also used to measure behaviour and social and emotional functioning, specifically internalising and externalising behaviour and

adaptability. Other parental and environmental measures were used to determine parental mental health; The Hospital Anxiety and Depression scale (HADS), the home environment; Home Observation for Measurement of the Environment (HOME) and the parent child relationship using a parent child interaction observation task (PCI).

The study found that pre-schoolers with mTBI exhibited higher levels of internalising, and externalising problem behaviours, and poorer adaptability and EF skills, as evidenced by the associated correlations. However analyses revealed there were no significant differences between the mTBI and control groups in terms of the measures of EF, behaviour and social and emotional functioning. These findings could suggest assessing EF in children aged between 2-5 years is difficult, or that the manifestations of the outcomes of these impairments are not yet fully observable due to young age.

The limitations of the study were the relatively small sample which was not sufficient enough to carry out regression analyses; the comparison group was not representative of the general population and lastly, the measure of the HOME was found to be out-dated and as such did not provide a comprehensive picture of the home environment.

Future studies could aim to more closely examine the relationship between age at injury and outcomes from mTBI. Also they could utilise the categories within the mild severity category for a more sensitive account of the consequences of mild traumatic brain injury in children. Therefore more research needs to be done on the effects of mild traumatic brain injury rather than focusing on hospital cohorts.

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## **The consequences of paediatric mild traumatic brain injury (mTBI) on executive functioning in preschool children assessed 24 months post injury**

Traumatic Brain Injury (TBI) is one of the most common causes of death and disability in children and adults under 35 years of age, and is a major health concern worldwide (Anderson, 2001; Babikian, 2009; Feigin et al, 2013; Langlois, 2005). It is estimated 10 million people are effected worldwide annually (Hyder, et al., 2007), and it is projected that TBI will be the third largest cause of global disease burden by 2020 (The Lancet Neurology, 2010). The consequences of TBI therefore have a major impact on society, the economy, but most significantly on the affected individual, and on their families quality of life (Donders & Warschausky, 2007; New Zealand Guidelines Group, 2005; Temkin, 2009; Thurman, 1999; van Velzen, 2009; Yeates, 2000).

Symptoms of TBI can persist across cognitive, behavioural, emotional, and social domains, regardless of age. Pre-school children are however particularly vulnerable, due to rapid development of the brain within the first years of life. Deficits in both cognitive and behavioural domains, in particular, may include social, intellectual and executive dysfunction and impairment in both internalising and externalising behaviours. Consequences of these impairments impact on a child's ability to function, and the subsequent outcomes manifest in the inability to attain and retain skills of those of their peers. Further population-wide research into TBI is therefore warranted; especially in the under researched area of mild TBI (mTBI) in pre-school children (the focus of this thesis) with the aim to add to research on mTBI in the paediatric population and enable the planning of effective prevention strategies and TBI care services worldwide (Feigin, et al., 2013).

This introduction is presented in three parts: Part one will focus on the definition, characteristics, diagnosis, epidemiology and aetiology of TBI. Part two will discuss TBI in terms of brain maturation and development and the outcomes of TBI. Part three will then focus on the main aim of this thesis, executive functioning and the consequences of dysfunction to this area in children. Lastly the introduction will be summarised, and the rationale for this study, and the aims and hypotheses are presented.

## **Introduction: Part One.**

### **Traumatic Brain Injury (TBI)**

There has been much discussion and debate in defining TBI; however, for the purposes of this study, the World Health Organisation's definition of Traumatic Brain Injury (TBI) is 'Acute brain injury resulting from mechanical energy to the head from external forces' (Carroll, Cassidy, & Holm, 2004; New Zealand Guidelines Group, 2006b) and is further defined by the characteristics of clinical diagnoses; type and severity.

There are two types of traumatic brain injury; an open TBI, which occurs when the skull and dura are penetrated, opened and is focal; and a closed TBI, an injury that occurs from *within* the skull from a collision, knock, or blow to the head as an *external force*, which is qualified by *severity* and is characterised as either *mild, moderate or severe*.

### **Diagnosis**

Clinical characteristics of TBI may include one or more of the following: confusion or disorientation; loss of consciousness; post traumatic amnesia (PTA) or other neurological abnormalities such as focal neurological signs, seizure and/or intracranial lesion (Carroll, et al., 2004). The severity of TBI can be estimated by measuring the duration of loss of consciousness with Glasgow Coma Scale score (GCS) (Teasdale, 1974) which rates three aspects of functioning: eye opening, motor response, and verbal response; high scores predicting a less severe injury (Teasdale, 1974). Severity can also be measured by the duration of Post-traumatic Amnesia (PTA). It must be pointed out that as the definition of TBI varies markedly across studies, the GCS and any additional symptoms, whether neurological or neuropsychological dysfunction, can used to determine the accuracy of the following classification system and as part of diagnosis (McKinlay, 2010; National Center for Injury Prevention and Control, 2003).

TBI can be classified into three severity categories, mild, moderate and severe. A severe TBI is defined as having a GCS score of between 3-8 and a PTA scale of 7+ days, and a moderate TBI is defined as a GCS of 9-12 and a PTA of between 1-6 days.

Mild TBI (mTBI) (including concussion) is the most common form of TBI and the least understood (thus is the focus of this thesis), is defined as the lowest GCS of 13-15, a PTA of less than 24 hours, with no brain lesion on a Computed Tomography (CT) scan, and a LOC of less than 20 minutes (Bellner, Jensen, Lexell, & Romner, 2003; Iankova, 2006). mTBI or concussion signs may include headaches, weakness, numbness, decreased coordination or balance, confusion or disorientation, slurred speech, nausea and vomiting. mTBI can also be further classified into *low risk* defined as a GCS of 15 on admission, without a history of LOC, amnesia, vomiting, or diffuse headache; *mild risk* defined as a GCS of 15 with loss of consciousness, amnesia, vomiting, and/or diffuse headache; and *high risk* defined as a GCS of 13-15 with risk factors of coagulopathy, drug or alcohol consumption, previous neurosurgical procedures, pre-trauma epilepsy, or age over 60 years. And using this type of classification may provide a better understanding of mTBI (Servadei, Teasdale, & Merry, 2001).

However, the above GCS measure is generally used in adult populations; therefore using the GCS to measure TBI severity is problematic, particularly when assessing pre-verbal populations such as infants and toddlers (Harrahill, 1996). That is a GCS score for a preschool child in the moderate range could indicate a more severe injury than an older verbal child. And although a more age appropriate pre-verbal paediatric version of the GCS has been developed, it is acknowledged that it is underutilised, and as such under-studied.

It must be noted here further, nevertheless, that although severity classification may predict long-term impairment; severity scores don't correlate exclusively with negative consequences in an individual's life, as there are other factors operating concurrently and each TBI sustained is different.

## **Epidemiology of TBI: Prevalence, Incidence & mortality rates:**

A review of international literature on TBI prevalence, has ascertained that there is variable epidemiological data available, due to discrepancies in methodology, which may be underestimating this major public health issue.

Prevalence of TBI (hospital admissions only), for example has been reported annually in the United Kingdom, Australia, and North America as being approximately 200-300 per 100,000 (Torner, 1996). Others report TBI incidences estimates at 610-735 per 100,000 in Australia (The Brain Injury Centre of Australia, 2003) or 600 per 100,000 hospitalisations and non-hospitalisations per year (Carroll, et al., 2004). Another American report suggested rates of 200 per 100,000 per year, with an annual incidence of 70 per 100,000 hospitalisations (Langlois, Kegler, & Butler, 2003).

In New Zealand of the children under 20 years of age admitted for TBI, most (70%) are treated outside of the hospital setting (Mc Kinlay, et al., 2008) and 70-90% sustain a mTBI (Feigin, et al., 2013; Theadom, et al., 2012). In New Zealand it was previously estimated there were 228 per 100,000 person-years (hospitalised) across all age groups (Caradoc-Davies & Dixon, 1995), however when factoring non-hospitalised groups a more recent figure suggests numbers are more likely to equate to 600 per 100,000 person-years (hospitalised/non-hospitalised) (New Zealand Guidelines Group, 2005). Thus in New Zealand it is estimated there are between 20,000 – 30,000 new cases of mild and 2,000-3,000 cases of moderate to severe TBI annually (Barker-Collo, Wilde, & Feigin, 2009).

These discrepancies exist as there are no standardised guidelines or a framework to define or conduct studies on TBI. They include the absence of a standardised operational definition of TBI; variable measures within age ranges; variable age ranges; variable data collection methods; discrepancies in study design, duration and type of study (For a comprehensive illustration of these discrepancies by study; see McKinlay, et.al (2009) - table 1 showing methodological characteristics of studies of mTBI in children and adolescents (1970-2008)).

Defining the operational term for TBI has been a much debated area of discussion, with differing countries and indeed health providers using varying descriptions; such as head injury, brain injury, Acquired brain injury (ABI) Traumatic brain injury (TBI), head impact injury, closed head injury (CHI) etc., of which each term may include or exclude diagnostic criteria of a term; even with the same name.

Another issue is differing criteria for severity, and within severity categories. For example, in the category of mTBI, highlight that any deficits associated with this group can be masked, as the majority of mTBI cases do not have long term consequences (Reitan & Wolfson, 1999). Further classification of the mTBI category as previously stated by Servadei, Teasdale, & Merry, (2001), therefore will not exclude these cases. Age of population or age ranges of studies also differ, most referring to the total population as a measure of incidence; however they may exclude age groups; for example a paediatric group may be described as children under 20; others describe the paediatric age range as children under 16 years of age. This is also widely inconsistent in adolescence and older age groups.

Data collection is also an area of concern as for example, most estimates of TBI typically utilise only hospital admissions and/or health care service data. Hospital admissions data, for example, may not account for fatal TBI; undiagnosed TBI, such as cases presenting with multiple trauma and others with concussion or mTBI; (Barker-Collo & Feigin, 2009). The disadvantage of which, results in the grossly underestimated prevalence of mTBI cases.

There are also gross discrepancies in study design. TBI research design varies with comparisons being within TBI groups; or with a control group. The type of control group used (other injury or non-injury) is also problematic as they may include/exclude criteria. The degree to which normal developmental milestones are assessed (Asarnow, et al., 1995), and measured is another concern with a wide variety of measures used producing varied results. The breadth of domain is also a factor; studies focusing on both single and multiple outcome domains.

There is variation too in duration of research; most studies being short term or isolated, rather than longitudinal studies; or either retrospective rather than prospective (Bruce, 1995). This problem is well highlighted in The Paediatric TBI Guidelines (2003) and by The New Zealand Guidelines Group Report (2006). It is also acknowledged by Kirkwood and Yeates (2010) as they state there is a definite need for well-designed longitudinal studies to improve understanding of mTBI in children and young people (Kirkwood, 2010; New Zealand Guidelines Group, 2006a; Williams, 2010). Variation is also apparent in the intervals between injury and follow-up assessments (Babikian, et al., 2011).

To this end differences in methodology are very evident and indeed make estimating the total incidence of TBI and more significantly mTBI difficult (Barker-Collo & Feigin, 2009).

To address some of the issues with previous research, the prospective population BIONIC study - Brain Injury Incidence and Outcomes in the Community (BIONIC) funded in 2009 by the Health Research Council, aimed to register all cases (of severity and age) of TBI in the Waikato districts (both rural and urban) over a 12 month period (see Theadom, et al, 2012, for more information). The study's goal was to make inroads in epidemiology through proposed guidelines; to provide a methodological framework for future comparable population-based epidemiological studies of TBI incidence and outcomes in developed countries (Theadom, et al., 2012). Theadom (2012), stated that methodological issues can be resolved as in the BIONIC study, where she suggests the utilisation of three core components; standard definitions, standard methods/measures and standard data presentation (Theadom, et al., 2012).

Findings from BIONIC show the total incidence of mTBI per 100,000 person-years was 749 cases and both moderate to severe cases at 41. Children aged between 0-14 years and adolescents and young adults (aged 15-34 years) were reported as constituting 70% of all TBI cases. TBI affected boys and men more so than women and girls, with most cases due to falls (38%) and mechanical forces (21%). The total incidence of mTBI is reported as being higher in minority groups identified as NZ Maori and pacific peoples, compared with people of European origin. Incidence of moderate to severe TBI in the rural population was 73 per 100,000 person-years and was almost 2.5 times greater than in the urban population (31 per 100,000 person-years).

## **Estimating paediatric mTBI – severity, age, and gender**

mTBI is regarded the most common classification of severity, as Kraus (1995) found in his report of 709 cases of paediatric traumatic brain injury, that 93% were mild (Kraus, 1995). Kraus (1995) also estimated the incidence of TBI in the paediatric population (under 16 years) between 100-300 per 100,000, consistent with von Holst (2007) study whose account of mTBI in the paediatric population was 70-90% of all TBI's (Kraus, 1995; von Holst, 2007).

A more recent study confirms this further, finding that the risk of sustaining a mTBI was more than 18 times greater than the risk for moderate to severe TBI in people aged 15-34; more importantly the incidence of mTBI was significantly greater in preschool children aged 0-4 years than those in any other age groups (Feigin, et al., 2013).

Similarly, Lehr's (1990) study found that preschool children were at higher risk, particularly 3 year olds (Lehr, 1990). Likewise Rivara (1994) found female infants under 2 years of age were more likely than any other paediatric group to sustain a TBI (Rivara, Jaffe, & Polissar, 1994). Interestingly, other data shows the fatality rate for children increases as age decreases (i.e., 50% for infants under the age of 2), and that recovery increases only with age, which means younger age is associated with greater vulnerability (Michaud, Rivara, Grady, & Reay, 1992).

Barnes et.al (1999), conducted a study to investigate if a child's age was a factor of outcome. Twenty-one children sustained their injury at or before 6.5 years of age, 19 between 6.5 and 9 years, and 9 years and 15 years of age. Assessments using the Woodcock Johnson reading mastery Test-Revised were carried out 3 years post injury, and found children injured under the age of 6 had difficulty acquiring reading skills, with the older age groups achieving reading skills effectively (Barnes, Dennis, & Wilkinson, 1999).

There are also obvious gender differences in the incidence of paediatric mTBI. In preschool children, for example, the male to females ratio is 1.5:1 (Hayes & Jackson, 1989; Horowitz, et al., 1983) likewise Kraus (1995), identifies boys of preschool age as twice as likely as girls to suffer a TBI (Kraus, 1995). Similarly, data from England and Wales has shown that for those under the age of 5, a male to female hospital admissions ratio was 1.3 to 1, compared to children aged 5 – 14 years of age (Hayes & Jackson,

1989). Feigin et al (2013) also found this was the case; the incidence of mTBI in boys and men compared with women and girls being two times greater for mild TBI (Feigin, et al., 2013).

### **Aetiology and risk factors**

There are a myriad of factors in the context of injury related predictors of outcome from childhood TBI; injury mechanism; pre-injury factors (child function; parental mental health and gender); injury related predictors of outcome (severity, location, neurologic signs); developmental factors (age at injury and developmental stage), and environmental factors (socio-economic status; home environment, education), (Anderson, Northam, Hendy, & Wrennal, 2001).

Non-accidental trauma is most common in children aged two years and under and occurs with a clinical course and pathological outcome which is unique, that of abuse or shaken baby syndrome (Bruce, 1995). Paediatric TBI specifically though, occurs mostly by falls or as passengers in cars (Berney, Froidevaux, & Favier, 1994; Crowe, Babl, Anderson, & Catroppa, 2009; Kraus, 1995). Falls being the mechanism of injury for 50% of preschool children aged 4 years or younger (Lehr, 1990). Reporting suggests that paediatric TBI has a relatively high incidence due to lack of a child's awareness of danger (Lehr, 1990), and that a child may be learning to walk; but it should be noted here that environment also plays a crucial role where closer supervision may aid in the prevention of falls (Anderson, Northam, et al., 2001; Chadwick, 1981). TBI can also be somewhat predicted based on injury risk, which is risk based on other factors. TBI for example, may be more common in families where parents are socially disadvantaged, unemployed or have mental health problems (Anderson, Northam, et al., 2001; Brown, Chadwick, Shaffer, Rutter, & Traub, 1981; Rivara, et al., 1993; Taylor, 1995); and more common in children with pre-existing learning and behavioural deficits (Anderson, Northam, et al., 2001; Asarnow, 1991; Brown, et al., 1981).

The pre-injury factors of major interest are gender, family characteristics (family function & environment, maternal and paternal education); prior injury history such as parental health and well-being (use of alcohol, drugs; parents health prior, or during - complications, prematurity); post pregnancy (Post natal depression etc.) and child pre-injury functioning which may include behavioural problems such as attention deficit disorders and conduct disorders (Broman & Michel, 1995; Bruce, 1995).

Some researchers suggest post-injury outcomes may be a reflection of premorbid cognitive, behavioural and social disturbances – this view is well accepted in paediatric TBI literature, even so, a number of studies have failed to support such findings, arguing that children who sustain injury cannot be differentiated from the general population with respect to pre-injury characteristics (Anderson, Northam, et al., 2001).

The age of the child at the time of injury is a risk factor as previously highlighted (Anderson & Moore, 1995), in that the injury would interrupt maturation of the brain. Children exposed to forms of trauma from a variation of causal mechanisms, at differing ages (Bruce, 1995), therefore have variations in pathophysiology, which must be considered when comparing age-based outcomes (Goldstein & Levin, 1985).

Environmental factors are also a predictor of outcomes. The family or home environment needs to be considered when predicting injury and recovery from TBI, given that marked behavioural and adaptive problems are found in children where there is more dysfunction within the home or the family is disadvantaged (Brown, et al., 1981; Gerring, et al., 1998; Kinsella, et al., 1997; Rivara, et al., 1993; Rivara, et al., 1994; Taylor & Alden, 1997; Taylor, et al., 1999; Yeates, et al., 1997). That is where parental child relationships are insufficient, or in cases where the home environment is non-stimulating or unsafe and socio-economic status is low.

In part one of the introduction we have discussed, TBI as a major health concern, its economic, public health and social impact; the debate of defining TBI, its diagnosis, clinical features, signs and symptoms. A discussion of prevalence and discrepancies in research methodology was also brought to the fore, highlighting the need for standardised research methodology. Epidemiology of TBI was then discussed in terms of international and New Zealand research, which illustrated the variability in prevalence, but also highlighted the BIONIC study which may set a precedent for new longitudinal studies. Paediatric mTBI prevalence was then estimated, with factors such as age, gender and ethnicity discussed to ascertain higher risk factors attributed to mTBI occurrence. Further aetiology also highlighted differing factors, as injury predictors of outcome: pre and post- injury, developmental and environmental factors.

## **Introduction: Part Two.**

In part two the focus is on effects of TBI on preschool children in terms of the maturation of the brain, and highlights the long term cognitive and behavioural consequences of TBI on children.

Lazar and Menaldino (1995) state that it is essential that a developmental perspective is taken with children with TBI, in the context of maturational and developmental changes; as this area of study requires the recognition of the recovery process long term (Lazar & Menaldino, 1995). Although it has been suggested that over-learned skills are less vulnerable to disruption; skills in the process of being developed are more effected specifically dependent on age at time of injury as there are critical periods of development (Barnes, et al., 1999).

### **Brain maturation and long-term consequences of preschool TBI**

Long-term consequences of TBI in children have been seen as characteristic of impairments in adults; however, when skills are underdeveloped, or immature at the time of injury, as is the case with children, resultant deficits are more pronounced (Anderson & Catroppa, 2006). Brain development proceeds very rapidly within the first few years of life, and is therefore particularly vulnerable as the regions of the brain continue to develop at differing rates (Tanner, 1990).

At birth, for example, the only highly developed parts of the brain are the brain stem and mid brain. These parts of the brain control consciousness, inborn reflexes (such as the Palmar grasp and Babinski reflex) and biological functions such as respiration, digestion, and elimination (Shaffer, 2002). The next areas to mature are the cerebrum and cerebral cortex (which surrounds the midbrain), and are responsible for voluntary bodily movements, cognitive functions such as perception and higher intellectual activities such as learning, thinking, and language.

Research shows that the most marked developmental changes happen before the age of five in terms of the prefrontal cortex and cerebral myelination (Giedd, et al., 1999). Children aged 0- 2 years for example produce a greater number of synapses than adults and are in a more receptive state, meaning neurons are open to experience and potentially more vulnerable to adverse outcomes and/or over-stimulation (Johnston,

1995). Robinson (2008) further reinforces this point by stating that ‘What also promotes differences in reactions to experience is the link between brain maturation and age’ (Robinson, 2008). Significant developmental change/shifts (or phylogenetic skills) do occur across differing cultures at approximately the same age (Hadders-Algra & Forsberg, 2002). Research tells us that these significant shifts occur between 2-3months, 8-12months, 14-18months, and 2-3 years of age (Robinson, 2008).

Emotional development in children aged two years of age for example, is a period in which there is increasing self-evaluation, awareness for standards of appearance and behaviour, increasing awareness of others and the child is starting to be able to undertake several steps in sequence while keeping a goal in mind. By age three, mastery is established in these above areas, while they learn more about persistence and achieving. At four years a child is preparing to go to school, and therefore needs mastery in skills of language, number; and psychosocial development such as emerging autonomy and initiative, thus any disruption in brain maturation precludes the inability to function in the school environment and to ‘fall behind’ in education (Robinson, 2008).

How various parts of the brain develop and when they mature at different stages throughout childhood (Shaffer, 2002) therefore continues to be a large area of study, particularly, in cases where maturation of the brain is interrupted, such as in the study of the vulnerable immature brain/CNS at the time of a TBI and the resulting outcomes (Shaffer, 2002).

