The Prenatal Effects of the Christchurch Earthquake on Executive Function at Five Years of Age

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Erin M. Dobson

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Abstract

Despite the frequency of earthquakes, particularly in New Zealand, little is known about the long-term effects that they can have on vulnerable populations, such as mothers and unborn babies. This study looks at the way in which a major earthquake can impact on neurodevelopment, specifically the executive function (*EF*) abilities of children five years following the disaster. The aims of this study were to determine if prenatal earthquake exposure had an effect on EF, to determine how timing of exposure influenced EF, if there were different EF outcomes for boys and girls, and how maternal perceptions of severity influenced the child's EF. Children from two groups (mothers from Christchurch who experienced the earthquakes and mothers from Dunedin and Timaru who did not) had their EF measured by a self-administered parent questionnaire, the Behaviour Rating Inventory of Executive Function Second Edition (BRIEF 2). Maternal demographics and earthquake severity experiences were gathered through a second self-administered questionnaire. This study found that children who prenatally experienced the earthquake had significantly worse scores on the measures of emotional control and emotional regulation than the standardised average provided by the BRIEF 2. Exposure during the third trimester was associated with the most significant increases in EF compared to children exposed during the second trimester and the standardised average. In addition to emotional control and emotional regulation difficulties, Christchurch boys also exhibited significantly higher scores on the Shift scale. Results also showed that the worse someone close to the mother was injured, the higher the child's scores on the Inhibit, Organisation, and Emotional Control scale, and the Behaviour Regulation index (BRI) were. Also, children of mothers who reported more significantly injuring themselves in the earthquake had higher Emotional Regulation (ERI) scores. Children whose mothers reported being overall extremely stressed by the earthquake had the largest mean difference in emotional control and ERI scores compared to the standardised average. Despite the small group sizes and continuing aftershocks the variations in trimester and maternal perception of stress indicates that prenatal exposure to a natural disaster does impact EF.

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Chapter 1: Introduction

Natural disasters occur regularly throughout the world and significantly disrupt the communities in which they occur. They cause displacement, financial loss, injuries, and death. Although natural disasters occur every year in different places all over the world, little research has been conducted on the long-term effects on the children who experience them, especially the children *in utero* for the disaster. This study will begin to fill that gap by looking at the children in Christchurch who prenatally experienced the devastating earthquake on the 22nd of February 2011. Five years after the earthquake these children are beginning school and developmental consequences may be apparent. Within the education community in Christchurch there is increasing concern that children beginning school are suffering more issues than children in the past (O’Callaghan, 2016). These children are reported to be displaying more volatile and aggressive behaviour, poor communication skills, uncontrollable behaviour, and clinginess. It has been reported that these children seem to be exhibiting the same two-year educational delays that have been seen following other natural disasters, such as Hurricane Katrina in the United States (O’Callaghan, 2016). This topic was selected for this thesis research because of my involvement in the education community in Christchurch. This has given me access to anecdotal evidence of concern for Christchurch children. Teachers and parents have made various comments regarding the behaviour and schooling of this cohort of children and there is a lack of understanding as to why some these children seem more difficult than same aged children who have been taught in previous years.

On the 22nd of February 2011 Christchurch was struck by a magnitude 6.3 earthquake, which killed 185 people and left several thousand injured. The following day the New Zealand government declared a national state of emergency. Within three days 75% of the city's electricity was restored. However, water and sewerage systems took much longer to restore, with some areas that were affected by liquefaction taking several years to fix. Six years on many homes are still in the process of being repaired or rebuilt. It is estimated that around 70,000 people left Christchurch in the weeks after the earthquake due to uninhabitable homes, lack of basic services, and constant aftershocks (McSaveney, 2014). Research shows that earthquakes cause major psychological and physiological stress for individuals in the community (Fuller, 2014). Earthquakes have been associated with changes in both adult and child brain functioning and increases in reports of distress and anxiety immediately following the disaster (Torche, 2011).

Short-term effects of earthquakes, such as those mentioned above, are well documented throughout history, however much less is known about the long-term effects of natural disasters. Recent research has demonstrated that natural disasters may be especially detrimental to vulnerable populations, such as the developing foetus (Fuller, 2014). Several studies have shown the negative effects of prenatal exposure to natural disasters on birth outcomes and complications such as preterm birth, shorter gestation periods and lower birth weights (Dancause et al., 2011; Simeonova, 2011; Torche, 2011), behaviour concerns in young children (King, Dancause, Turcotte-Tremblay, Veru, & Laplante, 2012), and school outcomes (Fuller, 2014). Prenatal exposure to natural disasters has also been associated with significant increases in psychological symptoms associated with psychiatric disorders such as depression and schizophrenia and developmental disorders such as autism and ADHD in children (Huizink et al., 2007; Huttunen & Niskanen, 1978; Watson, Mednick, Huttunen, & Wang, 1999). These studies have also shown that timing of exposure plays an important role in the outcomes for the children with exposure during the first trimester resulting in higher rates of negative birth outcomes (Dancause et al., 2011; Torche, 2011), lower cognitive functioning (King & Laplante, 2005), and more behaviour problems early in life (Laplante, Zelazo, Brunet, & King, 2007). However, these previous studies do not look at the effects of natural disasters on more subtle neuropsychological development, such as executive function (EF). This current study will add to the literature on natural disasters by investigating the effects of prenatal experience of natural disasters on EF five to six years later, and provide us with a New Zealand perspective on the effects.

It is difficult to explore the effects of prenatal maternal stress, as the maternal stressor can be associated with the mother's temperament, the baby's development, or with household characteristics, such as socioeconomic status (Dancause et al., 2011). The Christchurch earthquake provides the opportunity to investigate the impact of an independent stressor on EF. Earthquakes act as a natural experiment by randomising the distribution of stress exposure (King et al., 2012; Torche, 2011). Therefore, studying the impact of natural disasters provides a means to distinguish between the effects of maternal stress on the foetus and other factors that influence the child (King & Laplante, 2005). This relies on the assumption called exclusion restriction (Angrist, Imbens, & Rubin, 1996), meaning there are no other paths of affect, other than stress, where exposure to a significant earthquake has an adverse effect on EF. In this study disasters are categorised by "a disruption exceeding the adjustment capacity of the affected community" (Lechat, 1979, p. 11).

Current gaps in the literature

There is a growing body of literature surrounding the effects of natural disasters on the children who experience the event prenatally. Most of the research investigating prenatal effects of natural disasters focuses on birth outcomes (Dancause et al., 2011; Glynn, Wadhwa, Dunkel-Schetter, Chicz-Demet, & Sandman, 2001; King et al., 2012;

Simeonova, 2011; Torche, 2011; Torche & Kleinhaus, 2012; Xiong et al., 2008), or outcomes early in life, such as the first two years (Davis et al., 2007; Davis & Sandman, 2010; King & Laplante, 2005; Laplante et al., 2007). However, none of the previous research has investigated the effects on overall EF, rather studies have looked at specific aspects of EF, such as behaviour related to one EF component (King et al., 2012; Weinstock, 2008). Finally, no research has been carried out in an Oceania context, resulting in a significant gap in our understanding of long-term consequences of prenatally experiencing natural disasters in New Zealand. This study looks to extend current research by investigating the effects of prenatal exposure to the Christchurch earthquakes on EF five years following the disaster. This research will fill a gap in the existing literature, while providing information for communities and government in the event of a natural disaster.

Research aims

The aim of this research is to explore the relationship between prenatal exposure to the Christchurch earthquake and EF five years later.

The specific aims are to determine:

1. Whether EF development of Christchurch 5-year-olds is related to prenatal exposure to the Christchurch earthquake.

2. Whether the prenatal timing of exposure to the earthquake influences the effects on EF.

3. Whether there will be a difference in EF relating to the gender of the children.

4. Whether mother's perceived earthquake stress is related to the child's EF.

The next section reviews past literature on the prenatal effects of natural disasters on EF, behaviour, cognitive and language processing, and birth outcomes. The paper then proceeds with a description of the methods, results, and a discussion of the findings.

Chapter 2: Literature review

Natural disasters, such as the Christchurch earthquake, place great stress on communities and the individuals exposed to the disaster. The lack of access to basic amenities and continuing aftershocks create stress, which may influence the health and development of the foetus. The stress experienced by pregnant mothers may have a lifelong effect on the children (Laplante, Brunet, Schmitz, Ciampi, & King, 2008). An important aspect of pre-natal influences is the effect of timing of exposure, with those exposed at different points during pregnancy differently influenced. Typically, timing is divided into pregnancy trimesters: first (weeks 1 to 12), second trimester (weeks 13 to 27), and third trimester, (weeks 28 to birth). Second trimester exposure to severe stress and natural disasters typically results in more significant effects (Fuller, 2014; King & Laplante, 2005; van Os & Selten, 1998). Pre-natal influences may result in subtle neuropsychological developmental differences such as EF. Therefore, children prenatally exposed to an earthquake may have a different EF profile than their unexposed peers. There appears to be no research reported on the effect of earthquakes on developmental outcomes.