At this time, however, there are few studies which have researched mTBI particularly in pre-schoolers (<5 years), rather, most studies have focused on adolescents and adults and only the moderate and severe injury categories. This may be due in part to the notion that only a higher severity of the injury predicated the greater likelihood that impairments would remain long term and across a range of functional domains (Anderson, 2004, 2005). Taylor (2008) for example, found children aged between 3-6 years of age who sustained a TBI were more likely to have cognitive problems particularly based on severity of injury (Taylor, et al., 2008).

This lack of research, however, may also be due to the difficulty in accurately assessing pre-schoolers functioning, particularly when they are pre-verbal. In addition, it was assumed that because children had greater neuronal plasticity, their recovery from TBI was better or equal to that of an adult. This hypothesis may be due to the fact that children ‘appear to get better’ overtime or ‘grow into their deficits’ (Taylor & Alden,

1997). However longitudinal studies have found post injury assessment carried out at regular intervals over critical periods of development show impairments manifest over time in various domains (Satz, et al., 1997)

One longitudinal study carried out by Babikian, et.al (2011); found most studies reported minimal consequences on neurocognition in children aged 8-17 years following a mTBI; in general, finding no declines in health outcomes or long term deficits in both cognitive and behavioural functioning when compared to moderate to severe injuries (Babikian & Asarnow, 2009; Kirkwood, et al., 2008; Petersen, Scherwath, Fink, & Koch, 2008). A review of methodologically stronger studies, however found there was significant variability in outcomes, commensurate with injury severity within the 'mild' categories (Satz, et al., 1997). Other evidence also suggests that a significant proportion of children who have mTBI are at risk for long term impairments in the developmental process (Lowenthal, 1998); and that the younger the age at injury, the worse outcomes from TBI (Anderson, 2010). Further studies have also highlighted residual persistent post-concussive symptoms present in mTBI groups when compared to other injury groups (Barlow, et al., 2010; Yeates, et al., 2009).

mTBI can result in significant and on-going social and economic burdens for families and the broader community (Anderson & Catroppa, 2006). These manifest as residual functional impairments commonly measured in the physical, cognitive, educational, behavioural (internalising and externalising) and social domains (Anderson & Catroppa, 2006); these domains encompass many specific skills that develop as the brain matures; therefore preschool children are adversely affected. Table 1, highlights some common deficits.

Table 1

*Consequences of childhood TBI*

Domain (deficits)	Skills
Neurologic	Gross and fine motor incoordination, Cranial nerve function/sensory loss, Speech, Medical complications
Cognitive	Intellectual impairment, Attention, Memory and learning, Executive function, Speed of processing
Educational	Reduced progress in content related areas, Processing/retention difficulties, Writing difficulties, Specialist education or support
Emotional/behavioural	Adjustment difficulties, Psychiatric disorders, Regulatory dysfunction
Social	Social withdrawal, isolation or anxiety, Inappropriate social skills and social awareness
Lifestyle changes	Reduced independence, Impaired functional communication and mobility, Increased need for additional assistance, Reduced recreational options, Difficulties maintaining pre-injury relationships

*Note: Adapted from Anderson & Catroppa (2006), p.769*

As discussed earlier, the paediatric cognitive system is developing rapidly between the ages of 2-5 years, and thus a disruption such as a mTBI may cause cognitive, behavioural/emotional and social deficits.

The next section will explore the impact of mTBI on children specifically cognitive and behavioural functioning, followed by executive functioning in part three of this introduction. However it must be noted here that most research in this area focuses on either adults, school-aged children, or includes pre-schoolers within other age ranges; and predominately within higher severity categories of TBI. Subsequently studies on the outcomes following preschool mTBI are low in number; however following are a summary of some of the key findings within each domain (cognitive and behavioural) within the adolescence and paediatric age ranges which focus on long-term outcomes.

## **Cognitive functioning**

Cognitive symptoms may manifest as decreased speed in processing information or slowness in thinking, speaking, acting or reading; attention deficits, difficulty concentrating or increased distractibility; problem solving deficits, making decisions or conflict resolution; difficulty performing mental tasks; inability to sustain effort or decreased motivation; memory deficits, remembering, the loss of new skills, the inability to learn new information, and poor performance at school (Centers for Disease Control and Prevention, 1999; Sadock & Sadock, 2007). Babikian and Asarnow, 2009 and Yeates, et al, 2005 suggested neurocognitive deficits in attention, learning, and memory were the most common following a TBI (Babikian & Asarnow, 2009; Yeates, Armstrong, & Janusz, 2005).

Other studies have however found select neurocognitive deficits such as visual closure (Wrightson, McGinn, & Gronwall, 1995), as well as problems with memory, attention and language (Anderson, Catroppa, et al., 2001; Catale, Marique, Closset, & Meulemans, 2009), specifically in children following a mTBI. Within paediatric TBI populations therefore, problems with cognitive processing, particularly verbal and performance skills were found to be more frequent, and impairments tended to persist long term, (Ewing-Cobbs, Barnes, & Fletcher, 2003). Another study focusing on pre-schoolers also found significant problems when investigating the development of reading skills following a mTBI (Wrightson, et al., 1995).

The UCLA longitudinal study (Babikian, et al., 2011) of neurocognitive outcomes, involving 124 children with mTBI, other injury 94 and 106 non-injured children within the age range of 8-17, investigated memory, psychomotor processing speed, attention/concentration inhibition and language at 1, 6 and 12 months post injury. Results indicated significant group main effects across all sessions; the mTBI children showing poorer performance than the non-injured control group in 6 out of the 10 neurocognitive measures (Memory: prospective memory test; picture memory test; word list memory test; Motor and Psychomotor: Symbol digit modalities; colour trails; pin test; Attention/concentration inhibition: Span of apprehension test; Stroop Test Degraded stimulus continuous performance test; and Language: Peabody picture vocabulary test), one year post injury (see Asarnow, 1995, for a comprehensive description of the tests and scores for each of the domains above).

A study by Goldstrohm & Arffa (2005) also used neuropsychological assessments (Standard-Binet Intelligence scale IV; The Bracken Basic Concept Scale; the School readiness composite; NEPSY) to measure cognitive performance at the time of hospitalisation and 6months post injury in 29 children aged 3-6 years who had experienced mild to moderate TBI, and 34 non-injured children (Goldstrohm & Arffa, 2005). It was found in comparison to non-injured preschool aged children, the mTBI group had lower premorbid cognitive functioning and poorer development of pre-academic skills.

Research suggests that IQ profiles identify subgroups of children with TBI based on sparing and impairment of cognitive abilities (Thaler, et al., 2010). IQ profiles are also associated with differences in behavioural functioning following paediatric TBI (Thaler, et al., 2010). IQ has accompanied other test measures as part of a comprehensive battery of tests and in some cases to add further diagnostic or prognostic information not often considered when using traditional classification methods. In Thalers (2010) study, results indicated that children with TBI who perform better in the average range on the WISC-III may have better behavioural and emotional outcomes than children with TBI who have other WISC-III profile patterns. Thalers (2010) suggests that because the current results showed differences between IQ clusters on domains associated with outcomes, that longitudinal studies would help predict or identify clusters with regard to long-term academic, social and functional outcomes (Thaler, et al., 2010). Although it was suggested, as a limitation, that it is difficult to generalise from moderate and severe clusters and their outcomes, to mTBI. Assessments of cognitive functioning in mild to moderate TBI generally find children's performance is within the average range even given their IQ scores are lower than non-injured groups (Ashton, 2010). In school aged children at the time of injury IQ scores have improved over time but residual difficulties remain in the performance rather than verbal skills (Ashton, 2010; van Heugten, et al., 2006). However children may experience difficulties in executive functioning even if they do well in IQ tests (Gioia, Isquith, Kenworthy, & Barton, 2002).

### **Behaviour, social, emotional and adaptive functioning**

Behavioural problems manifest as psychiatric disorders such as depression, anxiety or post-traumatic stress; regulatory dysfunction such as increased impulsivity, disinhibition, apathy, and reduced insight; irritability, aggression, changes in

personality, getting lost or easily confused, fatigue, lack of energy, tiredness or listlessness, lack of motivation, mood changes, changes in sleeping patterns (sleeping more, or finding it difficult to fall asleep, insomnia); adjustment difficulties such as reduced self-esteem; changes in the way the child plays, emotional excitement, and lack of impulse control (Anderson & Catroppa, 2006; Centers for Disease Control and Prevention, 1999; Sadock & Sadock, 2007). Examples of this are a lack of interest in favourite toys or activities, loss of toilet training skills, the inability to be consoled, loss of appetite and a reduction in balance (Centers for Disease Control and Prevention, 1999).

In McKinlay's, et al (2009) study on long term behavioural outcomes of preschool mTBI, the behavioural and injury information was collected from an original birth cohort of 1265 children born in 1977, with a reported mTBI between the ages of 0-5, of which each was assigned to one of three groups (2 x mTBI & one control group). Measures of the Christchurch Health and development study (CHDS) carried out via parental interview, teacher report, standardised testing were adapted from Rutter and Conners questionnaire and DSM-III criteria for ADHD and ODD/CD (Fergusson, Horwood, & Lloyd, 1991; Mc Kinlay, et al., 2008) and medical records. Behaviour was measured relating to attention span, distractibility, defiance, irritability, aggression, property destruction, deceitfulness and rule violations. The results found clear evidence that more severe instances of mTBI in preschool children are more likely to result in long term adverse behavioural outcomes such as ADHD and ODD/CD more so in mTBI inpatient than mTBI outpatient groups. That is these findings suggest increased externalising behaviour after injury, meaning that these skills occur before age five and are more vulnerable to early injury.

A further study by Chapman et.al (2010) investigated the emergence of clinically significant problems in behaviour, executive functioning skills and social competence 18 months post injury of children aged 3-7 years who had sustained a severe or moderate injury and compared them with a cohort of children with orthopaedic injuries (OI). Measures used included parental self-reports (child Behaviour checklist – CBCL; Behaviour inventory of executive functioning BRIEF; Preschool and Kindergarten behaviour scales – PKBS; Home and community social and behaviour scales - HCSBS), demographic data, family functioning reports (Family assessment device – FAD; Life stressors and social resources inventory – LISRES and parenting practice questionnaire – PPQ) and home environment reports (The Home observation

for measures of the Environment - HOME), collected at baseline and time points 6, 12 & 18months. Results indicated that all measures were significantly correlated at  $p < .01$  level. Externalising problems measured by the CBCL and externalising scales, were reported as being significantly elevated in children with severe TBI across all time points. This suggested a long term effect on externalising behaviour consistent with other studies (Yeates, et al., 2005), which assessed children up to 30 months post injury (Anderson & Catroppa, 2006). Most interestingly the study found that children injured at a young age were more likely to have an increased frequency of externalising behaviour across follow up assessments. Likewise executive functioning skills as measured by the BRIEF were also found to be impaired in the severe TBI group across timelines when compared with control group across timelines. Evidence showed that increased permissive parenting, increased family dysfunction and lower socioeconomic status (SES) increased the probability of developing behavioural problems that were clinically significant.

Taylor (2002) also conducted a study to investigate the long term effects on behaviour and achievement on 53 children with severe TBI, 56 with moderate TBI and 80 children with orthopaedic injuries (OI) aged 6-12 years at the time of injury, and assessed using Child measures (CBCL; Vineland adaptive behaviour scales; and selected subtests of the Woodcock Johnson); family measures (Socioeconomic Composite Index; the Duncan socioeconomic index and Life stressors and social resource inventory – LSSRI) at baseline, and both 6 and 12month intervals (Taylor, et al., 2002). Findings suggested the severe TBI group had more behavioural problems and lower competence by parent report, lower academic performance, poorer adaptive functioning and weaker math and writing skills across all time points. Evidence also supported the influences between TBI and environmental factors on outcomes, that is family stress contributed to less rapid short term progress in academic performance; and socioeconomic status and unfavourable family circumstance contributed to lack of social skills.

In a meta-analysis carried out by McKinlay (2009) investigating outcomes associated with mTBI in childhood and adolescence, it was reported by Barkley, (1997), that behavioural outcomes following mTBI in children were usually assessed by a wide range of externalising or internalising problems, that involve the inability to self-regulate and inhibit behaviour, and are associated with executive functioning, and the functions of the frontal lobe. Deficits and neuro-behavioural changes associated with

post-concussive symptoms being oppositional, or inattention disorders (i.e., restlessness and hyperactivity) of which may be accounted for by pre-existing problems or family factors/characteristics. Some studies suggest that post injury behaviour reflects the pre-injury child (McKinlay, 2009).

Part two provided an overview of the developmental perspective in the context of maturational and developmental changes. Research suggested a significant proportion of children between the ages of 0-5 years are particularly vulnerable, and at risk for long term impairment as development during these early years is rapid. Plasticity and 'getting better' were therefore evidenced as being out-dated schools of thought, and did not predict outcome. It was also found that residual persistent post concussive symptoms present significantly in TBI populations versus control groups. Particularly in cognitive and behavioural domains, of which environmental factors, injury severity, age and location of injury can determine outcome.

It was also suggested that common neurocognitive deficits in memory, attention, language, and the development of reading skills and particularly in verbal and performance skills, which are reported as poorer performance in neurocognitive measures, occur with mTBI in the paediatric population. And profiles of performance can be used with other neurocognitive tests to identify difficulties in performance.

## **Introduction: Part Three.**

### **Executive Functioning**

In part three, this thesis will specifically address the area of executive functioning (EF) in preschool children with mTBI, and subsequent cognitive and behavioural dysfunction. Methods of EF assessment will also be discussed and highlight research in the subdomains of inhibitory control, switching, processing speed, working memory and attention.

Anderson, (2008) refers to EF as not a unitary cognitive process, but instead a psychological construct that is composed of multiple interrelated high level cognitive skills'(Anderson, 2008), including planning, organising, problem solving, memory, impulse or inhibitory control, decision making, selective attention and controlling of behaviour and emotions (Shaffer, 2002).

Similarly, Goia & Isquith, (2004) define EF as a set of interrelated capacities rather than a unitary function - 'Executive functions are a collection of related yet distinct abilities that provide for intentional, goal-orientated, problem-solving action'... and are an umbrella construct defined as control, supervisory or self-regulatory functions that organise and direct all cognitive activity, emotional response, and overt behaviour' (Goia & Isquith, 2004, p.138). Goia et.al (2004) further defined this collection of regulatory and management functions into specific sub-domains which included the abilities to initiate behaviour; inhibit competing actions or stimuli; selecting relevant task goals; planning and organising as a means to solve problems; to shift problem solving strategies or to be flexible when necessary; to monitor and evaluate one's own behaviour; and lastly to have the capacity to use working memory to hold information actively whilst problem solving (Gioia & Isquith, 2004; Pennington, Bennetto, McAleer, & Roberts, 1996).

Fuster (1985) also described a three component system which included; firstly the temporally retrospective function of working memory, secondly, the ability to hold old information in mind while actively processing new information; the temporarily prospective function of an anticipatory set; and thirdly the control of interference, which includes the ability to inhibit competing information and action (p.138).

Anderson (2002), simplifies all of the above by conceptualising an EF model into four separate domains (and sub-domains), and describes the subsequent impairments. A child who is impaired for example in the domain of attentional control and its subdomains (selective attention; self-regulation; self-monitoring; inhibition) is characterised by behavioural manifestations such as lack of self-control, impulsivity, lapses in attention and inappropriate responding. In the domain of cognitive flexibility (divided attention; working memory; conceptual transfer; feedback utilisation), considered a crucial component of EF, impairments can manifest as rigidity, individuals can have difficulty manipulating information, exhibit perseverative behaviour and be ritualistic. In goal setting (initiative; conceptual reasoning; planning; strategic management) impairments may manifest as having difficulties in problem solving, starting tasks, poor conceptual reasoning and individuals are not likely to complete tasks due to the inability of how to approach the task. The fourth domain information processing which includes the subdomains of efficiency, fluency, and speed of processing is characterised by hesitation, slow reaction time and reduced accuracy.

### **Executive functioning and development**

Executive functioning has been linked with the frontal lobes of the brain (dorsolateral cortex, orbitofrontal cortex, and frontal white), and anterior temporal lobes; MRI studies (of the pathophysiology of TBI) suggesting particular vulnerabilities to the brain in these regions (Gioia & Isquith, 2004; Levin, 2005).

As previously noted in part two of this thesis, the assumptions that preschool children have greater neuronal plasticity, and only TBI's with a higher severity predicated the likelihood impairments would remain long term, consequently meant EF has been largely ignored in the paediatric age range (Wiebe, et al., 2011). Difficulty in assessing young children due to the lack of validated standardised assessments available in this age range has also been highlighted as a methodological problem within TBI studies.

It was also noted earlier in this introduction, more recent studies (Huttenlocher, 1990; Thatcher, 1992; Wiebe, et al., 2011), however show that there is substantial development in the prefrontal systems in early childhood. For example, this study found that both memory and inhibition is in rapid development between the ages of 3 -

5 years, illustrating rapid gains in performance on inhibition and delay of gratification tasks (Carlson & Moses, 2001; Diamond & Taylor, 1996; Kochanska, Murray, & Harlan, 2000). Language ability, symbolic thought, self-understanding and goal directed behaviour also manifest during these pre-school years (Carlson, 2005; Espy, Kaufmann, McDiamid, & Glisky, 1999; Wiebe, et al., 2011).

Some studies have proposed that components of EF emerge in sequence across the preschool years; firstly working memory then inhibition, which together enable the development of shifting (Garon, Bryson, & Smith, 2008). Other studies suggest that working memory and inhibitory control are observable even at 7-8 months of age (De Luca & Leventer, 2008) and are present at 1 year of age (Diamond, 2002), progressing and improving till the age of 5 years when the higher EF skills such as goal-directed behaviour and planning are evident.

Documenting milestones in EF has thus been progressing to understand EF in preschool children, (for more info see the following reviews: (Carlson, 2005; Espy, et al., 1999; Garon, et al., 2008; Wiebe, et al., 2011); however age at the time of injury, or indeed the stage of maturation of the brain are not the only predictors of outcome in preschool children.

### **Executive functioning and behaviour**

Paediatric TBI has been linked to higher incidence of internalising and externalising symptoms in school aged children (Anderson & Catroppa, 2006; Chapman, et al., 2010; Schwartz, et al., 2003; Yeates, et al., 2005). Similarly reports based on the parent-rated measure of the BASC-2, found greater levels of externalising behaviours in the TBI group compared with the control group (Thaler, Mayfield, Reynolds, Hadland, and Allen (2012). In terms of adaptability, it was also found that children with mTBI had lower levels of adaptive behaviour and self-esteem and higher levels of maladaptive and aggressive behaviour when compared to the control group (Andrews, Rose, and Johnson, 1998). Other studies have found children with mTBI under the age of 5 years were more likely to have suffered other observed behavioural consequences; showing clinical symptoms of attentional deficit disorders such as ADHD, conduct disorder and mood disorders (Mc Kinlay, et al., 2008).

## **Executive functioning and parental and environment factors**

Both parental and environmental factors have an association with child TBI EF outcomes as well as other family characteristics. These parental factors, include the parents mental health, and the environmental factors, include family functioning, parental support, parent child relationships, family organisation and the home environment, as well as family characteristics such as socioeconomic status (SES), and parental education (Chadwick, 1981; Gerring, et al., 1998; Kinsella, Ong, Murtagh, Prior, & Sawyer, 1999; Max, et al., 1998; Rivara, et al., 1993; Rivara, et al., 1994; Taylor, et al., 2002; Taylor, et al., 1999; Yeates, et al., 2004; Yeates, et al., 1997).

Hughes, Hart and Ensor (2013) investigated parental mental health and EF development, in their study of children aged between 2-6 years. They found that children who were exposed to higher levels of parental depression were more likely to exhibit poorer performance on EF tasks than their peers.

Yeates et.al (2004), investigated the short and long term social outcomes following paediatric TBI, using a prospective, longitudinal design, that included 53 children with severe TBI, 56 with moderate TBI, and 80 with orthopaedic injuries, aged between 6-12 years of age, and assessed at baseline, 6, and 12 months post injury using the Vineland Adaptive Behaviour Scales (VABS). Results found negative social outcomes were exacerbated by poorer family functioning, and were accounted for in part by specific neurocognitive skills including executive functions, pragmatic language and social problem solving (Dennis & Barnes, 1990; Yeates, et al., 2004). Furthermore children from families of lower SES showed declines in socialisation scores. The study indicated therefore that the family environment does play an important role in influencing social outcomes following paediatric TBI, and is consistent with developmental research which implicates that parenting and the family environment can determine social functioning in children (Parker, Rubin, Price, & DeRosier, 1995; Yeates, et al., 2004).

In another study (Mangeot, et al 2002), the long term EF deficits of children with TBI were examined, using a prospective study of 33 children with severe TBI, 31 moderate TBI and 34 with orthopaedic injuries (OI), injured between the ages of 6-12 years and assessed 5 years post injury using the BRIEF measure of EF, the WISC intelligence test; the CBCL to assess emotional and behavioural problems, and the VABS for adaptive behaviour; The FBII used to determine post injury family burden

and lastly the FAD to assess general family functioning. The results indicated that children display significant deficits in EF 5 years post-injury who sustain a severe TBI; executive dysfunction related to injury severity (Mangeot, Armstrong, Colvin, Yeates, & Taylor, 2002). The BRIEF report showed that parent ratings were strongly related to measures of emotional and behavioural adjustment and adaptive behaviour in children. Parent ratings on the BRIEF also predicted parental psychological stress, perceived family burden and general family functioning suggesting children's residual behaviour problems may be related to family functioning as opposed to cognitive deficits (Mangeot, et al., 2002; Taylor, et al., 2002). Further analyses also found the severe TBI group was three times more likely to display clinically significant elevations on the GEC composite score than the OI group.

Wells, Minnes & Phillips (2009), examined whether environmental factors, as well as age at injury and injury severity were significant predictors of social and functional outcomes. In their study 30 children who sustained a mTBI aged between 0-10 years were assessed post injury (3.92-16.61 years) using the Wide range assessment of memory and learning (WRAML) or the children's memory scale (CMS), the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) for gross motor functioning and the Beery developmental test of visual motor integration (VMI) to determine fine motor impairment. Parent questionnaires including the child and adolescent scale of the environment (CASE); the child adolescent factors inventory (CAFI) and the child and adolescent scale of participation (CASP). These measures used to determine problems with physical, social and attitudinal aspects of the environment, family stresses/finances, physical design of buildings and crime/violence. Results found that outcomes are not exclusively based on severity, and that additional factors determine long term functional outcomes; for example age (Wells, Minnes, & Phillips, 2009). The present study's findings suggest the older the child is when a TBI is sustained, the fewer impairments they experience in social participation (Wells, et al., 2009). The environment in which a child lives is related to social participation and cognitive functioning; that is if a child is being brought up in a supportive nurturing environment and is accepted by the community, they are able to function at a level commensurate with their peers.

Parent child relationships are also a factor in the development of EF and both emotional and behaviour regulation. In a study on premature children associated with injury or a disruption of myelination, conducted by Woodward, Clark, Horwood and

Moor (2008), using a structured parent child interaction task, they found children aged 4 years had problems with emotion regulation, persistence and levels of sustained attention during problem solving (Clark, Woodward, Horwood, & Moor, 2008). They also found that parents who were responsive and sensitive to the needs of their children were associated with better regulatory competence. However further analysis found parents of preterm child were more likely to be intrusive during problem solving at 2 years of age, these findings consistent with mainstream developmental studies illustrating the importance of parental sensitivity in cognitive and social development (Landry, Smith, & Swank, 2003, 2006)

Socio-economic status (SES) has been found to be a predictor for EF, in that there is an association between the level of SES and TBI outcomes (Anderson, 2004), That is both a parents responsivity and the environment affects the child's inhibitory control and working memory; that is lower SES or exposure to poverty precludes a child's poorer performance on EF tasks (Raver, Blair, & Willoughby, 2013; Sarsour et al, 2011).

Similarly the family characteristic of parental education has been found to ascertain the level of performance for a child on an EF task; that is higher education in a parent was related to an increase in child performance on EF measures (Ardila, Rosselli, Matute, & Guajardo, 2005).

### **Consequences of executive dysfunction**

As highlighted in the above studies, executive functioning can be disrupted in many ways following a TBI, particularly dependent on the age at injury, and other parental factors such as parental mental health, and environmental factors such as parent child relationships, and the home environment. Family characteristics such as SES, and parental education are also significant in the prediction of dysfunction in EF in children.

As noted by Anderson, (2008); Goia & Isquith, (2004) and Fuster (1985) EF is a complex system. EF dysfunction in children can therefore have a detrimental effect on their lives and future abilities to function in a socially appropriate way. Impairments in EF mean children have an inability to control impulses in both emotions and behaviour, and are unable to attend or maintain focus on activities (Diamond, 2013). For preschool

children with mTBI these deficits are most marked in the advent of both externalising (hyperactivity, aggression) and internalising problems (anxiety, depression, somatisation), adaptability (social skills, functional communication,) and, EF skills (inhibitory control, emotional control, shifting, working memory, and cognitive flexibility).

In summary, the research presented suggests TBI has a clear impact on cognitive, executive and behavioural functioning. More studies are thus needed that follow a methodologically sound framework in the areas of executive functioning throughout development, specifically in preschool children with mTBI.

## **Rationale for the study, aims and hypotheses**

Studies show there is great variation in outcomes following paediatric TBI, and a failure to identify the range of important predictors of long term outcome. Many factors identified as predictive of outcome in adults are also significant in paediatric patients (injury severity, duration of coma, premorbid characteristics, and socioeconomic status). However a number of parameters specific to children also require consideration (age at injury, time since injury, family environment, parental health and parent child interaction). To fully investigate these issues, data from the large scale Brain Injury Incidence and Outcomes in the Community (BIONIC) and Consequences of Brain Injury in the Community (COBIC) longitudinal studies, acknowledging the possible interactions between injury and on-going maturation will be utilised.

This thesis will use this information to address the lack of knowledge of long term outcomes of paediatric mild traumatic brain injury. Specifically the consequences of mTBI on executive functioning in preschool children aged 4 years – 4 years 11 months old (recruited from the BIONIC study). Executive functioning will be explored in terms of inhibitory control, working memory, processing speed, and shifting, as well as both behavioural and emotional manifestations such as internalising and externalising behaviours and adaptive skills. Lastly, the effects of mTBI in preschool children will be examined in terms of child factors (age, ethnicity, gender), parental factors (parental mental health) and environmental factors (the home environment and parent child interaction).

Following are the aims and hypotheses.

**Aim 1:** To compare the parent-rated and performance-based executive functioning of preschool children who sustained a mTBI at age 2 years; at 24 months post injury, with an age matched comparison group of children free from TBI. With particular focus on inhibitory control, working memory, processing speed and shifting, as well as any behavioural manifestations of EF in the context of everyday environments.

**Hypothesis 1:** Children in the TBI group will be characterised by deficits in the ability to inhibit and/or control impulsive behaviours, hold attention, and

have a low speed of processing as well as behavioural difficulties, than TBI-free comparison children, 24 months post injury.

**Aim 2:** To compare the behavioural/emotional functioning of preschool children who sustained a TBI at age 2 years; at 24 months post injury, with an age matched comparison group of children free from TBI, in the areas of externalising, and internalising behaviour, and other behavioural symptoms and adaptive skills.

**Hypothesis 2:** Children in the TBI group will be characterised by deficits in both emotional and behavioural domains particularly in externalising and internalising behaviours and adaptive skills, than TBI-free comparison children.

**Aim 3:** In the TBI group, to examine the extent to which executive functioning outcomes can be explained by child factors (gender, age, ethnicity, socio-economic status); clinical characteristics around the time of injury (severity of TBI, and co-morbid conditions); and parental factors (parental health) and environment (home environment/parent child interaction).

**Hypothesis 3:** Adverse developmental outcomes amongst children with TBI will be significantly associated with factors of injury severity, younger age, comorbidity/ pre-existing conditions, the environment (parental health, parental support and the home environment).

## METHOD

### Participants

Two groups of participants (mTBI cohort & control cohort) aged between 4 - 4 years 11 months took part in this study; Consequences of mTBI on executive functioning in preschool children 24 months post-injury.

#### **mTBI group**

The mTBI group participants (aged 2 years of age at the time of injury and followed up 24months post injury) were recruited from the Brain Injury Outcomes New Zealand in the Community (BIONIC) study (a large population-based epidemiological study carried out between 2010-11 on traumatic brain injury), to participate in the current Consequences of Brain Injury in the Community (COBIC) study.

#### *Inclusion criteria*

To be included, participants of the BIONIC study needed to have sustained TBIs (The TBI definition, as described in the introduction, was in accordance with the World Health Organisation, WHO); between 1st March 2010 and 28th February 2011, and have met the operational criteria of symptoms for identification of TBI; which included one or more of the following: confusion or disorientation, loss of consciousness, post-traumatic amnesia, other neurological abnormalities such as focal neurological signs, seizure and or intracranial lesion (Carroll, et al., 2004). Further evidence of a TBI had to be accompanied by other medical or behavioural changes to be classified as a TBI, due to the study group being children. These symptoms or signs included any of the following: vomiting lethargy, persistent crying, very quiet (out of character), irritable, food refusal, sleepiness, seizures, disorientation, unequal pupil size, headache, whingeing (etc.), or parents describing their children as 'out of sorts' (or similar)'. This included children who had a fall, banged their head, and vomited after the accident. mTBI was defined as the lowest GCS of 13-15, or post traumatic amnesia (PTA) within 24 hours of injury (Bellner, et al., 2003; Iankova, 2006). Within the mTBI group children were categorised as having sustained low risk, medium risk or high risk injuries in accordance with criteria developed by Servadei et al (2001). Inclusion in the

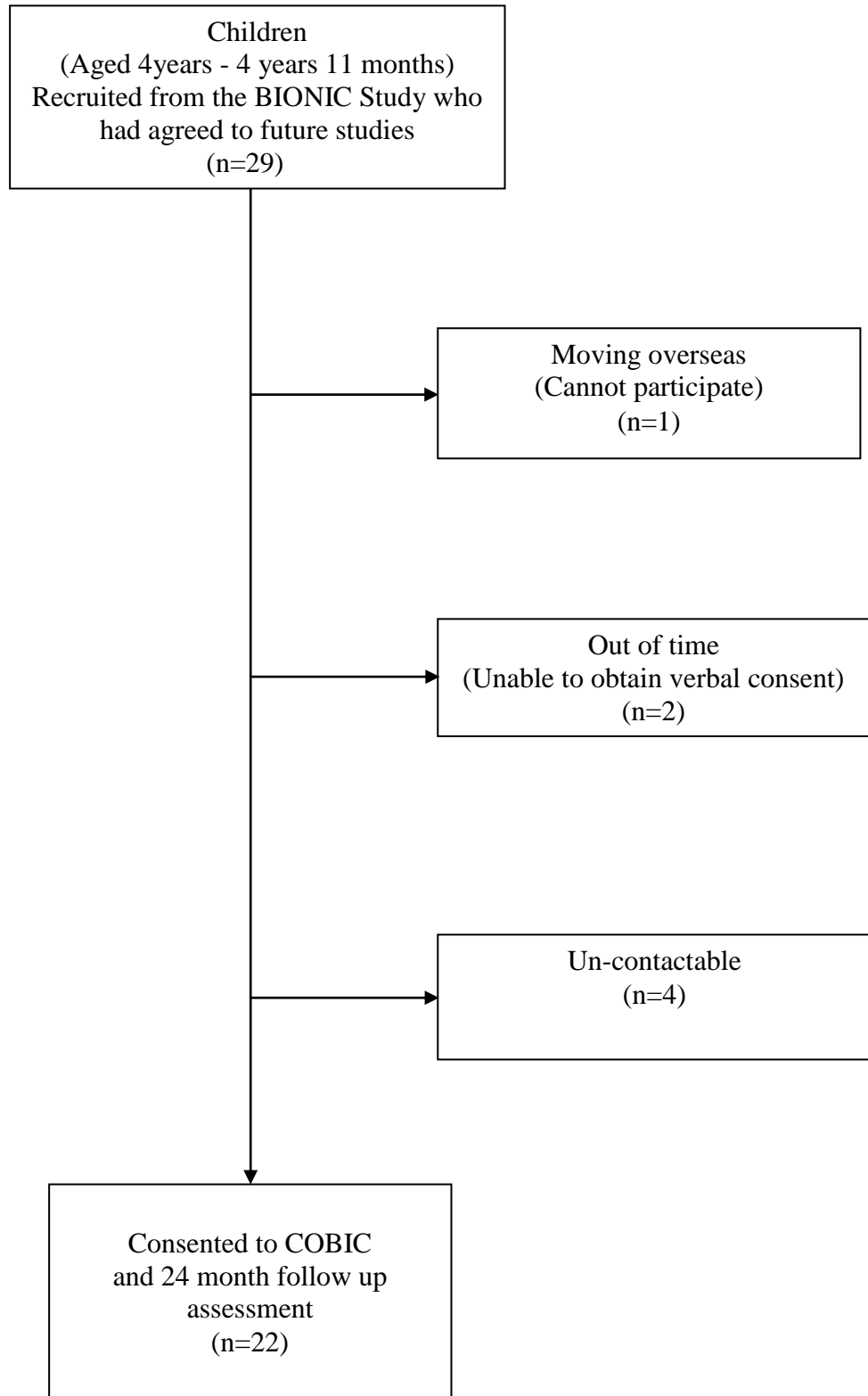
study also required the children to be aged between 4 years and 4 years 11 months old, and to reside in the Hamilton, or Waikato area.

### *Recruitment*

Participants from the BIONIC study who had previously agreed to be contacted for future research, were in the first instance sent a letter and information sheet (see appendix A) about the current COBIC study.

The letter and information leaflet were sent one month prior to the participants 24 month assessment due date, and was followed up one week later by a phone call from the researcher. The researcher answered any questions and obtained verbal consent for participation in and videotaping of the assessment session/s. An appointment time was arranged to carry out the assessment/s and obtain written consent (see Appendix A) in the participant's home. The outcome of recruitment for the mTBI cohort is shown in figure 1.

Twenty nine households were telephoned and of those, four were un-contactable. The term 'uncontactable' was only used when the following process was exhausted. Participants were initially followed up by phone one week after a letter was sent to their address; if contact by phone or mobile was unsuccessful, a further compliment slip was forwarded to the address asking the family to 'Please contact us'; if there was still no response, the alternative address and phone number supplied were called to ascertain further contact details; at this stage if there was still no response the participant was deemed to be 'uncontactable'.



*Figure 1. Flowchart summarising the recruitment and assessment completion of the children (aged 4years – 4 years 11 months) in the mTBI cohort*

## **Matched control group**

### *Recruitment*

The matched control group was recruited by referral from the mTBI group child's peers, and by advertising to the same early childhood centres and kindergartens attended by mTBI children. To recruit control participants parents were given additional COBIC flyers, at the time of the 24month follow up assessment, to distribute to their friends.

The childhood centres and kindergartens managing teachers were also phoned and informed about the COBIC study, its purpose and to ask permission to distribute flyers and put up posters in the classrooms. Where possible, the researcher visited the managing teacher, and staff, talked about the study, then left information for them to pass onto parents. Interested parties phoned or emailed the researcher for further information. The researcher then explained the study and checked the eligibility of the participant by phone.

### *Eligibility*

Eligibility was determined (see appendix B, for eligibility checklist) by participant's having no prior reported TBI (TBI free since birth). This was ascertained by asking the caregivers if the child had ever hit their head so hard, they had to seek medical attention. If the caregiver was uncertain, further questions were asked to clarify if a TBI was sustained. Eligibility was also determined by matching by age, gender and residence in the same area to the mTBI cohort. After eligibility was ascertained, an appointment for the assessment was made and verbal consent for participation was obtained.

The outcome of the recruitment for the matched control cohort is shown in figure 2:

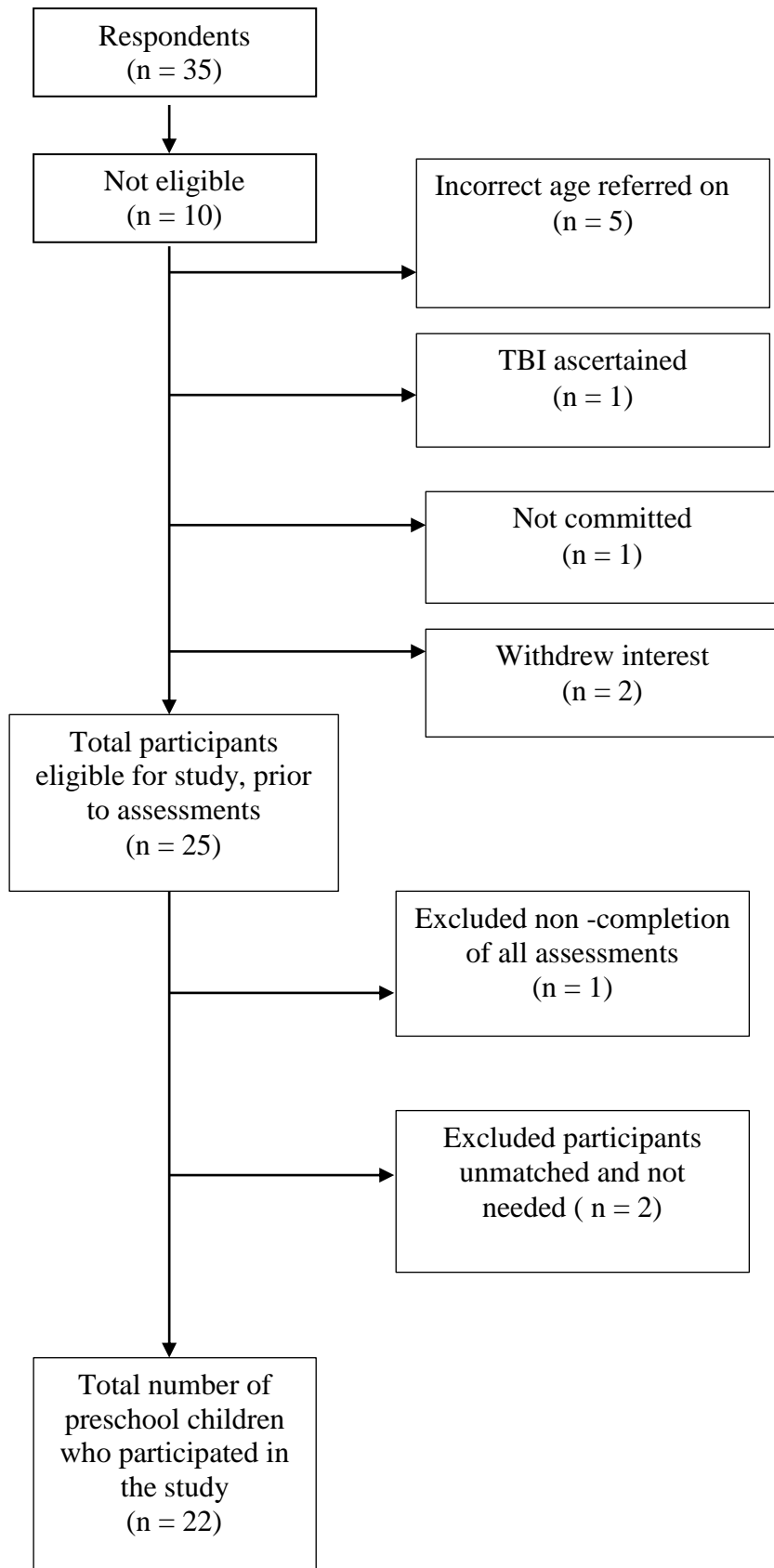


Figure 2. Recruitment outcome for the matched control group

### **Sample characteristics (of both the mTBI & control cohorts)**

In total consent was obtained from forty four children's families (22 mTBI & 22 controls) to participate in the COBIC study. A Chi-square test or Fishers Exact test (FET) (if frequencies were under 5) were carried out to ascertain any significant differences between the two group's demographics. A one way between groups ANOVA with partial Eta squared effect size was also used to compare the group differences in age (parent and child) and socio-economic status (SES).

As can be seen in Table 2 a greater proportion of males than females were affected by mTBI. Both samples show a higher percentage of children in New Zealand categorised as of European ethnicity sustained a mTBI. Mothers were on average thirty-two years of age and predominately New Zealand European. No statistically significant differences were found between the sample groups.

Characteristics of the sample with mTBI were also determined by injury, time since injury (or date of assessment), mTBI classification, place of injury, mechanism of injury, activity at time of injury, number of TBI's and the location of the case.

Table 3 shows the highest proportions of children with mTBI were the medium and high risk classifications. The most common place of injury was in a private house or compound, and was predominately due to a fall. Of the children with mTBI 77.3% had experienced a second mTBI, and a further 22.7% a third mTBI. Most cases were located via the Waikato Hospital.

Table 2

Summary of demographics: Participant characteristics at time of assessment

Demographic	Group		Test Statistics
	mTBI (n = 22) <i>n, %</i>	Control (n = 22) <i>n, %</i>	
<b>Child gender</b>			
Males	14 (63.6)	14 (63.6)	
Females	8 (36.4)	8 (36.4)	
<b>Parent gender</b>			
Male	2 (9.1)	2 (9.1)	
Female	20 (90.9)	20 (90.9)	
Child Age at assessment – years, <i>m (sd)</i>	4.34 (0.49)	4.35 (0.47)	$F(1, 42) = 0.016, p = 0.900,$ $ES = .000$
Parent age at assessment – years, <i>m (sd)</i>	32.80 (6.13)	35.53 (6.05)	$F(1, 40) = 2.12, p = 0.153,$ $ES = .050$
<b>Region</b>			
Urban	15 (68.2)	18 (81.8)	$FET = 1.09, p = 0.488$
Rural	7 (31.8)	4 (18.2)	
<b>Parent Ethnicity</b>			
NZ European	14 (63.36)	17 (77.3)	$FET = 4.46, p = 0.391$
Maori	6 (27.3)	2 (9.1)	
Asian	1 (4.5)	2 (9.1)	
Other	1 (4.5)	2 (9.1)	
<b>Child Ethnicity</b>			
NZ European	12 (54.5)	17 (77.3)	$FET = 4.38, p = 0.229$
Maori	8 (36.4)	3 (13.6)	
Pasifika	1 (4.5)	0	
Asian	1 (4.5)	2 (9.1)	
Socio- economic Status (SES), <i>m (sd)</i>	53.44 (24.31)	60.86 (27.42)	$F(1) = 0.902, p = 0.348,$ $ES = 0.021$

Note: ES = Partial Eta squared, F = One way ANOVA, FET = Fishers Exact Test.