Theoretical Framework

The foetal origins hypothesis emphasises the role of environmental conditions before birth and the way in which these conditions can result in long-term changes to development (Fuller, 2014). The prenatal period involves a significant amount of neurodevelopmental changes and is therefore a period of vulnerability. A range of exposures, such as smoking, nutrition, and stress have been found to result in long-term changes to brain development and behaviour of the foetus (Kinsella & Monk, 2009). According to the foetal origins hypothesis negative influences, such as high levels of stress, occurring during sensitive periods of foetal development result in the foetus adapting and making enduring changes that could provide immediate survival at the expense of long-term health and development (Fuller, 2014).

The life cycle model of stress places emphasis on the timing of exposure to an environmental event. According to this model adverse life events have different effects depending on which area of the brain is undergoing change when the adverse event occurs (Lupien, McEwen, Gunnar, & Heim, 2009). The hypothalamic-pituitary-adrenocortical (HPA) axis, autonomic nervous system (ANS), and immune-inflammatory system are all involved in mental health, where mental health is referring to a variety of human functions from cognition, behaviour, temperament, and personality to mental disorders such as depression and schizophrenia. These systems could be susceptible to adverse prenatal events, such as natural disasters and severe stress, as the hippocampus, the frontal cortex, and the amygdala are undergoing significant development during the foetal period (Raikkonen, Pesonen, Roseboom, & Eriksson, 2012). Although there is no defined area of the brain that EF can be attributed to, it is widely agreed that executive functions are primarily mediated by the frontal lobes, but it is also associated with other brain regions including subcortical structures and thalamic pathways (Jurado & Rosselli, 2007). Therefore, the particular stage of foetal brain development at which exposure to a maternal stressor occurs could be particularly important for the development of EF, and exposure to a maternal stressor during these crucial periods could influence the child's EF abilities.

Executive Function

Executive functions are a set of higher order cognitive processes that are crucial for behavioural and cognitive regulation (Alvarez & Emory, 2006). Although there is a lack of universal agreement on the definition of EF, many developmental studies (Huizinga, Dolan, & van der Molen, 2006; Lehto, Juujarvi, Kooistra, & Pulkkinen, 2003; Miyake et al., 2000) broadly define EF as including inhibition, cognitive flexibility, and working memory, which is the structure adopted for the purpose of this study. These components of EF develop and are measurable from an early age (Anderson & Reidy, 2012), making them relevant for this study of EF in five year olds. EF is considered to be very important for complex human behaviour, and problems in EF are associated with behavioural or psychiatric deficits (Biederman et al., 2004).

Inhibition refers to the ability to stop one's own behaviour, thoughts and responses when necessary (Best, Miller, & Naglieri, 2011; Miyake et al., 2000). This is important for learning and for completing tasks, as children who have difficulties with inhibition are often impulsive and struggle to control their own behaviour (Dowsett & Livesey, 2000). Inhibition also refers to the ability to control one's own emotions (Best, Miller, & Jones, 2009). Working memory is the capacity to retain information in an accessible state, for manipulation, in order to complete a task. This construct involves the control and monitoring of incoming information in regards to relevance and replacement of old information with more relevant information (Huizinga et al., 2006). It also involves the ability to evaluate one's actions and manipulate data, such as updating rules and depends on the development of inhibitory behaviour (Best et al., 2011). Cognitive flexibility is sometimes referred to as shifting, as shifting is the behaviour that exemplifies cognitive flexibility. Cognitive flexibility refers to the ability to shift between tasks and response sets, to change one's course of action when necessary, learn from mistakes, and produce alternative behaviour (Anderson, 2002; Miyake et al., 2000). An aspect of cognitive flexibility is adapting when activities or procedures are changed and the subsequent adaption to the new demands. Children who cannot do this often repeat the same behaviour and continue to make the same mistakes or break the same rules (Anderson, 2002). Refer to table 1 for examples of behaviour associated with problems in EF components (Gioia, Isquith, Guy, & Kenworthy, 2015).

Table 1. How EF problems in children could appear to others

EF component	What problems with this component may look like in children
Inhibition	• May blurt out comments when others are talking, i.e. on the mat • May start a task before hearing all the instructions • Struggle to control their emotions • May over-react to small problems, i.e. cries easily
Working Memory	• Have trouble remembering and following instructions • Can't remember a short sequence of numbers • Child constantly raises hand to answer questions but can't remember the answer when called on
Cognitive Flexibility	• Will stick with a plan, even when it's obvious that the plan is not working • May get frustrated if asked to change their approach • Can solve a problem one way but have trouble when asked to show working using a different approach

The impact Executive function has on education. Research has shown that problems in EF can result in learning and behavioural difficulties (Mazzocco & Kover, 2007). The qualities that are considered important for academic success, such as; self-control, self-discipline, creativity, flexibility, are EF related behaviours, therefore, when these are impaired children's learning is also impaired. Research has shown that EF is more important for beginning school than IQ and can continuously predict reading and maths capabilities throughout a child's school career (Best et al., 2011). Preschool EF is more predictive of school success than preschool academic achievement (Bull, Espy, & Wiebe, 2008). Additionally, EF has been associated with academic success for children of all ages, both with and without learning disabilities (Best et al., 2011). Longitudinal studies indicate that EF contributes to academic achievement rather than academic achievement contributing to EF (Best et al., 2011).