Table 3

Child mild Traumatic Brain Injury (mTBI) group injury characteristics

Variables	mTBI (n = 22)	
	n (%)	m (sd)
		2.31 (0.29)
Age at injury – years		4.34 (0.49)
Time since injury – at date of assessment – years		
<b>Mild TBI classification</b>		
Mild, low risk	3 (13.6)	
Mild, medium risk	8 (36.4)	
Mild, high risk	7 (31.8)	
Mild, unspecified	3 (13.6)	
Severe	1 (4.5)	
<b>Place of Injury</b>		
Highway/Road/Street	1 (4.5)	
Private house/compound	15 (68.2)	
Recreational area	2 (9.1)	
School	3 (13.6)	
Other	1 (4.5)	
<b>Mechanism of injury</b>		
Fall	19 (86.4)	
Exposure to mechanical force	1 (4.5)	
Traffic/MVA	2 (9.1)	
<b>Number of mTBI</b>		
Second	17 (77.3)	
Third	5 (22.7)	
<b>Case Located</b>		
Waikato hospital	11 (50)	
General practitioner	4 (18.2)	
Accident and Medical Clinic	3 (13.6)	
Accident Compensation Corporation	4 (18.2)	

Note: MVA = Motor vehicle accident; mTBI = Mild traumatic brain injury.

To examine whether there were any differences in FSIQ scores between the groups, the total number of children in each category was calculated. WPPSI-III FSIQ scores were categorised to ascertain FSIQ ranges, which are described in table 7.

Table 4.  
*Description of frequency of children in each the WPPSI-III FSIQ categories*

WPPSI-III	mTBI (n = 22)	Control (n = 22)
Descriptive categories	n, (%)	n, (%)
Borderline (70-79)	1 (4.5)	0 (0)
Low average (80-89)	2 (9.0)	1 (4.5)
Average (90-09)	9 (40.90)	6 (27.3 )
High Average (0-9)	7 (3.8)	10 (45.45)
Superior (20-29)	2 (9.09)	5 (22.73)
Very Superior (30+)	1(4.5)	0 (0)

*Note:* WPPSI-III = Weschler Preschool and Primary Scale of Intelligence - III

Table 4 shows that more children in the mTBI group were in the average to borderline categories compared to the control group. The control group also had a higher number of children in the high average to very superior range compared to the mTBI group.

Further analysis using the Fishers Exact test (FET), found that there was no difference in the proportion of children in the distribution of the categories (FET = 4.617, p = 0.487).

Assessments commenced March 2012 (2 years post-BIONIC recruitment), and took place at the participants homes.

### **Measures**

Parents or legal guardians were asked to complete a battery of questionnaires. These consisted of a demographic/history questionnaire; a general information questionnaire; and a questionnaire about rehabilitation services received and health economic data.

Age appropriate and standardised measures were selected and administered. Parents completed the Behaviour Rating Inventory of Executive Functioning (BRIEF-P) questionnaire to assess their child's executive functioning; the Behavioural Assessment System for Children (BASC-2) to measure adaptive behaviour and social and emotional functioning; as well as the Strength and Difficulties Questionnaire (SDQ) to assess social and behavioural competence. Parents were also asked to complete a questionnaire about their own mental health; the Hospital, Anxiety and Depression Scale (HADS). The researcher completed an observational report of the stimulation and support in the home environment, the Early Childhood Home Observation for Measurement of the Environment (EC HOME). The children participated in two Object Colour Interference (COI) and Day & Night (D&N) tasks that were videoed for later coding, measuring impulse or inhibitory control and working memory. They also completed three tasks with their parent or caregiver; the Parent Child Interaction task (PCI) to ascertain parent/child synchrony. Lastly the child was asked to complete four subtests (matrix, information, picture completion, and symbol search) from the short form Weschsler Preschool and Primary Scale of Intelligence (WPPSI-III) to ascertain estimated IQ. Each measure is described in more detail below.

## **Materials**

### **Parent/caregiver Questionnaires**

#### *Child health history questionnaire*

The child's health history questionnaire gathered information on the child's age, height, conception type (naturally or IVF), if the child had any health problems and included rating how well the parent felt the child behaved (1 = poor – 5 = excellent). The second part of the questionnaire asked about the child's medical history – had they been a patient in a hospital, why they were in hospital, any prescription and any of the following medical problems.

#### *About mum when pregnant*

This questionnaire gathered information on the mother; and asked for her to rate her general health during pregnancy on a rating scale (1= excellent, 5=unknown). It asked if she had any problems or conditions during pregnancy, whether medicine or tools were used during the birthing process and if she had consumed alcohol, drugs or smoked during pregnancy. Questions were also asked about the child as a baby e.g., was the child breast fed and for how long; how the child's health and development would be rated (1=excellent, 7=unknown) in their first year. The parent was also asked to check which behaviours apply or how the child acts when at school or day-care (i.e. – Nervous, worried; relaxed, calm; happy)

#### *Family and pets*

The last question in this questionnaire on family asks who the child lives with, and if there are any animals in the home and how many.

#### *General Information Questionnaire*

The second questionnaire collected more demographic information including ethnicity of the parent, occupation, hours worked per week, main income earner, their occupation; level of education, and marital status. The occupation of the main income earner was used and coded (translated into scores on the Australian Socioeconomic Index 2006 (AUSE106) (McMillan, Beavis, & Jones, 2009), using the Australia and New Zealand Standard Coding of Occupations. AUSE106 scores range from 0-100 (higher scores meant higher SES). The second part of the questionnaire asked whether

the child had any particular health problems; any disability/diagnosed head problem (physical, cognitive or mental); a main disabling injury or illness; and whether the family was in receipt of a benefit for the main illness. For the follow up assessments, the questionnaire asked also if the child had entered permanent residential care; been admitted to hospital, had another serious fall or head injury since the last assessment. The third part applied to BIONIC participants only, and asked if they had any aids, appliances or modifications to the home or any unpaid help.

*Rehabilitation received and health economic data (all participants)*

In the third questionnaire all participants were asked if A) they received any services in the last seven days or B) received any services in the last 28 days. If they did, indicated how many visits, hours per week, who paid for the service and how satisfied they were with the level of service they received on a scale of 1 (unsatisfied) to 10 (very satisfied). These questions were designed to allow the calculation of the economic cost of the injury, however, they are not used in the current analysis.

## **Cognitive Measures**

### **Parent –rated measures of Executive functioning**

#### *The BRIEF*

The Behaviour Rating Inventory of Executive Function BRIEF is designed to assess executive function; primarily executive function and emotion regulation (Gioia, P.K, S, & L., 1996). The BRIEF-P, the preschool version (Gioia, Espy, & Isquith, 2003) a standardised rating scale was developed to provide an insight into everyday behaviours associated with specific domains of executive functioning in children aged 2 to 5 years 11 months of age. Specifically, this measure establishes if a child has had any behavioural problems within the past six months. The BRIEF-P was selected as it has been utilised in TBI populations, reliability is good (Cronbach's Alpha = .96) and it distinguishes between clinical and control groups (Guy, Isquith, & Gioia, 2004; Mangeot, et al., 2002).

The BRIEF-P form contains a list of 63 statements that describe young children, divided into five clinical scales: inhibit, shift, emotional control, working memory, plan/organise (Gioia, et al., 1996).

*The inhibit scale* assesses inhibitory control and impulsivity, or the ability to resist impulse, and the ability to stop or control one's own behaviour at the appropriate time.

*The shift scale* assesses the ability to move freely from one situation, activity, or aspect of a problem to another as situations demand. Key aspects are the ability to make transitions, tolerate change, problem solve flexibly and to switch or alternate attention.

*The emotional control scale* measures the impact of executive function difficulties on emotional expression and assesses a child's ability to modulate or control their emotional responses.

*The working memory scale* measures the capacity to hold information in mind for the purpose of completing a task, encoding information, or generating goals, plans, and sequential steps to achieving goals. Working memory in young children is essential to sustain problem-solving activities, carry out multistep activities, complete basic mental manipulations, and follow complex instructions.

*The plan/organise scale* measures the child's ability to manage both current and future task demands within a situational context. This scale contains two components; Planning and organisation. To plan the child needs the ability to predict future events based on information available; develop steps to achieve a goal, provide instruction and implement goals, enabling them to complete a task in a timely manner. In preschool children, for example, developmentally appropriate planning often involves implementing a goal by strategically selecting the most effective steps to reach that goal i.e., planning involves the sequencing together a series of actions or responses. Organisation means having the ability to bring order to information and prioritise actions, in order to achieve a goal.

The BRIEF also contains four composite and summary indexes (*Inhibitory self-control index (ISCI)*, *flexibility Index (FI)*, *emergent metacognition index (MI)*), which form the *Global Executive composite (GEC) score*, (Guy, et al., 2004) and two validity scales (negativity and inconsistency). The ISCI index is composed of the inhibit and emotional control scales; the EMI is composed of the working memory and plan/organise scales; FI is composed of the shift and emotional control scales which all form the Global Executive Composite (GEC).

Parents/caregivers complete the BRIEF-P by rating their child's behaviour on a 3 point Likert scale using the descriptors; NEVER, SOMETIMES and OFTEN.

The BRIEF-P took approximately ten - fifteen minutes to administer and is scored using BRIEF-P software developed by the test authors. *T*-scores ( $m=50$ ,  $sd =10$ ) were used to interpret the child's level of executive functioning and *t*-scores at or above 65 were considered clinically significant.

### **Performance-based measures of executive functioning**

#### *The Colour Object interference task*

The original STROOP task (Stroop, 1935) entailed presentation of words, which were the name of a colour; these words were printed in a colour that was not congruent with the word, (e.g., the word 'blue' was printed in red ink). This task was manufactured to observe and measure the predominant tendency of adult readers to attend to the meaning of a word, rather than to the word's features, in this case the

colour. Stroop tasks were selected for this study as they are sensitive to inhibition deficits in adult populations' post-TBI and research has provided many insights into adult cognition, attentional control systems using this measure. For this study, however, due to the developmental stage of the group under research (under 5 years of age), a more age-appropriate pictorial adaptation of the adult word-colour Stroop test was used. Pioneered by Prevor & Diamond (2005), the object interference Stroop type task assesses a child's inhibition of a natural response and measures processing speed, cognitive flexibility and inhibition. A child's predominant tendency is to say what an object is (Prevor & Diamond, 2005). That is, a child may be unable to inhibit the response 'object' after being instructed to say the 'colour' of the object. When instructed to name the colour of the object, it was found that children were slower and less accurate. Children were only faster and more accurate at naming the colour of a stimulus when the form could not be named. These are the STROOP effects, faster more accurate responding to naming objects rather than colours, and slower less accurate responding for incongruent stimuli than congruent/neutral stimuli. The age of the participant may also be a factor in terms of working memory and inhibitory control skills as these evolve throughout preschool development.

The colour object interference task was based on theta developed by Prevor & Diamond (2005) and consisted of four sets of twelve cards (see appendix X. for predetermined order of cards); each card (A5 in size), on white paper and laminated. Each card featured one predetermined object (carrot, tree, heart, lemon, whale, teddy bear, orange, frog, apple, banana, water and horse) in one of the six predetermined colours (red, orange, yellow, green, blue, brown) of which each colour appeared twice in each trial. Each set of cards were bound into a flip book for easy administration. Set A (12 trials) were test cards, and contained line drawings of objects (carrot, tree, heart, lemon, whale, teddy bear, orange, frog, apple, banana, water, horse) in the 'wrong' or incongruent colour associated with the object (e.g., a green carrot). Set B (12 trials) were also test cards, and contained line drawings of objects (the same as in set A) in the 'correct' or congruent colour associated with the object (e.g., an orange carrot). Set C (12 trials), a post-test set designed to ascertain the children knew their colours, contained line drawings of abstract shapes in colour (red, orange, yellow, green, blue, brown). Set D (12 trials), was also a post-test set designed to ascertain the child knew the name of the object, and contained all black line drawings of the objects in Set A,

(see figure 3, for examples of each set). All sessions were recorded on video for later calculation of latency.



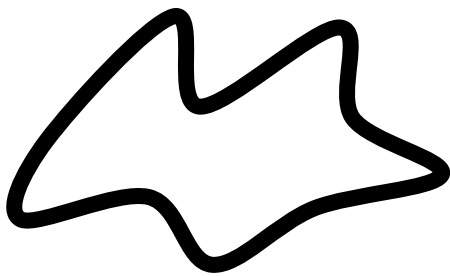
***SET A (incongruent colour)***

***Green Carrot***



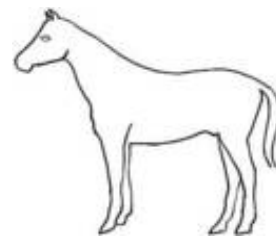
***SET B (congruent colour)***

***Yellow banana***



***SET C (Abstract form)***

***Blue abstract shape***



***SET D (Form)***

***Horse drawn with black outline***

*Figure 3. Showing examples of cards in set A: an incongruent colour (a green carrot); set B: a congruent colour (a yellow banana); Set C: an abstract form (blue abstract shape) and Set D: form (a black line drawing of a horse).*

### ***Training & pre-test:***

Training included the researcher beginning by introducing the task. *'You will be shown four sets of cards, A, B, C & D, we will start with Set A.'* *'When you look at a card, I want you to tell me, what colour the picture is drawn in.'* The researcher then showed the child a picture of a blue whale and instructing the child said, *'let's try a practice one'*. *'What colour is the picture drawn in?'* If the child was incorrect, and said the object rather than the colour, the researcher said, *'not quite' because you are supposed to tell me what colour, the picture is drawn in, so for this one it would be blue'*. The researcher then re-presented the blue whale card and repeated the practice trial. If a correct response was given the researcher proceeded to the tests. If the response was incorrect three times, the child was excluded from completing the remainder of the test and from the analysis, due to not understanding the instructions.

### ***Testing:***

As with the pre-training, the child was presented with a set of cards; the researcher then reminded the child, that the test would start with Set A and that *'When you look at a card, I want you to tell me, what colour the picture is drawn in'*. In this condition, the researcher provided no feedback on whether the response was correct or incorrect.

Each card in set A was presented consecutively once a response (whether correct or incorrect) to the prior card had occurred. If a child did not respond in under 8 seconds, the verbal prompt *'what colour is this one'* was used. If the child responded immediately after the prompt, the next card was presented; if the child took too long (over 10 seconds) or did not respond to the current card, the next card in the set was flipped over for presentation. The test session was videotaped for later scoring of responses.

On completion of set A (incongruent colour to object), set B (congruent colour to object) was presented exactly as set A. On completion of set B, set C (abstract objects) was presented, again the same as in set A & B, however if the child responded, *that's a plane*, if trying to make sense of the abstract shape, the verbal prompt, *'remember you are supposed to tell me what colour the picture is drawn in'* was used to put the child back on task. Lastly Set D, the second post-test condition was presented, and further instructions were given to the child *'Now this set of cards is different from the other*

*cards, 'I would like you to tell me, what the picture is of'. The researcher then flipped the top card and presented the child with the first card. If the child responded incorrectly, and said black or brown, the researcher used the same process as the pre-test - 'not quite' because you are supposed to tell me what the picture is, so for this one it would be a whale'. In addition, if the child said, 'a whale or the whale' the researcher would echo 'whale' or asked the child to 'just say whale'. If the child was correct on the next trial the researcher continued with the remainder of the cards in set D. The colour-object task took approximately 5 minutes to administer.*

To score the colour object interference Stroop type task, Premex software was used to calculate latency of response. The latency of response was measured in seconds from the time the card was presented to the child (which is defined as when the child's eyes are looking directly at the card), to the time the child verbally responded correctly or incorrectly. If the child responded incorrectly, however, then self-corrected with a second response, only the first response latency was calculated. It was also recorded whether a response was correct (Y), incorrect (N), or there was a non-response (NR). A non-response was defined as no verbal response within 10 seconds. The non-response duration was calculated after testing, by averaging the longest latency scores over both groups. This occurred after testing as no prior operational definitions had been considered for this outcome. The colour object interference task, via Premex, generated per card reaction times. The number of correct responses for each set and the mean latency for correct responses were the scores used in the analysis. Prolonged reaction times were perhaps indicative of cognitive slowing/impairment or as errors as these can manifest as impulsive responding, misperception or confusion.

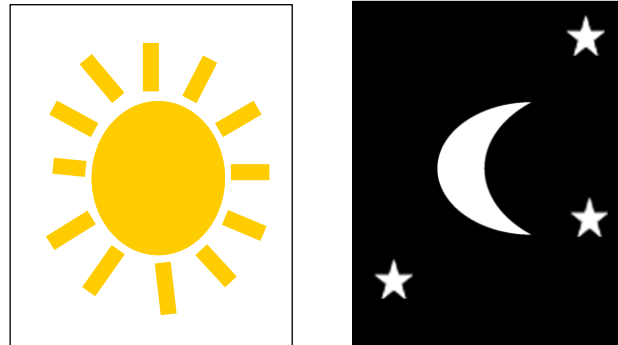
### ***The Day & Night task***

The Day & Night Stroop (1994) task was also adapted from the adult word-colour Stroop test (Stroop, 1935). The day and night task was developed by Gerstadt, Hong & Diamond (1994), and is age appropriate for children aged 3.5 – 7 years. The task required the children to inhibit the natural tendency to give a different verbal response (inhibitory control)(Gerstadt, Hong, & Diamond, 1994). In addition however it also required, at the same time for the child to learn and keep two rules in mind (switching and working memory). The day & night task required the child to say the opposite of what they were seeing, that is when presented with a card with a yellow

sun4on it, they had to say ‘night’, and when presented with a card with a moon and stars on it, they had to say ‘day’.

Diamond (1988, 1990, 1991a) hypothesised that both memory (or sustained attention), and inhibition require the executive use of the frontal cortex, much like Piaget’s (1954) AB task which requires a child to ‘keep in mind’ where a toy was hidden (location A), and after its removal to a new location (location B), inhibit their response to search for it in location A (Diamond, 1988, 1990, 1991a). Gerstadt, Hong & Diamond (1994), suggested that children with a TBI or prefrontal cortex injuries in particular would perform significantly worse on the Day & Night task

The Day and Night task was videotaped for later scoring. The task included a set of 16 test cards with 2 practice cards, separated from the test trials by a cardboard insert. All cards were A5 in size, laminated, and bound into a flip book for easy administration. Eight of the cards had a yellow sun on a white background, and the remaining eight a white moon and stars on a black background (see figure 4 for examples). These were presented in a predetermined order (night (n), day (d), d, n, d, n, n, d, d, n, d, n, n, d, n, d,).



*Figure 4. Showing examples of the yellow sun card on a white back ground and the moon and stars card on a black background.*

### ***Training & pre-test:***

Training included the researcher showing the child a card with a white moon and stars on a black background, and instructed the child – ‘*When you see this card I want you to say ‘day’*’, the word day was emphasised, the researcher then waited for the child to echo the word ‘day’. If the child did not say ‘day’, the researcher would say ‘*day*’ and

present the card again and point to the card. The researcher then removed the 'day' card and presented the child with the white card with the yellow sun and instructed the child *'When you see this card, I want you to say 'night'*, and then waited for the child to echo the word 'night. Again if the child did not respond, the researcher would use both a verbal prompt and say 'night' and use a gestural prompt by pointing at the card. Three practice trials, re-using the practice cards (flipping the cards back and forth) were conducted to ascertain the child knew the instructions. Children were excluded if they failed the three practice trials (see results section for further information).

This procedure was then repeated this time without the researcher giving instructions – if the child hesitated, or did not respond the researcher prompted the child by saying *'What do you say for this one?'*. If the child responded correctly, the researcher praised the child and proceeded to the test trials. If the child responded incorrectly, or did not respond at all on either of the practice trials, the child was reminded of the rules and presented with the card that they had identified incorrectly.

### ***Testing:***

The child had to pass the two practice trial tests to ensure understanding of the task. If these 2 trials were correct they were counted as trials 1&2. The task took 2 minutes to administer.

Scoring was based on the dependent variables: response (what did the child say), and whether the response was correct (Y/N); how long from the time the card was presented to the time the child gives a verbal response (response latency on each trial), and also response latency over all trials within the session. Premex software was used to score the videotaped sessions.

## **Performance-based measure of Intelligence**

### *The WPPSI*

The Wechsler Preschool and Primary scale of Intelligence (WPPSI-III) (Wechsler, 2002), is divided into two age bands 2.6 – 3.11 and 4.0 – 7.3, with different subtest batteries for each age band. With the ages 4.0 – 7:3, there are seven core subtests.

Thaler et al (2010) study, found that children with TBI can be identified using IQ tests, that these subgroups are stable across different samples, and are moderately associated with behavioural disturbances that persist long term during recovery. The WPPSI-III is sensitive to such clinical conditions as ADHD, learning disability and traumatic brain injury (Donders & Warschausky, 1997; Mayes & Calhoun, 2004).

The short-form version of the WPPSI-III, by Sattler & Dumont (2004), was however selected for the current study to provide an estimate of IQ, as it contained four core subtests: Information; Matrix reasoning; Symbol search, and Picture Completion. It was also chosen to fit the current research parameters, and has good reliability and validity (respectively  $r = 0.948$ ,  $r = 0.921$ ). The information subtest has a total of 34 items, consisting of 6 picture items, and 28 verbal items. The verbal items require a brief verbal response from the child. For verbal items, the child answers questions that address a broad range of general knowledge topics (Sattler & Dumont, 2004).

The matrix reasoning subtest has a total of 29 items. For each item, the child looks at an incomplete matrix and selects the missing piece/part from 4 or 5 response options. Matrix reasoning is a core performance subtest for ages 4-7.3. Matrix analogy tasks are good measures of fluid intelligence and reliable estimates of general intellectual ability (Brody, 1992; Raven, Raven, & Court, 1998). Four types of items were designed to provide a reliable measure of visual information processing and abstract reasoning skills.

The picture completion subtests has a total of 32 items. All items require the child to view a picture and point to or name the important part missing from the picture. The picture completion subtest is a supplemental performance subtest for ages 4-7.3. It is designed to measure visual perception and organisation, concentration, and visual recognition of essential details of objects (Sattler, 2001).

The symbol search is the final subtest, a supplemental processing speed subtest for ages 4-7.3. It also involves short term visual memory, visual-motor coordination, cognitive flexibility, visual discrimination and concentration (Kauffman, 1994; (Sattler, 2001). It encompasses tap auditory comprehension, perceptual organisation, and planning and learning ability (Kaufmann, 1994). In symbol search the child scans a search group and indicates whether a target symbol appears in the search group by marking the appropriate symbol with a pencil. All children are given 120 seconds to complete this task.

The WPPSI-III takes approximately 20 minutes to administer. The total of these scaled scores then determines the estimated Full scale IQ (FSIQ) found on the subtest short form (Sattler & Dumont, 2004). FSIQ scores below 69 are considered extremely low; 70-79 borderline; 80-89 low average; 90-109 Average; 110-119 High average; 120-129 superior and over 130 Very superior.

## **Behavioural measures**

### **Adaptive behaviour, social and emotional functioning**

#### *BASC-2*

The Behavioural Assessment System for Children (BASC-2, preschool version) designed for children aged 2- 5 years (Merenda, 1996; Reynolds & Kamphaus, 2004) is a multidimensional measure used to assess the domains of adaptive behaviour, and social and emotional functioning. The BASC-2 consists of 134 statements that describe how children may act, divided into four indexes, each of which has several subscales. These composite indexes/scales are: Externalising problems (scale scores - Hyperactivity, Aggression); Internalising problems (Scale scores - Anxiety, depression, somatisation); Behavioural symptoms index (Scale scores - Atypicality, withdrawal, attention problems) and adaptive skills (Scale scores - adaptability, social skills, activities of daily living, functional communication).The parent is asked to circle the response that best describes how the child has behaved over the past month. The parent rates these behaviours based on a four point Likert scale, NEVER, SOMETIMES, OFTEN, and ALMOST ALWAYS. The BASC takes approximately 10-15 minutes to administer.

Scoring was completed using the BASC-2 ASSIST Plus software. Summary scores relating to adaptive (e.g. Interpersonal relations) and clinical scales (e.g., anxiety, aggression) were generated in addition to composite measures of adaptive skills, behavioural symptoms, externalising problems and internalising problems (Reynolds & Kamphaus, 2004). The current study used the all composite indexes/scales scores internalising, and externalising behaviour, behavioural symptoms and adaptability. These scales have good reliability and validity and provide details of adaptive, and maladaptive behaviour (Flanagan, 1996; Reynolds & Kamphaus, 2004; Reynolds, 2002; Weis, 2007; Wilder, 2003). BASC-2 clinical cut off scores are higher scores that determine greater problems; T-scores over 70 reflect a clinically significant ‘caseness’; while T-scores between 60-69, on the clinical scales reflect children ‘at risk’ with the exception of adaptability which has a low clinical cut off of 31-40.

### *SDQ*

The Strengths and Difficulties Questionnaire (SDQ) (version 4-16 years) is a commonly used screening test to evaluate young person’s behaviours, emotions and relationships, specifically both social and behavioural competence (Goodman, 1997). It has been used in TBI populations (Petersen, et al., 2008); has good internal reliability (Cronbach’s Alpha = .73), and can predict independently diagnosed psychiatric disorders (Goodman, 2001). The SDQ (Goodman, 1997) consists of a list of 25 statements that measure the child’s strengths and difficulties which are summarised into indexes; emotion, conduct, hyperactivity, peer problems, and pro-social behaviour. Parents are asked to look at each statement and think about their child’s behaviour over the last six months. Parents rate statements the first 25 statements using four Likert Scale descriptors; NOT TRUE, SOMEWHAT TRUE and CERTAINLY TRUE.

The remaining statements (questions 26 – 26.4) use a variable number of Likert Scale descriptors, scored at 0, 1, 2, 3 and 9. Item 26 asks, overall do you think that your child has difficulties in one or more of the following areas: emotions, concentration, behaviour or being able to get on with other people? Items 26.1 – 26.4 are only answered if the parent answered yes to the above question (26.).

The SDQ takes approximately two minutes to administer. Scoring is carried out using SPSS software. The score summary is tallied into the following indexes; Emotion,

Conduct, Hyperactivity (Inattention), peer problems, and pro social behaviour. The total difference (based on the first four scales) and level of Impact were calculated.

Total difficulty scores range from 0–40 (Goodman, 2001). A total score of  $\geq 20$  is used to indicate an abnormal total score or of concern score (Mellor, 2005). Previously established abnormal or of concern scores (Mellor, 2005) were used to determine if participants had difficulties in relation to emotional symptoms (subscale scores  $\geq 7$ ), conduct problems (subscale scores  $\geq 5$ ), hyperactivity (subscale scores  $\geq 7$ ), peer problems (subscale scores  $\geq 6$ ), and prosocial issues (subscale scores  $\leq 4$ , where lower scores indicate difficulties and higher scores prosocial strengths).

### **Parental/Environmental Measures**

#### *HADS*

The Hospital Anxiety and Depression scale (HADS) (Zigmond & Snaith, 1983) is designed to measure whether an adult is feeling depressed or anxious (Anson & Ponsford, 2006). This questionnaire was used as it screens and identifies people who may need help managing depression. The HADS consists of 14 statements that ask the person how they have been feeling in the last two weeks. The respondent looks at each statement which contains 4 variable descriptors i.e., for question 1 - I feel tense or 'wound up' the descriptors are: Most of the time; A lot of the time; From time to time, occasionally; or Not at all and scored 3, 2, 1 and 0 respectively and circles the appropriate response. The HADS takes approximately two minutes to administer. Scores range between 0 and 21 for each scale. To calculate the overall score the researcher sums up the scores separately for depression and anxiety; scores over 11 are considered clinically significant.

#### *HOME*

The researcher completed an observation called The early childhood Home Observation for Measurement of the Environment (EC HOME), (Caldwell & Bradley, 1984, 2003). The Early Childhood (EC) HOME is designed for use with children between 3 and 6 years of age and measures the quality and quantity of stimulation and support available to a child in the home environment. The aim is to understand the

child's opportunities and experiences or to understand what life is like for that particular child. The HOME is used for a number of reasons; including identification of at risk families, evaluation of parent education programmes, planning family intervention, and research in child development. It contains 55 items clustered into 8 subscales: 1) Learning materials (11 items), 2) Language stimulation (7 items), 3) Physical environment (7 items), 4) Parental responsivity (7 items), 5) Learning stimulation (5 items), 6) Modelling of social maturity (5 items), 7) Variety in experience (9 items), and 8) Family participation (4 items). Information was gathered by the researcher by conversing with the parent, through observation or by asking a direct question. To score a binary format was used, i.e., a plus (+) or minus (-) was placed in the box alongside each item depending on whether the behaviour is observed or not during the visit, or if the parent reports that the conditions or events are characteristics of the home environment. Scores for each item are recorded on the record form, and then later the subtotals and the totals are transferred to the summary sheet. The possible subscale scores are equal to the total number of items in each scale. The summary sheet contains median scores obtained by the standardisation samples for all subscales and for the total inventory, so actual scores can be compared with these. HOME scales include collections of individual items, which when taken together, provide an index of the degree of stimulation and support available to a child.

#### *Parent Child Interaction tasks (PCI)*

The structured parent-child interaction task (Clark, et al., 2008) was used to ascertain parent child interactional synchrony (Adapted from Mize & Pettit, 1997) that is to assess the harmony, interconnectedness, responsiveness, reciprocity, engagement, mutual focus, and shared effect between child and parent, or how coordinated and balanced the interaction is; taking into account 'turn taking' balance. The task involved the parent and child attempting three age-appropriate problem solving tasks.

The parent is informed that the task will be recorded for later scoring and the purpose of the task was to observe the problem solving skills of the child, while having the support of someone familiar. It was stressed that completion of the task wasn't the aim, but how problem solving was approached. The parent was then introduced to the three tasks; each task was presented in a red flax bag, with verbal instructions from the researcher on how to complete them. The parent was then asked to introduce them to the

child one at a time, in the following order: Puzzle, Magnetic board, Castle. The first task was a puzzle completion task, the second task involved replication of the word 'flower' glued onto a magnetic board – the child was required to copy the word underneath, by searching for the correct magnetic letters provided; the third task was a castle building task in which the child had to copy a glued together example of a castle from the blocks provided. The session was timed, and after 4 minutes on one task the parent was asked to move onto the next task. The parental child interaction; takes approximately 12-15 minutes to administer.

After administration, each task was observed and coded using five subscales (adapted from Chase-Lansdale et al., 1998 and the Dunedin parenting study ), of the child's interpersonal behaviour. They are Positive affect – measures overall quality of child's positive expressions/responses; Negative affect - measures the intensity and frequency of the child's degree of unhappiness, sadness, and hurt, Expressed activity level – assesses how motorically active the child is during the observation; Sustained attention/persistence - measures the extent to which the child actually was problem-orientated in the session, Dependence on/help from parent –reflects the extent to which the child displays personal initiative or expects the parent to provide help or direction and Quality of transition across tasks which assess the ability of the child to move from one task to the next .

The subscales used for the parent's interpersonal behaviours which were video recorded for later qualitative coding, were Positive affect toward the child - measures the overall quality of a parents positive expressions towards their child (adapted from Chase-Lansdale et.al., 1988); Negative Affect toward the child -which measures the intensity and frequency of the parents degree of disapproval, anger, and negativism expressed toward the child (Adapted from Chase-Lansdale et.al 1988); Supportive presence – measures the degree of positive regard and emotional support to the child (adapted form Chase-Lansdale et.al., 1988); Facilitation of self-regulation – assesses the extent to which a parent scaffolds each task in a way that allows them to direct and structure their play (adapted from Dunedin parenting study); and Intrusiveness/Over controlling – assesses the extent to which parental behaviour is ill-timed, intrusive, excessive and inappropriately controlling (Adapted from Chase-Lansdale et.al., 1988).

Each subscale was rated on a scale of 1 – 5, the lower rating of one represents a low intensity or frequency of the interpersonal behaviour/s; whereas a high rating of

five represents intense, frequent, or includes the target interpersonal behaviour/s. The parent and child scales are then reviewed to ascertain an overall Interactional synchrony. A score of between one (interaction between partners is characterised as being asynchronous and disjointed rather than smooth and interconnected), and five (Partners are engaged in the same activity, are mutually responsive to one another)(Chase-Landsdale, Brooks-Gunn, & Zamsky, 1994).

Coding was completed by independent observers ‘blind’ to children’s TBI severity (Clark, et al., 2008) and TBI or control group allocation. Training was carried out on observations of the parent and child subscales to ensure inter-rater reliability over the course of the parent-child interaction coding. This entailed the independent observer group viewing the same videos, but independently, and completing their coding sheets for four separate cases. The group then met to discuss the scores and what each subscale entailed and came to an agreement. After the final training session the intraclass correlation coefficient (ICC) reliability score was calculated. The ICC scores range from 0 (no reliability) to 1.0 (perfect reliability), with inter-rater reliability having to be above 0.80. On completion of the training the result was (ICC = 0.91). The coders therefore began coding independently.

## **Procedure**

### **Ethical approval**

The COBIC study received ethical approval from the Northern Y Ethics Committee (ref: NTY/11/02/06), and the University of Waikato, School of Psychology Ethics committee.

### **Recruitment of participants**

As explained in the participants section, mTBI participants aged 4– 4 years 11 months of age were recruited through the BIONIC study. The same process was employed for the control group, with the exception control children were recruited through mTBI children’s preschools and referred by mTBI parents to participate in the study.

The questionnaires and tests were administered in a predetermined order to enable the child to familiarise themselves with the researcher i.e., see the researcher interacting with the parent; with the aim to encourage the child to participate fully in the sessions.

The researcher explained the study to the parent, asked if they had any questions, then obtained written consent. The health history questionnaires (Child health history, medical history, questions about mum when pregnant, about the child as a baby and in school and home, and about the family) were read to the parent by the researcher and filled in. Following this the general information was obtained and the rehabilitation received and health economic data form was filled out. Following this, the researcher videoed the parent/child interaction. The parent was encouraged to sit quietly during the child's testing. During this time the parent filled out the following questionnaires; the BRIEF, SDQ, and BASC and the researcher administered the object interference test and the day and night test to the child. The last test to be administered to the child was the WPPSI intelligence test.

The assessments were administered over one 3 hour or two 1.5 hour sessions dependent on child/parent preferences. In some cases a third appointment was warranted to complete the assessments. All participants were informed that a copy of the videotaped parent child interaction, day & night, and colour object interference tasks would be provided on CD and sent by post on completion of the assessments. All child participants received stickers during the first assessment and a certificate at the final assessment. The parent received a \$20 gift voucher from The Warehouse for the assessment as a token of appreciation. Parents were also posted a feedback report (a one page letter) which summarised the child's thinking and problem solving, and executive functioning, followed by an overall summary.

## **Data**

Data was collected exclusively by the author of this thesis, from March 2012 to October 2012. All data was entered into the University of Waikato's COBIC/BIONIC computer database and IBM SPSS statistics 20 software was used for analysis and interpretation.

## **Analysis**

### **Background sample characteristics**

The child health history questionnaire was analysed to compare the frequency (n), and percentage (%) of main health or any medical problems in children as identified by parents of the both the mTBI and control groups. Frequency (n) and percentages (%) of any health problems during pregnancy, as identified by the parent, was also compared, including the mean (m), range and frequency of breast feeding, and birthing date. The parent-rated measure of intelligence (WPPSI) was also analysed to compare the mTBI and control group's means, using an independent t test and Cohens d for effect size.

### **Executive functioning analysis**

Data for this study was initially checked for normality and skewness. A significant value ( $<.05$ ) on the Kolmogorov-Smirnov test indicated a deviation from normality; skewness was also determined if a value was further from zero. Homogeneity of variance was also tested for with a Levene's test. When confirming all data was normally distributed independent t tests were undertaken to compare the means between the mTBI and control groups. A significant difference between the groups was determined if t test value  $<.05$ . A Cohen's d was used to determine effect size.

Analysis based on aim one: to compare the executive functioning of preschool children who sustained a TBI at age 2 years; at 24 months post injury, with an age matched comparison group of children free from TBI; in the areas of inhibitory control, working memory, processing speed and shifting.

Comparisons of executive functioning between the TBI and control groups using an independent t test were conducted on scores from the BRIEF (P) and the performance-based measures of the Object interference and Day & Night Stroop tasks. Cohens d was used to ascertain effect size and both Chi-square and Fishers Exact Test analyses were used to find the differences in frequency of children in each group who scored in the clinically significant range for the BRIEF-P composite scales. Further analysis using the correlation coefficient Pearsons r, measured the relationship between the EF measure (BRIEF) and performance-based measures (COI & D&N).

## **Behavioural and emotional functioning analysis**

Analysis based on aim 2: To compare the behavioural/emotional functioning of preschool children who sustained a mTBI at age 2 years; at 24 months post injury, with an age matched comparison group of children free from mTBI, in the areas of externalising, and internalising behaviour, and other behavioural symptoms and adaptive skills.

Comparisons of behaviour and social functioning between the mTBI and control groups using an independent t test were conducted on scores from the parent rated measures of the BASC-2 and SDQ. Cohen's *d* effect sizes were also calculated for each comparison. The Fishers Exact Test was used to find the differences in frequency of children in each group who scored in the clinically significant range for the BASC-2 composite scales and SDQ. Further analysis using the correlation coefficient Pearson's *r*, measured the relationship between the behavioural measures (BASC-2, SDQ) and parent-rated measure (BRIEF) of executive functioning.

## **Parental/Environmental factors analysis**

Based on aim 3: To examine the extent to which executive functioning outcomes can be explained by child factors (gender, age, ethnicity, SES); clinical characteristics around the time of injury (severity of TBI, and co-morbid conditions); parental factors (parental health) and the environment (home environment/parent child interaction).

Comparisons of the environment between the mTBI and control groups using the Independent t test, and Cohens *d* effect size were conducted on measures of parental mental health (HADS), the home environment (HOME), and parent child interaction (PCI). The Fishers Exact test was used to find the differences in frequency of children in each group who scored in the clinically significant range for the HADS measure of parental mental health. Further analysis using the correlation coefficient Pearson's *r*, measured the relationship between the environmental measures (HADS, HOME and PCI) and the both the parent-rated measure of executive functioning (BRIEF) and performance based measures of COI and D&N.

## RESULTS

Sample characteristics were investigated in the areas of parental health during pregnancy and both child health and intelligence (WPPSI) to determine differences in the mTBI and control groups characteristics.

The results section then presents the outcomes of statistical analyses of this study's aims and hypotheses and is separated into three parts.

In part one; measures of executive functioning - the parental measure of executive functioning (BRIEF) is analysed and clinical cut off scores are examined. Secondly the performance-based measures of executive functioning (COI and D&N) are presented. Correlation analyses are then conducted between the parent-rated measure of EF (BRIEF-P) and the two performance-based measures of EF (COI and D&N).

In part two, analyses of both the parental measures of behaviour (BASC-2, and SDQ), are presented and clinical cut off scores are analysed. Secondly, correlation analyses are undertaken between the parental measures of executive functioning (BRIEF), and behaviour (BASC-2 and SDQ).

In part three, the parent-rated measures of parental mental health (HADS) is analysed and clinical cut off scores examined. Secondly measures of the environment (HOME) and the Parent Child interaction observation (PCI) are analysed. A correlation analyses is then presented between performance-based measures of executive functioning (COI and D&N) and the measures of parental mental health (HADS); the home environment (HOME) and the Parent child interaction observation (PCI).

The results section concludes with an overall summary of findings.

## Other sample characteristics

In the literature review, it was mentioned that there are many predisposing factors related to the incidence of mTBI. The descriptive characteristics of parental health during pregnancy (shown in table 5), and child health history (shown in table 6) were examined to identify if there were any differences in the number and proportions of children in the mTBI group and control groups.

Table 5

Frequency and percentage of any health problems during pregnancy as identified by the parents

	Group	
	mTBI ( <i>n</i> = 22)	Control ( <i>n</i> =22)
	<i>n</i> , (%)	<i>n</i> , (%)
<b>Pregnancy type</b>		
Naturally	22	22
IVF	0	0
<b>Problems during birth</b>		
Emotional stress	5 (5.7)	4 (18.18)
Preeclampsia	2 (9.09)	0
Unexpected bleeding or spotting	2 (9.09)	3 (3.64)
High blood pressure	1 (4.55)	0
Other	1 (4.55)	1 (4.55)
<b>Breast feed</b>		
	21, (95.45), <i>m</i> = 10.6, <i>range</i> = 4 – 116 weeks	21, (95.45), <i>m</i> = 13, <i>range</i> = 2 – 182 weeks
<b>Was birth, before, on or after due date?</b>		
Before ( <i>n</i> , %)	8; (36.36), <i>m</i> = 13, <i>range</i> = 1-28 days	8; (36.36), <i>m</i> = 10.06 , <i>range</i> = 4-21 days
On due date ( <i>n</i> , %)	2, (9.09)	5, (22.73)
After due date ( <i>n</i> , %)	11; (50), <i>m</i> = 6.64, <i>range</i> =1 -14 days	12; (54.55), <i>m</i> = 5.92, <i>range</i> = 1-14days

Note: mTBI = Mild traumatic brain injury; *m* = mean; *n* = number.

Table 5 shows that all participants conceived naturally; and the main problem at birth was emotional stress for both groups. There were no differences between the groups in the frequency of breast feeding and early or late births duration; however, in the duration of breast feeding, the control group was breast fed for longer. Overall, the examination of parental health shows a slightly higher frequency of problems and conditions during pregnancy for the mTBI group when compared with the control group.

Table 6

*Child health history: Frequency of main health problems or any medical problems in mTBI and control group children aged 4 years – 4 years 11months as identified by parents.*

	Group	
	mTBI ( <i>n</i> = 22)	Control ( <i>n</i> = 22)
	<i>n</i> , (%)	<i>n</i> , (%)
<b>Main health problems</b>		
ADD/ADHD	2 (9.09)	0
Ear problems	4 (8.8)	1 (4.5)
Asthma	5 (22.72)	1 (4.5)
Eczema	1 (4.5)	1 (4.5)
Speech therapy	1 (4.5)	0
Cerebral Palsy	0	1 (4.5)
Other behaviour	0	1 (4.5)
<b>Total frequency of main health problems</b>	<b>3</b>	<b>5</b>
<b>Any medical problems</b>		
Ear	12 (54.54)	12 (54.54)
Nose	6 (27.27)	2 (9.09)
Eye	3 (3.6)	1 (4.5)
Hearing	6 (27.27)	2 (9.09)
Seizures	7 (3.8)	0
Attention problems (ADHD/ADD)	4 (8.8)	0
Sleeping problems	5 (22.72)	3 (3.6)
<b>Total frequency of medical problems</b>	<b>43</b>	<b>20</b>
<b>Combined total frequency of cases</b>	<b>56</b>	<b>25</b>

*Note:* mTBI = Mild traumatic brain injury; ADD = Attention deficit disorder; ADHD = Attention deficit hyperactivity disorder. It must be noted some children had two or more medical problems.

Table 6, shows the main health problems were asthma and ear problems; and the most common medical problems were related to the nose and hearing. The highest frequency medical problem was seizures, of which incidence was exclusively within the mTBI group. There was also exclusivity in frequency of pre-morbid attention problems

(ADHD & ADD) in the mTBI group over both categories. Overall, there were more main health problems and more medical problems within the mTBI group in comparison to the control group.

## Part One: Measures of executive functioning

Pre-school children who sustained a mTBI at age 2 years (assessed at 24 months post injury), and a matched group of children free from TBI were compared. The focus was on inhibitory control, working memory, processing speed and shifting, as well as any behavioural manifestations of executive functioning in the context of the everyday environment. The analysis used the parent-rated executive functioning measure BRIEF-P of which the main composite scores and subscales were examined using an independent t test to determine whether there were any significant differences between the two sets of scores. To further determine effect size Cohens *d* was utilised.

Table 7

*Descriptive and inferential statistics for the BRIEF-P for the mTBI and control groups*

BRIEF-P	Group		Statistics	
	mTBI (n =22)	Control (n = 22)	Independent t- test	Cohens <i>d</i>
	<i>m, (sd)</i>	<i>m, (sd)</i>	<i>t, (df), p</i>	<i>d</i>
<b>Scale</b>				
IH	58.59 (13.40)	54.52 (10.12)	$t(41) = 1.119, p = 0.270$	0.342
SHI	53.00 (11.49)	52.29 (7.77)	$t(37.019) = 0.240, p = 0.812$	0.072
WM	57.41 (12.05)	57.48 (12.45)	$t(41) = -0.018, p = 0.986$	0.006
<b>Index</b>				
ISCI	57.32 (14.47)	55.19 (11.25)	$t(41) = 0.537, p = 0.594$	0.164
FI	53.32 (13.38)	53.86 (8.73)	$t(41) = -0.156, p = 0.877$	0.048
EMI	57.50 (12.99)	57.9 (10.64)	$t(41) = 0.085, p = 0.932$	0.042
GEC	57.68 (14.47)	56.48 (10.50)	$t(41) = 0.31, p = 0.757$	0.120

*Note:* BRIEF-P = Behaviour Rating Inventory of Executive Function-Preschool, IH = Inhibit; SH = Shift; WM = Working Memory; ISCI = Inhibitory Self-control Index; FI = Flexibility Index; EMI = Emergent Metacognition Index; GEC = Global Executive Composite.

As shown in table 7, overall the mTBI group had higher means across all scales and indexes in contrast with the control group. It was noted that the mean for the Inhibitory control scale (IH) was relatively high for the mTBI group (58.59), which could indicate greater dysfunction in this area. There was however no statistically significant differences in the means between the mTBI and control groups across the scales and indexes, and effect sizes for the group difference were small. Scale and composite scores for the BRIEF-P were also analysed to examine the differences in the number of children who scored in the clinically significant range in each group. The BRIEF-P analysis used the  $X^2$  if frequency was over 5; and the FET test if frequency was equal to or under five.

Table 8

*BRIEF-P: Children above clinical cut off score of 65: n, (%) across scales and indexes*

BRIEF-P	Group				Statistics
	mTBI (n = 22)		Control (n = 22)		
Scales	n, (%)		n, (%)		$X^2$ , FET (n <5)
	Clinical	Normal	Clinical	Normal	
IH	6 (27)	16 (72.73)	3 (3.64)	19 (86.36)	FET = 21.17, p = 0.820
SHI	3 (13.64)	19 (86.36)	0	22 (100)	FET = 17.93, p = 0.425
WM	6 (27)	16 (72.73)	9 (40.90)	13 (59.09)	CHI (24) = 20.32, p = 0.678
<b>Indexes</b>					
ISCI	5 (22.73)	17 (77.27)	3 (13.64)	19 (86.36)	FET = 22.80, p = 0.85
FLEX	3 (13.64)	19 (86.36)	1 (4.55)	21 (95.45)	FET = 23.614 , p = 0.333
EMI	6 (27)	16 (72.73)	7 (31.82)	15 (68.80)	CHI (27) = 29.53, p = 0.336
GEC	5 (22.73)	17 (77.27)	5 (22.73)	17 (77.27)	FET = 18.44 , p = 1.00

*Note:* FET = Fishers Exact Test; CHI = Chi squared test, mTBI = Mild traumatic brain injury. IH = Inhibit scale, SHI = Shift scale, WM = working memory scale. ISCI = Inhibitory self-control index, FI = Flexibility Index, EMI = Emergent metacognition index, GEC = Global executive composite.

Results in table 8 show a higher number of clinical cases in the IH scale, and both ISCI and FLEX indexes of the mTBI group when compared with the control group. This suggests a greater proportion of children in the mTBI group had the inability to

control their behaviour at an appropriate time. In contrast, there were a greater proportion of children in the control group with clinical cases in the WM scale, and EMI index; indicating the lesser capacity to hold information in mind for the purposes of completing a task. Both groups shared an equal frequency for EMI. Overall, however, there were no statistically significant differences in the number of clinical cases between the mTBI and control groups.

### **Performance-based measures of Executive Functioning**

#### *The Colour-object interference (COI) Task*

Further analysis of executive functioning utilised the performance-based measure of the Colour-Object interference (COI) task which examines both inhibitory control and working memory.

In total 44 children (mTBI 22 and control 22) were asked to participate in the COI test. Following the administration of the post-test conditions, which determined if a child could name the colour of the object (Set C) and name the objects (Set D) correctly, the researcher excluded the children from the analysis who: 1.) did not identify all six colours correctly; 2.) did not respond; 3.) did not identify all objects correctly; or 4.) had missing data/incomplete assessment.

In the mTBI group a total of 5 children were excluded from the analysis due to the above criteria; 3 children were excluded due to incomplete assessments/missing data; 1 child was excluded for only responding to the colours red, orange and green; while 2 other children either did not respond to SET D cards or responded 'brown' to all cards in this set. No control participants were excluded from the analysis.

The first aim of this executive functioning performance-based measure (colour object interference task) was to initially determine if the mTBI group differed from the control group in the executive functions of inhibitory control, working memory (accuracy) and processing speed (the measurement of reaction times or the latency of response). Table 9, shows the mean reaction times for each test condition (mTBI vs. control) based on the percentage correct.

The second aim was to determine if the STROOP effect (object naming vs colour naming) was present – by analysis of the mean reaction times (for correct

responses) and accuracy for sets A, B, C & D for both the mTBI and control groups. For both aims analyses, an independent t test was used to determine any differences between the means in the mTBI and control groups, for each condition.

Results presented in table 9, show that the STROOP effect was evident, as there was faster more accurate performance in naming the objects (Set D - post-test condition), than for naming the colours (Sets A, B, & C). Examination of the means and percentages suggested that naming objects was faster and accuracy was higher for the children in the control group when compared to the mTBI group, however a between groups analysis indicated that these differences were not statistically significant.

The STROOP effect was also evident in the slower less accurate responding for naming colour in the incongruent condition (Set A), compared with the congruent (Set B), and neutral/abstract (Set C) conditions. Examination of the means suggested that the mean time for the incongruent condition (Set A) for the children in the mTBI group was slower and less accurate than for the control group, suggesting the children in the mTBI group found it more difficult to inhibit the prepotent tendency to name the object over the colour; however a between groups analysis indicated that these differences were not statistically significant.

Table 9

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

Set	Dependent Variable	Group		Statistics	
		mTBI (n = 21) <i>m (sd)</i>	Control (n = 22) <i>m (sd)</i>	Independent t-test <i>t(df), p</i>	Cohen <i>d</i>
<b>A</b>					
	Time (s)	5.05 (4.35)	3.88 (1.048)	$t(39) = 1.227$ , $p = 0.227$	0.393
	% correct	75.44 (20.31)	81.44 (17.99)	$t(39) = 1.003$ , $p = 0.322$	0.321
<b>B</b>					
	Time (s)	3.87 (1.11)	3.51 (0.84)	$t(39) = 1.197$ , $p = 0.238$	0.383
	% correct	85.09 (12.60)	79.92 (18.12)	$t(37.4) = 1.070$ , $p = 0.29$	0.349
<b>C</b>					
	Time (s)	3.85 (0.97)	3.86 (1.00)	$t(39) = 0.028$ , $p = 0.978$	0.009
	% correct	82.02 (7.98)	77.65 (15.12)	$t(32.31) = 1.155$ , $p = 0.257$	0.406
<b>D</b>					
	Time (s)	3.51 (0.69)	3.42 (0.94)	$t(38) = 0.350$ , $p = 0.729$	0.113
	% correct	80.70 (25.92)	92.04 (15.53)	$t(39) = 1.727$ , $p = 0.092$	0.553

Note: Set A = Incongruent colour-naming; Set B = Congruent colour-naming; Set C = neutral colour-naming; Set D = Object-naming. to calculate Cohens d [www.uccs.edu](http://www.uccs.edu) used. In Set D (n = 8) as one participant did not respond to any cards correctly, although it was obvious the child could identify all objects in the set.

### *Day & Night (D&N) Task*

Further analysis of executive functioning utilised the performance-based measure of the Day & Night task which examines inhibitory control, working memory and shifting.

In total 44 children were asked to participate in the D&N test. Of these 22 were mTBI and 22 control. As a result of the pre-test however, 3 children failed the initial trials, and a further 4 children would not participate or engage in the test and thus were excluded from the analysis. The total number of participants included in the analysis equated to 36 (18 mTBI and 18 control).

The aim of this executive functioning performance-based measure (Day & Night task) was to determine if the mean reaction times (for correct responses) of the mTBI group differed significantly from the control group in terms of the executive functions of inhibitory control, working memory (accuracy) and processing speed (the measurement of reaction times or the latency of response). Analysis was conducted using an independent t test.

*Table 10*

*Comparison of mTBI and control group on reaction time and accuracy for the Day & Night task*

Dependent Variable	Independent t-test		Cohens <i>d</i>	
	mTBI ( <i>n</i> = 18 ) <i>m, (sd)</i>	Control ( <i>n</i> = 18 ) <i>m, (sd)</i>		
Time (s)	3.71 (2.91)	3.40 (1.99)	<i>t</i> (34) = 0.365, <i>p</i> = 0.77	0.25
% correct	55.55 (19.71)	51.23 (22.10)	<i>t</i> (34) = 0.69, <i>p</i> = 0.540	0.22

*Note:* Cohen's *d* calculations used the website [www.uccs.edu](http://www.uccs.edu).

Results in table 10, show that the mTBI group responded slower to the stimuli with a higher percentage correct, in contrast to the control group who responded quicker but incurred more errors as a consequence. However, a between groups analysis found there were no statistically significant differences between the groups.

To examine the relationship between both the executive functioning parent-rated measure BRIEF-P, and the performance-based measures COI and D&N, a further series of between measures correlations were conducted. The aim of this bivariate correlation was to establish if there was a significant positive relationship between the three EF measures in terms of working memory, shift and inhibitory control.

As shown in table 11 a significant positive relationship between inhibitory control and shift in colour naming in sets A and C was found, and also with working memory and set C in the mTBI group, suggesting the ability to hold and shift information is related to better performance. In contrast, however there were no significant relationships found between the performance-based measures and executive functioning scales of the BRIEF for the control group.

Table 4

Performance-based measures and parent-rated measures of working memory, shift, and inhibitory control – (COI, DN, BRIEF)

BRIEF-P	mTBI (n=22)		
Measure	Inhibitory control	Shift	Working memory
<u>COI – mean latency correct</u>			
SET A	0.490*	0.388*	0.362
SET B	0.026	0.235	-0.034
SET C	0.486*	0.624**	0.414*
SET D	0.256	0.333	0.230
<u>DN - mean latency correct</u>			
Full Set	0.088	-0.211	-0.043
<hr/>			
BRIEF-P	Control (n=22)		
Measure	Inhibitory control	Shift	Working memory
<u>COI – mean latency correct</u>			
SET A	0.098	0.108	0.208
SET B	-0.049	-0.208	-0.110
SET C	-0.195	-0.220	-0.121
SET D	0.091	-0.213	-0.006
<u>DN - mean latency correct</u>			
Full Set	-0.148	-0.353	0.006

Note: \* correlation is significant at the 0.05 level (1-tailed). \*\*Correlation is significant at the 0.01 level (1-tailed).

BRIEF-2 = Behavioural Rating Inventory of Executive Function – Preschool version; COI = Colour object interference STROOP type task; DN = Day & Night STROOP Type task.

## Performance-based measure of intelligence

### WPPSI

The WPPSI- III is designed to assess the children's estimated intelligence quotient (IQ). Fortyfour participants (22mTBI & 22 controls) were included in the analysis. The WPPSI-III was used with the other cognitive measures such as the parent-rated BRIEF-P and the performance-based object colour interference and the day & night tasks to provide a comprehensive test battery and an estimate of IQ.

Table 52

Comparison of FSIQ means between mTBI and control groups

Dependent Variable	Statistics			
	mTBI (n= 22 )	Control (n = 22 )	Independent t-test	Cohens
	<i>m, (sd)</i>	<i>m, (sd)</i>	<i>t(df) p</i>	<i>d</i>
FSIQ	106.88 (13.325)	111.82 (12.003)	$t(42) = 1.343, p = 0.186$	0.414

Note: Cohen's *d* calculations used the website [www.uccs.edu](http://www.uccs.edu).

Results presented in table 12 found no significant differences in estimated IQ between the two groups.

## Part two: Measures of behaviour

### *The BASC-2*

The purpose of aim 2 was to compare the behavioural/emotional functioning of both the mTBI and control groups, particularly in the areas of externalising, and internalising behaviour and other behavioural symptoms and adaptive skills.

To determine if there are any differences between parental ratings of the mTBI and control groups in behaviour and emotional functioning, analyses of the BASC-2 main composite t-scores were carried out using an independent t test.

*Table 6*

*Comparison of t-scores for parent ratings of BASC-2 for the mTBI and control Groups*

BASC-2	Group		Statistics	
	mTBI (n =22)	Control (n=22)	Independent t- test	Cohens
	<i>m, (sd)</i>	<i>m, (sd)</i>	<i>t, (df), p</i>	<i>d</i>
EXT	51.82 (12.31)	50.09 (7.95)	$t(35.929) = 0.553, p = 0.584$	0.167
INT	46.18 (11.08)	46.27 (8.64)	$t(42) = 0.030, p = 0.976$	0.009
ADAPT	52.05(11.51)	49.48 (8.79)	$t(41) = 0.820, p = 0.417$	0.25
BSI	47.41(9.95)	51.24 (6.86)	$t(41) = 1.463, p = 0.151$	0.45

*Note:* BASC-2 = Behavioural Assessment System for children – 2<sup>nd</sup> edition; INT = Internalising problems; EX = Externalising problems; Adapt = Adaptive skills; BSI = Behavioural Symptoms Index.

The BASC-2 results in table 13, show that the mTBI group had higher means for externalising problems in contrast to the control group who had higher means for the behavioural symptoms index and internalising problems albeit marginally.

For adaptability a higher score means better functioning (clinical cut off scores are 31-40 for adaptability); the mTBI had a higher score than the control group which may suggest the control group exhibited less ability to adapt to new situations. Differences between the two groups however were not statistically significant.

Further analysis was carried out to determine any significant differences in the number/proportion of children meeting the clinical cut off scores for the BASC-2 between the groups. The FET test was used as frequency was equal to or below five. The results in table 14 show no significant differences between the number of clinical cases in the mTBI compared with the control group. It must be noted however that when the ‘at risk’ cases are added to the clinical cases the total number of cases (clinical + at risk) is greater in proportion in the mTBI group indexes than the control group.

Table 14

*BASC-2: children above clinical cut off score of 70: n, (%) across indexes*

BASC-2						
		Group				Statistics
		mTBI (n = 22)		Control (n = 22)		
Indexes	<i>n, (%)</i>			<i>n, (%)</i>		<i>FET</i>
		Clinical	Normal	Clinical	Normal	
EXT	2 (9.09)	20 (90.90)		1(4.55)	21 (95.45)	FET = 22.978 , p = 0.318
INT	1(4.55)	21 (95.45)		0 (0)	22 (100)	FET = 23.94, p = 0.303
BSI	2 ( 9.09)	20 (90.90)		1(4.55)	21 (95.45)	FET = 22.23, p = 0.528
ADT	1(4.55)	21(95.45)		0 (0)	22 (100)	FET = 24.50, p = 0.455
		At risk		At risk		
EXT	3 (13.64)			0 (0)		
INT	1 (4.55)			1 (4.55)		
BSI	1(4.55)			1 (4.55)		
ADT	4 (18.18)			0 (0)		
Total cases	15			4		

*Note:* FET = Fishers Exact Test. BASC-2 clinical cut off scores are higher scores that determine greater problems; T-scores over 70 reflect a clinically significant ‘caseness’; while T-scores between 60-69, on the clinical scales reflect children ‘at risk’ with the exception of adaptability which has a low clinical cut off of 31-40.

## **Executive functioning and behaviour**

In terms of aims 1 & 2, the purpose of these analyses was to examine any behavioural manifestations of executive functioning in the context of everyday environments.

A Pearson  $r$  correlation analyses was therefore undertaken between the parent-rated executive functioning measure BRIEF-P, and the parent-rated behavioural measure BASC-2 to ascertain any relationship between the two measures. The mTBI and control group were examined separately to identify any within group differences. It was hypothesised that a positive relationship would exist between executive functioning and behaviour.

Results presented in table 15, did show the control group had significant positive correlations between all BRIEF scales and indexes, and the BASC's EXT, INT and BSI indexes. There were also significant positive relationships between Shift, FLEX, EMI, and GEC and the BASC's adaptability scale.

In contrast, the mTBI shows significant positive correlations between the BRIEF and BASC EXT, INT, BSI indexes with the exception of the BASC adaptability scale, which shows all negative relationships with the BRIEF.

Table 15.

*Pearson's r correlations between BRIEF-P and BASC-2 composites for the mTBI and control group*

Measure	BASC control (n=22)	EXT	INT	BSI	ADAPT
<b>BRIEF</b>					
IH		0.647**	0.416**	.0596**	-0.323
Shift		0.516**	0.772**	0.672**	-0.419*
WM		0.384*	0.398*	0.503*	-0.354
ISCI		0.771**	0.467*	0.714**	-0.350
FLEX		0.834**	0.736**	0.889**	-0.445*
EMI		0.537**	0.451*	0.590**	-0.380*
GEC		0.739**	0.584**	0.741**	-0.409*
Measure	BASC mTBI (n=22)	EXT	INT	BSI	ADAPT
<b>BRIEF</b>					
IH		0.902**	0.671**	0.844**	-0.552**
Shift		0.636**	0.573**	0.699**	-0.436*
WM		0.681**	0.419*	0.686**	-0.707**
ISCI		0.929**	0.751**	0.869**	-0.580**
FLEX		0.796**	0.721**	0.826**	-0.504**
EMI		0.680**	0.459*	0.704**	-0.745**
GEC		0.849**	0.660**	0.851**	-0.665**

*Note:* \* correlation is significant at the 0.05 level (1-tailed). \*\*Correlation is significant at the 0.01 level (1-tailed).

## The SDQ

The SDQ (Goodman, 1997) measures the child's strengths and difficulties summarised into indexes; emotion, conduct, hyperactivity, peer problems, and pro-social behaviour. To determine any significant differences between the two groups' means, an independent t test was carried out.

Table 16

Comparison of child's strengths and difficulties between mTBI and control groups across indexes

SDQ	Group		Statistics	
	mTBI (n=22)	Control (n= 22)	Independent t test <i>t, df, p</i>	Cohens <i>d</i>
	<i>m, (sd)</i>	<i>m, (sd)</i>		
<b>Indexes</b>				
Emotion	2.55 (2.26)	1.91(1.63)	$t(42) = 1.070, p = 0.291$	0.324
Conduct	2.41(2.18)	1.55 (1.44)	$t(36.42) = 1.554, p = 0.129$	0.475
Hyperactivity	4.59 (2.63)	3.86 (2.50)	$t(42) = 0.941, p = 0.352$	0.285
Peer	1.73 (1.70)	1.77 (2.3)	$t(42) = 0.074, p = 0.941$	0.02
Pro-social	7.00 (2.64)	8.09 (2.02)	$t(42) = 1.540, p = 0.131$	0.46

Notes: SDQ = Child strengths and difficulties questionnaire (version: Parent 4-6 years).

The results in table 16 show the mTBI group had higher means for the indexes of emotion, conduct and hyperactivity when compared to the control group. In contrast the control group had higher means in both the peer and pro-social indexes. Trends indicated more conduct problems in children in the mTBI group, and suggested more pro-social behaviour in the control group. It is also interesting that the means show variation from the cut off scores, as per the NZ means by the Ministry of Health; which are E: 2.2; C: 2.5; H: 3.2; P: 2; PS: 8.4. However, there were no statistically significant differences between the means of the mTBI and control groups and only small effect sizes in the emotion, conduct and hyperactivity indexes.

SDQ total difficulty scores range from 0–40. A total score of  $\geq 20$  used to indicate an abnormal total score or 'of concern' score. Previously established abnormal or of concern scores (Mellor, 2005) were used to determine if participants had difficulties in relation to: Emotional symptoms (subscale scores  $\geq 7$ ), Conduct problems

(subscale scores  $\geq 5$ ), Hyperactivity (subscale scores  $\geq 7$ ), Peer problems (subscale scores  $\geq 6$ ), and Pro-social issues (subscale scores  $\leq 4$ , where lower scores indicate difficulties and higher scores pro-social strengths).

Table 17

SDQ: Frequency and percentage of children above clinical cut off scores or 'at risk'

SDQ	Group				Statistics
	mTBI (n = 22)		Control (n = 22)		
	n, (%)		n, (%)		
Indexes	Clinical	Normal	Clinical	Normal	FET
Emotion	1(4.5)	21 (95.45)	0 (0)	22 (100)	FET = 3.09, p = 0.972
Conduct	5 (22.72)	17 (77.27)	1(4.5)	21 (95.45)	FET = 10.21, p = .078
Hyper	5 (22.72)	17 (77.27)	3 (13.64)	19 (86.36)	FET = 7.711, p = 0.632
Peer	0 (0)	22 (100)	3 (13.64)	19 (86.6)	FET = 9.22, p = 0.238
Pro-social	3 (13.64)	19 (86.36)	4 (18.18)	18 (81.82)	FET = 9.589, p = 0.344
Total cases	14		11		

Note: FET = Fishers Exact score. This was used as all frequencies were equal to or under five. mTBI = mild traumatic brain injury. Hyper = hyperactive.

Results in table 17, show a higher proportion of children with clinical 'caseness' in the mTBI group for the indexes of emotion, conduct and hyperactivity, in comparison to the control group. These findings suggest that the children in this group may be less proficient in social and behavioural competence, when establishing relationships with others. The results also found a large proportion of children in the control group had higher means in both the peer and pro-social indexes, indicating they were less proficient in relationships with peers but had an overall strength in pro-social behaviour. An analysis of variance using the FET, however, found no statistically significant differences in the number of clinical cases between the mTBI and control groups.

## **Executive functioning and social and behavioural competence**

A correlation was carried out to determine if the children's behaviours, emotions and relationships (screened using the SDQ) had a relationship with the parental reports of the BASC-2 and BRIEF-P. It was hypothesised that a positive relationship would exist between executive functioning and social and behavioural competence.

Results shown in table 18, found in the mTBI group that all SDQ measures were significantly correlated with the BRIEF indexes with the exception of the pro-social variable and the GEC.

Within the control group, findings indicated that the ISCI was significantly associated with conduct and hyperactivity; as well as the FI and EMI associated with conduct, hyperactivity and pro-social; and the EMI associated with the hyperactivity and pro-social scales. Results also show that within the mTBI group, all SDQ measures were positively associated with all the BASC-2 indexes.

Findings also showed that within the control group, the EXT was significantly related to the hyperactivity and pro-social scales; INT was associated with emotion, hyperactivity, and pro social scales; BSI was related with all SDQ items and adapt significantly correlated with emotion, hyperactivity and pro social scales.

Table 18

Correlation between the parental ratings of the BRIEF and BASC and SDQ measures

SDQ Measure	mTBI (n=22)					Control				
	Emotion	Conduct	Hyper	Peer	Pro-social	Emotion	Conduct	Hyper	Peer	Prosocial
<b>BRIEF-P indexes</b>										
Inhibitory self-control (ISCI)	0.675**	0.810**	0.821**	0.567**	-0.159	0.113	0.589**	0.795**	0.203	-0.783**
Flexibility (FI)	0.669**	0.632**	0.695**	0.649**	0.076	0.321	0.396*	0.667**	0.348	-0.831**
Emergent metacognition (EMI)	0.431*	0.614**	0.750**	0.655**	-0.090	0.035	0.268	0.844**	0.243	-0.500*
Global executive Composite (GEC)	0.602**	0.729**	0.816**	0.658**	-0.080	0.156	0.449*	0.881**	0.273	-0.731**
<b>BASC-2</b>										
Externalising Problems	0.705**	0.860**	0.768**	0.511**	-0.242	0.085	0.308	0.647**	0.323	-0.0667**
Internalising Problems	0.843**	0.570**	0.493**	0.401*	-0.0189	0.492**	0.091	0.484*	0.264	-0.495**
Behavioural Symptoms Index	0.805**	0.758**	0.689**	0.537**	-0.174	0.507**	0.369*	0.716**	0.602**	-0.711**
Adaptive skills	-0.444*	-0.554**	-0.0590**	-0.654**	0.185	-0.426*	-0.271	-0.425*	-0.285	0.544**

Note: \* correlation is significant at the 0.05 level (1-tailed). \*\*Correlation is significant at the 0.01 level (1-tailed). BRIEF-2 = Behavioural Rating Inventory of Executive Function – Preschool version.

BASC = Behavioural Assessment for Children, 2<sup>nd</sup> edition. SDQ = Child strengths and difficulties questionnaire.

### Part three: Parental and Environmental measures

The purpose of aim three was to examine the extent to which executive functioning outcomes could be explained by child factors (age, ethnicity, gender, ses); clinical characteristics around the time of injury (severity of injury, and co-morbid conditions) and both parental and environmental factors such as parental mental health (HADS), the home environment (HOME) and parental support (PCI). The later parental and environmental factors will be presented here.

#### *HADS*

Using an Independent t test, the differences between the mTBI and control groups were compared in terms of the Hospital Anxiety and Depression Scale (HADS), a measure of parental mental health.

Table 19

*A between groups comparison of the HADS anxiety and depression indexes*

Variable		Mean (sd)	Independent t test	Cohens
HADANX24mth	mTBI (n=22)	5.77 (3.741)	$t(41)= 1.346,$ $P= 0.186$	0.420
	Control (n=22)	4.38 (2.974)		
HADDEPP24mth	mTBI (n=22)	3.18 (3.111)	$t(41)= 0.648,$ $p = 0.521$	0.202
	Control (n=22)	2.62 (2.539)		

*Note:* HADS = Hospital Anxiety and Depression Scale. . Effect size computed using calculator from website [www.uccs.edu/ibecker/](http://www.uccs.edu/ibecker/)

The results of the comparison, in Table 19, show the mTBI group had higher means in both anxiety and depression scales when compared with the control group. However, there are no statistically significant differences between the mTBI and control groups in anxiety and depression scale scores.

Significant HADS scale scores or ‘caseness’ are determined by a score of more than or equal to 11. Using a Fishers exact test (FET), a test used to calculate the exact probability of smaller samples, the frequency of ‘caseness’ was calculated.

Table 20

HADS (Clinical 'caseness' – Fishers exact test)

HADS	mTBI (n =22)		Control (n = 2)		Statistics
Variables	Normal n, (%)	Clinical n, (%)	Normal n, (%)	Clinical n, (%)	FET, p
Anxiety	20 (90.90)	2 (9.09)	21 (95.45)	1(4.54)	FET = 9.94, p = 0.72
Depression	21 (95.45)	1(4.54)	21 (95.45)	1(4.54)	FET = 5.11, p = 0.95

Note: FET = Fisher's Exact Test. HADS = Hospital Anxiety and Depression Scale.

The results of this comparison in table 20 show no significant difference in the number of clinical cases between parents of the mTBI and control groups.

### **Executive Functioning behaviours and parental mental health**

The mental health of a parent can interfere with the relationship and interaction between a parent and their child; and although results have found no differences between the groups in terms of parental mental health scores, thus far, the author of this thesis was interested in identifying if there was a relationship between parental mental health, and the executive and behavioural functioning of the child.

The bivariate Pearson's *r* correlation analyses was therefore conducted on both groups between parental behavioural and executive functioning measures (BASC-2, BRIEF-P) and parental mental health (HADS) to investigate any relationship between the measures. It was hypothesised that there would be a positive relationship between parental mental health (both anxiety and depression) and the child's executive and behavioural functioning.

Table 21

Pearson's Correlation coefficients between parent ratings composite scores on the BRIEF-P and BASC-2 and the HADS indexes between the mTBI and control groups

HADS	mTBI (n=22)		Control (n= 22)	
Measure	HADS Anxiety	HADS Depression	HADS Anxiety	HADS Depression
<b>BRIEF-P indexes</b>				
Inhibitory self-control (ISCI)	0.385*	0.350	0.192	0.207
Flexibility (FI)	0.367*	0.184	0.197	0.058
Emergent metacognition (EMI)	0.219	0.192	0.212	0.277
Global executive Composite (GEC)	0.333	0.250	0.253	0.251
<b>BASC-2</b>				
Externalising Problems	0.597**	0.572**	0.217	-.094
Internalising Problems	0.456*	0.333	0.165	-0.060
Behavioural Symptoms Index	0.543**	0.510**	0.302	0.085
Adaptive skills	-0.148	-0.279	-0.285	-0.097

Note: Pearson's  $r$  \* correlation is significant at the 0.05 level (1-tailed). \*\*Correlation is significant at the 0.01 level (1-tailed). BRIEF-2 = Behavioural Rating Inventory of Executive Function – Preschool version. BASC = Behavioural Assessment for Children, 2<sup>nd</sup> edition. HADS = Hospital Anxiety and Depression Scale.

Results shown in table 21, within the BRIEF measure of executive functioning, and the mTBI group correlations, indicate an association between parental anxiety and both child inhibitory self-control (ISCI) and the flexibility (FI) indexes. That is, higher parental anxiety scores are associated with the higher ISCI and FI index scores suggesting children in the mTBI group had difficulty in the regulation of self-control and flexibility or the inability to shift information and regulate emotion.

Results within the BASC-2 measure of behaviour, and the mTBI group correlations found a significant positive relationship between parental anxiety and externalising, internalising and behavioural problems of the child. Indicating higher

scores in parental anxiety are significantly correlated with the child’s hyperactivity, aggression, anxiety, depression, somatisation, and can result in atypicality, withdrawal, and attention problems. Further significant positive correlations within the mTBI and BASC-2 measure found that as well as parental anxiety, parental depression is also related to externalising problems such as hyperactivity, aggression and behavioural problems such as withdrawal and typicality. There were no significant correlations for the control group over both measures.

### Performance-based executive functioning and parental mental health

A Pearson’s *r* correlation analyses was undertaken between the scores on measures of parental mental health and both the object interference and day and night tasks (HADS, CIO, & DN) of which the mean latency correct was used. It was hypothesised that there would be a significant relationship between the child’s performance on task and parental mental health.

Table 22

*A correlation of the HADS, CIO, and DN measures*

HADS	mTBI (n=22)		Control (n= 22)	
Measure	HADS Anxiety	HADS Depression	HADS Anxiety	HADS Depression
<b>COI</b>				
SET A	0.455*	0.488*	-0.002	0.012
SET B	0.445*	0.197*	-0.282	-0.021
Set C	0.700**	0.393	-0.213	0.028
Set D	0.391	0.254	-0.204	-0.087
<b>Day &amp; Night</b>				
Full set	0.426*	0.272	0.351	0.011

*Note:* Pearsons *r* \* correlation is significant at the 0.05 level (1-tailed). \*\*Correlation is significant at the 0.01 level (1-tailed). COI = Colour object Interference task, DN = Day & Night task HADS = Hospital Anxiety and Depression Scale.

Results in table 22 show that, in the mTBI group, there was an association with parental anxiety, and child response, over the three COI conditions. That is, high scores of anxiety for the parent, meant an increase in response time or slower less accurate performance to name a colour in SETs A & B, and more significantly in SET C.

A relationship between child performance on task and parental depression was also significant. Suggesting children in the mTBI group performed poorer in inhibitory and working memory when the parent was anxious and depressed. A significant relationship also existed between the day and night task and anxiety, however no such association was found with depression. An analysis of the control group with both anxiety and depression and both the performance measures of executive functioning found no existing correlations or relationships between the variables.

### **HOME**

The HOME inventory (Caldwell & Bradley, 1984, 2003) measures the quality and quantity of stimulation and support available to a child in the home environment. To examine any differences in the environment between groups an independent t test was used.

Table 23

*Comparison of the HOME means and standard deviations between mTBI and control groups*

HOME-EC	Group		Independent t test	Cohens
	mTBI (n =22)	Control (n = 22)		
Subscales			<i>t, df, p</i>	<i>d</i>
Learning Materials	8.86 (1.67)	9.32 (1.21)	$t(42) = 1.034, p = 0.307$	0.315
Language stimulation	6.23 (1.11)	6.86 (0.35)	$t(25.166) = 2.564, p = 0.017$	0.766
Physical environment	5.95 (1.65)	6.50 (0.80)	$t(30.426) = 1.397, p = 0.173$	0.425
Responsivity	6.27 (1.12)	6.77 (0.53)	$t(29.90) = 1.893, p = 0.068$	0.571
Academic stimulation	4.68 (0.65)	4.82 (0.50)	$t(42) = 0.782, p = 0.439$	0.242
Modelling	3.55 (0.80)	3.86 (0.35)	$t(28.799) = 1.707, p = 0.099$	0.502
Variety	6.41(1.94)	7.14 (.49)	$t(42) = 1.393, p = 0.171$	0.42
Acceptance	3.86 (0.47)	3.95 (0.21)	$t(42) = 0.830, p = 0.411$	0.247
Total Score	46.59 (6.60)	49.23 (3.04)	$t(30.528) = 1.682, p = 0.103$	

Notes: EC HOME = Home observation for measurement of the environment, early childhood version.

Results presented in table 23 show that the mTBI group had lower means across all subscales when compared to the control group. There was a trend towards difference in responsiveness, which describes the level of warmth in the relationship between the child and parent, i.e., response to questions, kisses, and praise; and the subscale modelling. A statistically significant difference was found between the groups in language stimulation suggesting children in the mTBI group had poorer language development than the control group. Medium effect sizes for language stimulation, responsiveness and modelling were also noted.

### **Executive functioning, behaviour and the HOME environment**

The home environment is very important in terms of a child's development, health and wellbeing. A Pearson's  $r$  correlation analysis was conducted between the BRIEF, BASC, and HOME, measures to determine any relationship between executive functioning, behaviour and the home environment. It was hypothesised that executive functioning and behaviour would correlate positively with a favourable home environment.

Results shown in table 24, within the BRIEF measure of executive functioning, found the mTBI group had negative associations between the Inhibitory self-control index (ISCI) and the HOME's learning materials, responsiveness and variety items; the emergent cognition index (EMI) and the HOME's learning materials, physical environment, and variety; and the Global composite score (GEC), and learning materials and the physical environment. It was also found within the mTBI group that the BASC-2 indexes of externalising problems, internalising problems, and behavioural symptoms of the children had a significant negative correlation with learning materials. However, the BASC adaptability index was significantly positively related with the HOME's learning materials, physical environment and variety, suggesting adaptability is associated with stimulation in the home environment.

Table 24

Comparison of parental-ratings and environmental observation for the mTBI group

HOME	mTBI (n=22)							
Measure	Learning materials	Language stimulation	Physical environment	Responsivity	Academic stimulation	Modelling	Variety	Acceptance
<b>BRIEF-P indexes</b>								
Inhibitory self-control (ISCI)	-0.524**	-0.212	-0.267	-0.446*	-0.024	0.201	0.401*	-0.28
Flexibility (FI)	-0.356	0.017	-0.259	-0.181	0.106	0.021	-0.155	0.046
Emergent metacognition (EMI)	0.0394*	0.0130	0.522**	-0.242	0.026	0.101	0.363*	0.137
Global executive Composite (GEC)	-0.461*	-0.138	-0.368*	-0.332	0.034	0.149	-0.351	0.084
<b>BASC-2</b>								
Externalising Problems	-0.490*	-0.087	-0.212	-0.331	0.070	0.144	-0.252	0.029
Internalising Problems	-0.410*	-0.042	-0.206	-0.280	-0.031	0.028	-0.152	0.152
Behavioural Symptoms Index	-0.458*	-0.023	-0.334	-0.330	0.034	0.111	-0.278	0.010
Adaptive skills	0.410*	0.090	0.594**	0.263	0.066	0.150	0.429*	0.187

Note: \* correlation is significant at the 0.05 level (1-tailed). \*\*Correlation is significant at the 0.01 level (1-tailed).

BRIEF-2 = Behavioural Rating Inventory of Executive Function – Preschool version. BASC = Behavioural Assessment for Children, 2<sup>nd</sup> edition. HOME = Home Observation Measure of the Environment.

In contrast the BRIEF results as shown in table 25 for the control group show a negative association between ISCI and the HOME physical environment and academic stimulation; an association between FI and academic stimulation; and both the EMI and GEC and the HOMES learning materials and language stimulation.

Table 25

Correlations between the HOME and parental-rated measures of the BRIEF and BASC.

HOME	Control (n=22)							
Measure	Learning materials	Language stimulation	Physical environment	Responsivity	Academic stimulation	Modelling	Variety	Acceptance
<b>BRIEF-P indexes</b>								
Inhibitory self-control (ISCI)	-0.335	-0.154	-	0.107	-0.393*	-	-0.007	-
Flexibility (FI)	-0.264	-0.039	-0.187	-	-0.465*	-	-0.039	-
Emergent metacognition (EMI)	-0.479*	-	-	.000	-0.314	-	-0.113	-
Global executive Composite (GEC)	-0.432*	-0.300	-0.373	0.012	-0.401*	-	-0.076	-
<b>BASC-2</b>								
Externalising Problems	-0.251	0.005	-0.284	-	-0.629	0.022	-0.234	-
Internalising Problems	-0.031	0.091	-0.213	-	-0.241	0.201	0.056	-
Behavioural Symptoms Index	-0.336	-0.152	-0.313	-	-	0.023	-0.455*	-
Adaptive skills	0.350	0.230	0.301	0.113	0.377*	0.218	0.637**	0.108

Note: \* correlation is significant at the 0.05 level (1-tailed). \*\*Correlation is significant at the 0.01 level (1-tailed).

BRIEF-2 = Behavioural Rating Inventory of Executive Function – Preschool version. BASC = Behavioural Assessment for Children, 2<sup>nd</sup> edition. HOME = Home Observation Measure of the Environment.

Results also show within the BASC measure a positive relationship between the behavioural symptoms and adaptability indexes and the HOME's, academic stimulation and variety items.

A further analysis of the home environment was carried out between the performance-based measures of executive functioning and the HOME, as presented in table 26.

## Performance- based executive functioning and the home environment

Table 26

A comparison between the performance-based executive functioning tests and the HOME

HOME	mTBI (n=22)							
Measure	Learning materials	Language stimulation	Physical environment	Responsivity	Academic stimulation	Modelling	Variety	Acceptance
<b>COI</b>								
SET A	-0.577**	-0.284	-0.266	-0.639**	-0.131	-0.750**	-0.269	-0.382
SET B	0.203	0.461*	0.315	0.129	0.220	-0.024	0.248	-0.017
SET C	-0.134	0.230	-0.082	0.035	0.261	-0.110	0.016	-0.011
SET D	0.057	0.233	-0.277	-0.149	-0.027	-0.239	-0.048	-0.395
<b>DN</b>								
Full set	-0.100	-0.009	-0.164	-0.024	-0.129	-0.123	0.132	0.292
<b>Control (n=22)</b>								
Measure	Learning materials	Language stimulation	Physical environment	Responsivity	Academic stimulation	Modelling	Variety	Acceptance
<b>COI</b>								
SET A	-0.286	-0.317	0.251	0.084	-0.199	0.107	-0.775**	c
SET B	-0.110	0.012	0.326	0.268	0.095	0.184	-0.442*	c
SET C	-0.151	-0.009	0.366	-0.091	-0.192	0.266	-0.296	c
SET D	-0.055	-0.228	0.229	-0.006	-0.168	-0.055	-0.745**	c
<b>DN</b>								
Full set	-0.220	-0.033	-0.553**	0.219	0.143	0.027	-0.314	c

Note: \* correlation is significant at the 0.05 level (1-tailed). \*\*Correlation is significant at the 0.01 level (1-tailed). COI = Colour object Interference task, DN = Day & Night task, HOME = Home Observation Measure for the Environment.

Results in shown in table 26, for the mTBI group, indicated a significant negative correlation between set A and learning materials, responsivity and modelling; as well as with set B and language stimulation. This suggests an increase in learning materials, responsivity, and modelling from the parents was related to the child's ability to be quicker and more accurate on the COI performance-based task. There were however no significant correlations between the measures for the day and night task, and the HOME in the mTBI group.

Results for the control group showed a negative association between Set A, B and D on the COI task with the HOME's variety scale. The Day & Night task results also showed that a significant negative relationship existed between performance on the task and the physical environment.

### *Parent Child Interaction (PCI)*

Ratings from the observed parent –child interaction task were used to provide an insight into the association between environmental factors and mTBI outcomes; specifically between the parent child relationship and the child's executive and behavioural functioning. This analysis therefore compared any differences between the means in the mTBI and control groups using an Independent t test.

The results presented in table 27 show the mTBI group had lower means for facilitation of self-regulation, positive affect, supportive presence and interactional synchrony when compared with the control group. These observations may suggest parents of the mTBI group are less likely to be able to scaffold tasks to enable their child to control their emotions and behaviour, and to be actively and positively engaged in a task with the child facilitating less than competent functioning. In contrast the control group had lower mean scores for negative affect and intrusiveness, but higher means for positive affect and interactional synchrony.

There were statistically significant differences, of medium effect size, between the groups in facilitation of self-regulation and in supportive presence suggesting inhibitory control in children is associated with the level of support from parents.

Table 27

Comparison of the PCI means and standard deviations between the mTBI and control groups

	Group		Statistics	
	mTBI (n = 22)	Control (n = 22)	Independent t test	Cohens
	<i>m, (sd)</i>	<i>m, (sd)</i>	<i>t, (df), p</i>	<i>d</i>
<b>Parent variables</b>				
Positive Affect	3 (0.926)	3.45(0.67)	$t(42) = 1.865, p = 0.069$	0.575
Negative Affect	1.41(0.590)	1.23 (0.43)	$t(38.341) = 1.169, p = 0.250$	0.377
Supportive presence	3.68 (1.211)	4.36 (0.77)	$t(34.397) = 2.265, p = 0.030$	0.772
Facilitation of self-regulation	3.77 (0.612)	4.8 (0.66)	$t(42) = 2.124, p = 0.040$	0.655
Intrusiveness	2.55 (1.224)	1.91(0.97)	$t(42) = 1.910, p = 0.63$	0.589
Interactional Synchrony	3.41 (0.796)	3.77 (0.81)	$t(42) = 1.499, p = 0.141$	0.462

Note: mTBI = Mild traumatic brain injury. Cohens d used calculator from website: [www.uccs.edu/lbecker/](http://www.uccs.edu/lbecker/)

### Executive functioning, behaviour and parent child interaction

A bivariate correlation was conducted between the parent child interaction (PCI) observation and executive functioning and behaviour. It was hypothesised that parent child interaction and parental-rated measures of the BRIEF and BASC would have a significant relationship.

Table 28

Correlation of PCI observations, executive functioning and behaviour in the mTBI group

PC-Interaction	mTBI (n=22)					
	Positive effect	Negative effect	Supportive presence	Facilitation	Intrusiveness	Interactional Synchrony
<b>BRIEF-P indexes</b>						
Inhibitory self-control (ISCI)	0.149	0.090	-0.407*	-0.110	-0.112	-0.181
Flexibility Index (FI)	0.185	-0.072	-0.085	0.009	-0.212	0.023
Emergent metacognition (EMI)	.063	0.245	-0.238	0.057	-0.153	-0.090
Global executive Composite (GEC)	0.139	0.150	-0.302	-0.030	-0.143	-0.112
<b>BASC-2</b>						
Externalising Problems	0.059	-0.074	-0.292	-0.113	-0.041	-0.138
Internalising Problems	-0.042	-0.150	-0.365	-0.295	-0.106	-0.306
Behavioural Symptoms Index	0.147	-0.150	-0.286	-0.174	-0.113	-0.096
Adaptive skills	-0.088	-0.038	0.233	-0.047	0.149	0.134

Note: \* correlation is significant at the 0.05 level (1-tailed). \*\*Correlation is significant at the 0.01 level (1-tailed).

BRIEF-2 = Behavioural Rating Inventory of Executive Function – Preschool version. BASC = Behavioural Assessment for Children, 2<sup>nd</sup> edition. PC Interaction = Parent-Child Interaction task.

Results in table 28, using the BRIEF-P for the mTBI group, show only a significant negative relationship between ISCI and supportive presence. The further comparison with the BASC measure found no significant correlations between the variables within the mTBI group.

Table 29

Correlation of PCI observations, executive functioning and behaviour in the control group

PC-Interaction	Control (n=22)					
	Positive affect	Negative affect	Supportive presence	Facilitation	Intrusiveness	Interactional Synchrony
<b>BRIEF-P indexes</b>						
Inhibitory self-control (ISCI)	-0.169	0.014	-0.081	-0.038	-0.204	-0.241
Flexibility Index (FI)	-0.345	0.179	-0.355	-0.088	-0.128	-0.405
Emergent metacognition (EMI)	-0.081	0.049	-0.099	-0.213	-0.069	-0.368
Global executive Composite (GEC)	-0.171	0.060	-0.160	-0.146	-0.120	-0.370*
<b>BASC-2</b>						
Externalising Problems	-0.338	0.036	-0.187	-0.003	-0.171	-0.350
Internalising Problems	-0.524**	0.458*	-0.305	-0.208	0.083	-0.271
Behavioural Symptoms Index	-0.255	0.138	-0.283	0.074	-0.301	0.326
Adaptive skills	-0.055	0.030	0.133	-0.019	0.219	0.548**

Note: \* correlation is significant at the 0.05 level (1-tailed). \*\*Correlation is significant at the 0.01 level (1-tailed).

BRIEF-2 = Behavioural Rating Inventory of Executive Function – Preschool version. BASC = Behavioural Assessment for Children, 2<sup>nd</sup> edition. PC Interaction = Parent Child Interaction.

Results in table 29 for the control group show the BRIEF's GEC and the interactional synchrony to be negatively correlated. There was also a significant negative relationship between the BASC index INT and positive effect. A significant positive relationship also existed between the BASC adapt index and parental interactional synchrony of the parent child interaction task, suggesting an increase in child adaptability was associated with a positive parent child relationship. A positive relationship was also found with both internalising problems and negative affect, suggesting an increase in parental negative affect was associated with more internalising problems in the child.

## Summary of findings

Sample characteristics which included a mother's health during pregnancy and the child's health history were examined to understand if these factors contributed to increased incidence of mTBI in children. The frequency of medical and health problems were found to be higher for the mTBI group, perhaps indicating these problems during and after birth may contribute to a higher likelihood of sustaining a mTBI in a child's life.

In part one, the BRIEF was used as a measure of executive functioning to determine any differences in both scales and indexes between the two groups, as well as the frequency of clinical cases as determined by FET and CHI tests. Across all measures there were no statistically significant differences between the groups.

A correlation conducted between the performance-based measures of the COI and DN, and the parent-rated measure of executive functioning (BRIEF) however found a significant relationship between inhibitory control and shift in colour naming in SET A in the mTBI group and significant associations in SET C with all three variables (inhibitory control, shift and working memory).

A post hoc analysis of child estimated IQ using the performance-rated measure of the WPPSI-III found no statistically significant differences between the mTBI and control groups.

In part two, the BASC-2 was used as a measure of behaviour and emotional functioning, to determine any differences in the indexes between the two groups as well as in the frequency of clinical 'caseness', as determined by FET and CHI tests. However, neither analysis showed any statistically significant differences between the groups.

The parent-rated measure of a child's behavioural strengths and difficulties (SDQ) was also used to determine any differences between the groups. However there were no significant differences between the groups as well in the number of clinical cases between the groups. A further correlation analyses between the SDQ, BRIEF and BASC was also conducted to determine any relationship between the measures. It was found in the mTBI group all SDQ scales associated with the BRIEF indexes with the

exception of the pro-social variable and GEC. Results also indicated that all SDQ measures within the mTBI group were associated with all BASC indexes.

In Part three, an examination of parent-rated measures of parental mental health (HADS), the home environment (HOME), executive functioning (BRIEF) and behaviour (BASC) were conducted to ascertain any differences between the groups on each measure and to identify any significant correlations between the measures.

An analysis of the HADS found no significant differences in the means between the groups either in depression or anxiety, or in the frequency of clinical 'caseness'. A correlation analyses however, between the performance-based executive functioning measures (COI & DN) and the HADS found there was a significant association between parental anxiety and child response over the three COI conditions, and also with child performance on task and parental depression in the mTBI group. A significant relationship also existed between the D&N task and anxiety of the parent, however no such association was found with depression.

The HOME measured the quality and quantity of stimulation and support available to a child in the home environment. Results found a significant difference between the two group's means in the subscales of language stimulation and a trend towards difference in responsivity and modelling and a medium effect size. Further correlation between the HOME, and parental-rated measures of the BRIEF and BASC, found in the BRIEF an association between the inhibitory self-control scale and emergent cognition indexes, and the HOMEs learning materials, physical environment and variety, this suggested that the mTBI group's executive functioning was better when they were sufficiently stimulated by their environment. Further results from the BASC also found positive associations with the HOME, meaning there was a relationship between a child's executive functioning and behavioural symptoms and a safe, supportive and stimulating environment. Lastly a correlation of the performance-based measure of EF (COI & DN) and the HOME was conducted, and it was found in the mTBI group significant negative correlations between Set A and learning materials, responsivity and modelling as well as in set B with language stimulation. There were no significant correlations between the measures for the D&N task and the HOME.

The last measure, an observation of parental child interaction (PCI) was used to analyse the association between interactional synchrony and the BRIEF, and BASC

measures. Results found a significant relationship in the mTBI group, between the Inhibitory self-control index (ISCI) in the BRIEF and supportive presence in the PCI. Significant correlations were also found in the control group between the BRIEF's GEC and the PCI interactional synchrony and between the BASC index INT and both positive and negative effect. A significant positive relationship also existed between the BASC adapt index and parental interactional synchrony of the parent child interaction task suggesting child adaptability was related to a better parent child relationship.

## DISCUSSION

### Main purpose

The main purpose of this study (aim 1) was to determine whether mTBI injury in pre-school children had an effect on their normal cognitive development, specifically executive functioning and the sub domains of inhibitory control and working memory (switching/processing speed/accuracy/fluency) 24 months post injury compared with an age-matched control group. The analysis included using the BRIEF parent-rated behavioural questionnaire, and two EF performance-based Stroop type tasks. A further measure of IQ (WPPSI-III) was also utilised to provide a comprehensive test battery of overall cognitive functioning.

Behavioural functioning was also examined in terms of its relationship to EF (aim 2), and specifically comparing the internalising and externalising behaviours and adaptability indexes of the BASC-2 between the two groups. Examination of behavioural functioning also included the associated social and emotional outcomes (emotion, conduct, hyperactivity, peer, pro-social) therefore the SDQ measure considering these outcomes was implemented.

Lastly factors that may contribute or be predictive of risk of injury were explored (aim 3), specifically age/maturation of the brain/state of development, and both parental/environmental factors measuring parental mental health (HADS), the home environment (HOME), and parent child synchrony (PCI).

It was hypothesised in aim 1 that preschool children in the mTBI group would be characterised by deficits in executive functioning particularly in the regulation of impulsion, or the inability to inhibit, and/or control impulsive behaviours, have difficulty in holding their attention, and have a low speed of processing, manifest with behavioural difficulties. That is, performance on EF tasks would be poorer, and parent-rated scores would indicate more EF problems than those of their peers. Further correlation between the measures would also predict that parent-rated scores of the BRIEF-P would be significantly related to the child's performance on the two EF tasks. That is, low scores on inhibitory control, shift or working memory would be significantly associated with poor performance on the EF tasks.

Aim 2 explored these behavioural manifestations further, and hypothesised that children in the mTBI group would be characterised by deficits in both emotional and behavioural domains, particularly in externalising and internalising behaviours and adaptive skills. That is, parent-rated scores on the BASC-2 and SDQ would indicate more behavioural/emotional problems for the mTBI group than those of their peers. This would also be apparent in the number of mTBI clinical cases (or scores above cut off range) examined in the BASC-2 and SDQ measures. Further correlation between the measures would also predict that the parent-rated scores of the BASC-2, BRIEF-P, and SDQ would be significantly associated with the scales and indexes of EF and both behaviour and emotion. That is EF and behaviour would be significantly correlated with the child's emotional strengths and weaknesses (emotion, conduct, hyperactivity, and both peer and pro-social behaviours); i.e., a decrease in inhibitory self-control would mean an increase in hyperactivity.

Thirdly in aim 3, it was hypothesised that children with mTBI and the adverse developmental outcomes would be significantly associated with the parental and environmental factors; such as parental mental health (HADS), the home environment (HOME) and parent-child interactional synchrony (PCI). These factors would be examined in relation to the children's performance on task and their behaviour. In particular, it was predicted that higher parental mental health scores in either/both anxiety or depression on the HADS measure would be significantly associated to an increase in executive dysfunction (inhibitory self-control, flexibility) and behavioural problems (externalising, internalising, adaptability) in the child. It was also predicted higher parental mental health scores would mean a decrease in performance on the EF tasks. In relation to the HOME measure it was predicted that lower scores on this observation sheet would mean an increase in both EF dysfunction and behavioural problems. Lastly it was predicted that higher scores on the PCI measure (for positive effect, supportive presence, facilitation of self-regulation, and interactional synchrony) related to a better quality of interaction between the parent and child and thus a decrease in both EF dysfunction and behavioural problems in the child.

As the results showed in the previous section, the hypotheses presented in aim 1, which posited that children with mTBI would present with more executive functioning skill deficits than their matched peers was not supported. There were also no significant differences in the parent-rated measure of executive functioning (BRIEF) main

composite scores between the mTBI and control groups, as well as in the frequency of clinical cases. This finding is consistent with Babikian et al (2011) who reported no declines in health outcomes or long term deficits in both cognitive and behavioural functioning when compared to moderate or severe injuries. However, it was noted that the mTBI group had higher mean scores across all scales and indexes (particularly inhibitory control – IH & Inhibitory self-control index -ISCI), as well as having a higher percentage of clinical cases in the IH, ISCI and flexibility (FLEX) scales and indexes in contrast to the control group. These trends are highlighted as these assessments were conducted 24 months post injury, and it is more likely, issues in the area of executive functioning may become more evident over time. This notion is supported by Barlow, 2010, and Yeates, 2009 who highlighted residual persistent post-concussive symptoms present in mTBI groups when compared to other injury groups.

Aim 1 also hypothesised that children in the mTBI group would exhibit a low speed of processing, have an inability to hold information in mind, and be impulsive on performance-based tasks. These notions consistent with Anderson, (2001), and Catale, (2009) who found neurocognitive deficits with memory, attention and language specifically in children following a mTBI. Although both Stroop effects (in the COI) were observed in the mTBI group, that is; there was a faster more accurate performance in naming the objects than for naming the colours; and there was slower less accurate responding for naming colour in the incongruent condition than the congruent and abstract conditions; across both Stroop effects, again the hypotheses was not supported as there were no statistically significant differences between the groups. Although this performance-based measure found no significant differences however it does support the notion that children of this age range (see Robinson, 2010 & Prevor & Diamond, 2005), are less likely to inhibit their prepotent response to say what the object is rather than its colour.

A further performance-based measure of executive functioning also highlighted that age is factor in performing the Day & Night task; younger children having more difficulty at inhibiting their impulsion (verbal response), whilst remembering two rules and keeping them in mind, particularly those between the ages of 4 years and 4 years 5 months (Gerstadt, et al., 1994) again, however this measure found no significant differences between the two groups. Lastly it was also highlighted in the introduction that both parent-rated and performance-based measures of executive functioning are

required to present a comprehensive assessment of EF, this was explored in the correlations of the BRIEF and both EF performance based measures of COI and DN; and as predicted found significant relationships in the mTBI group in terms of inhibitory control, working memory and the ability to shift information and the mTBI group's performance on the tasks.

In aim 2, it was hypothesised that children in the mTBI group would be characterised by deficits in both emotional and behavioural domains particularly in externalising and internalising behaviours and adaptive skills. This notion consistent with McKinlay et al (2009), Chapman (2010) and Yeates et al, (2005), whose studies suggested both increased externalising and internalising behaviour up to 30 months post injury, within moderate to severe TBI groups in children under the age of seven. This hypothesis however was not supported as the BASC-2 measure results of behaviour and emotional functioning, and its associated clinical caseness found no statistically significant differences between the groups. Likewise in the examination of the SDQ, no significant differences were found between the groups in terms of emotion, conduct, hyperactivity, peer and pro-social behaviour, as was the case with the number of clinical cases. However, the prediction that a positive relationship between EF and behaviour would be significantly correlated with the child's emotional strengths and weaknesses (of the SDQ) was substantiated. This finding consistent with Taylor (2002), and McKinlay (2009), who found behavioural problems that involve the inability to self-regulate and inhibit behaviour are associated with executive functioning and lower competence by parent-report with poorer adaptive functioning and lower academic performance.

Aim three hypothesised that environmental factors of parental mental health, the home environment and parent child interaction would contribute or be predictive of executive functioning in children. The measure of parental mental health (HADS) which measured the existence of any anxiety and depression found no significant differences between the groups and in terms of clinical caseness. However when the HADS was correlated with the EF measure BRIEF-P and BASC-2, the measure of behaviour and emotions, an association between parental anxiety and child performance (in inhibitory control and flexibility) was found in the mTBI group. This was consistent with Mangoet et al (2002), study which found parental psychological stress (predicted by the BRIEF-P) was strongly related to measures of emotional and behavioural adjustment and adaptive

behaviour in children. A significant positive relationship was also found within the BASC-2 and HADS in terms of parental anxiety and both externalising and externalising behavioural problems in the child such as hyperactivity, aggression, and attention. Further analysis within the mTBI group also found an association between parental depression and externalising problems. Performance on tasks and parental mental health was also analysed; as predicted there was a significant relationship with both parental anxiety and depression and the child's performance on the COI task. This finding was consistent with Hughes, Hart and Ensor (2013) who found children who were exposed to higher levels of parental depression were more likely to exhibit poorer performance on EF tasks than their peers.

In the introduction it was also highlighted that the home environment can be a factor in the development of the child pre and post injury. The HOME observation form found the mTBI group had lower means for all subscales; results showing a significant difference between the two groups in the subscale language stimulation and a trend towards responsivity and modelling. A further investigation highlighted the association between the measures of EF, behaviour and the home environment in the mTBI group and as predicted found an overall relationship between learning materials in the home environment associated with both externalising and internalising behavioural problems and inhibitory self-control and emergent cognition. This finding is consistent with developmental research which implicates that parenting and the family environment can determine social functioning in children (Parker, et al 1995; Yeates, 2004). The Home environment (HOME) and EF performance based tests (COI & DN) also found associations between processing speed, and accuracy, and learning materials, responsivity and modelling in the mTBI group in the COI. This is also consistent with Ewing-Cobbs, Barnes, & Fletcher (2003) that within paediatric TBI populations, problems with cognitive processing, particularly verbal and performance skills are associated with the learning environment. There were no significant correlations between the measures for the D&N task and the HOME.

The parent child interaction analysis found a significant difference between the groups in terms of facilitation of self-regulation, and supportive presence in the mTBI group suggesting inhibitory control in children was associated with the level of support from parents. Again this was consistent with Mangeot et al (2002), and Yeates (2004) who found that the family plays an important role in influencing social outcomes

following paediatric TBI. Further correlation analysis found only a significant negative relationship between ISCI and supportive presence. That is a decrease in supportive presence lead to an increase in inhibitory self-control in the child.

### **Strengths & Limitations**

As mentioned in the introduction there are many discrepancies in the methodology of studies examining TBI. Although, these discrepancies can be accounted for through the utilisation of three core components: standard definitions, standard methods/measures and standard data presentation (Theadom, et al., 2012).

Given this area of discussion, the limitations in this study would be in the areas of population size (n=44); whereby the sample was not sufficient enough to carry out regression analyses which would allow a better investigation of the roles of various factors in outcomes. Secondly, the comparison group, although matched by age, gender, and geographical area were recruited on a voluntary basis, and eligibility did not exclude any premorbid conditions (apart from mTBI). This perhaps was further exacerbated by information given to possible participants which offered feedback on their child's executive functioning; that is parents who were either worried about their child's development or wished to measure their child's overall ability were more likely to take part in the study, which meant the comparison group was not representative of the general population. Lastly, the observation inventory the HOME, of which the information was obtained by observation and informal interviewing, was found to be out-dated and as such did not provide a comprehensive picture of environment. The HOME that is, did not contain any questions in the categories of 'learning materials' and 'language stimulation' on technology such as computers, laptops or tablets; the HOME only referring to the ownership of books and subscribing to newspapers as positive stimulation in home environment.

Strengths in methodology are evident in that the current study has identified a specific age range that of pre-schoolers aged 0-5 years. Of this age range there are specific age related measures that can be used within this time frame, as well as later in the 'school' years, to follow development and subsequent skill attainment, such as the BRIEF, BASC, and SDQ which have sequential age band versions available. The

current study main strength however, was that it was also part of the longitudinal sub-study COBIC, which used the same methodology from the population based BIONIC study previously mentioned in this thesis.

### **Future Studies**

As highlighted throughout this thesis, longitudinal studies of mTBI in preschool children are low in number, particularly those which follow a child over a period of five years. To better understand the maturation of the brain, the developmental stages of a child and the impacts of mTBI, study in this preschool age group and severity need to be followed over time to ascertain the persistent outcomes over the domains. Future studies need also to consider the categories within the mild severity category for a more sensitive account of the consequences of mild traumatic brain injury in children. This more sensitive approach will include rather than exclude children who may have otherwise ‘slipped through the cracks’ due to sub-standard criterion, and provide them with the intervention they require.

The area of executive functioning in preschool children was also highlighted in this study, and it was acknowledged that EF skills are rapidly developing during the pre-school period, particularly between the ages of 2-5 years. In terms of these skills, an approach which utilises both parent-rated as well as performance-based measures of EF has been invaluable, and it cannot be stressed enough that a comprehensive battery of standardised, age appropriate measures and tests that are valid and reliable is essential to establish the actual outcomes of TBI as a whole.

### **Clinical Implications of the study**

This study found that indeed mTBI does have consequences on executive functioning, as evidenced by EF, behavioural/emotional measures and performance based tests analyses. That is, children who have sustained a mTBI experience both externalising and internalising problems as well as poorer adaptability which in turn manifest as inappropriate social interactions and poor performance in executive

functioning tasks. The implications of these impairments are evident in the future attainment of skills and the retention of current skills in children, affecting not only themselves, but their families, communities, and society at large.

## **Conclusions**

It has been emphasised that assessment of children is problematic, and that methodological discrepancies affect the measurement of outcomes. The hypotheses tested in this study which have analysed any differences between mTBI children and non-injured children, have not been supported, although correlations between both parent-rated, and performance-based measures of EF and behaviour, emotion and social domains have shown positive relationships consistent with current research.

This may suggest children with mTBI assessed at only one time point is not sufficient to measure a 'real' account of cognitive, executive, behavioural, social and emotional outcomes. That is, children who have sustained an injury at 2 years of age, and have been assessed 24 months post injury, are going through rapid development, and thus manifestations of problems may not be apparent for some time (Carrol, et al , 2004). This reinforces the need to follow children specifically with a mTBI, over time, and to use a developmental framework and longitudinal population-based design incorporating data from a number of sources.

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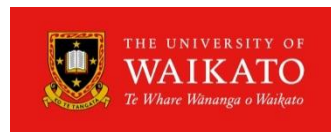
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## APPENDICES

## Appendix A



### **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 1<sup>st</sup> March 2010 and 28<sup>th</sup> February 2011.

OR

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

We are asking for your consent (as their parent/proxy) for your child to take part. We will talk to your child directly and we would also like to ask you some questions about your child's behavior and wellbeing as well as 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 session/s 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 behaviour 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 (3 gifts or \$60 in total).

### **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 16<sup>th</sup> birthday in a secure place at the University of Waikato. All computer records will be password protected. All future use of the information collected will be strictly controlled in accordance with the Privacy Act.

### **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](mailto:advocacy@hdc.org.nz).

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

### **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](mailto: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.*

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

This 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

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

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 B



### 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:     
d d m m y y

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