Components of EF, such as inhibition and working memory, are consistently associated with achievement in mathematics and reading, while shifting is not always associated with academic achievement (Blair & Razza, 2007). Problems in inhibition, working memory, and cognitive flexibility have been associated with impairments in mathematics, independently of IQ (Bull & Scerif, 2001). Similarly, impairments in working memory and inhibition have been associated with problems in reading and writing (Altemeier, Jones, Abbott, & Berninger, 2006). For children aged six to nine better inhibition was associated with fewer externalizing behaviour problems one year later, but was not associated with their behaviour at the time of measurement. This suggests a developmental lag, where it is likely that the cognitive capacity for inhibition develops earlier than the external behaviour patterns associated with it (Riggs, Blair, & Greenberg, 2003).

It is highly likely that children's emotional regulation can influence a child's school adjustment (Graziano, Reavis, Keane, & Calkins, 2007; Shields et al., 2001). When children can deal with frustration they are more able to adapt to the structure of the classroom and follow the rules within the classroom (Graziano et al., 2007). Emotional regulation has been positively associated with teacher and parent reports of academic success, productivity at school, and standardised maths and literacy scores. Kindergarten aged children who have age appropriate emotional regulation skills are better able to handle the shift in environment and rules that come with the transition to the school environment compared to those children who exhibit poor emotional regulation skills (Graziano et al., 2007). Children who have more emotional control tend to be viewed by teachers and peers more favourably and are seen as easier to get along with (Shields et al., 2001). Teachers tend to have a more positive view of children with good emotional regulation skills compared to children who have poor emotional regulation skills. This may be because teachers see children with poor emotional regulation as harder to manage than children with good emotional regulation as they can monitor their own behaviour in the classroom (Graziano et al., 2007).

The impact of maternal stress on executive function. In a longitudinal study with 88 mothers, Buss, Davis, Hobel, and Sandman (2011) investigated the impact of pregnancy-specific anxiety, state anxiety, and depression at 15, 19, 25, 31, and 37 weeks gestation on EF of the child at 6-9 years of age. Pregnancy-specific anxiety refers to fears and concerns related to pregnancy such as “I am concerned or worried about losing my baby”. They found that maternal pregnancy-specific anxiety had a more significant impact on EF than state anxiety and depression, that is, the higher the pregnancy specific anxiety of the mother, the poorer their EF of the child was found to be. High pregnancy specific anxiety was associated with poorer visuospatial working memory in both boys and girls, while a negative effect on inhibition was only found when the mother experienced high pregnancy specific anxiety and the baby was a girl. Timing of anxiety also moderated the effects, with visuospatial working memory performance being influenced by anxiety throughout gestation, compared to inhibition, which was only significantly influenced by anxiety if it occurred between 15 and 25 weeks gestation (Buss et al., 2011). This research is in line with the literature supporting the foetal origins hypothesis, that prenatal exposure to maternal stress has a lasting effect on cognition and behaviour (Raikkonen et al., 2012).

Quebec’s Ice Storm

Multiple studies, including longitudinal research, have been conducted on the prenatal effects of an ice storm in Quebec, Canada in 1998. Damage from the ice resulted in power failures for more than three million people in 700 districts for between six hours to more than 45 days (King & Laplante, 2005). The storm was considered to be one of the worst and most costly natural disasters in Canadian history, resulting in 35 deaths and provincial costs of at least $1.5 billion (King, Dancause, Turcotte-Tremblay, Veru, & Laplante 2012). The aim of Project Ice Storm was to determine how an independent stressor, such as a natural disaster, during pregnancy can impact on the unborn child and how long these effects could last. Project Ice Storm included 141 families and completed repeat assessments with the mothers and their children over several years (King & Laplante, 2005). This research distinguished between objective stress, which measured the severity of the storm exposure for the woman, and subjective stress, measuring the woman's psychological reactions to the storm (Dancause et al., 2011). Project Ice Storm research has shown how prenatal exposure to a natural disaster is associated with increases in internalizing and externalising behaviour problems, increases in autistic symptoms, and decreases in cognitive and language functioning, birth weight, and gestation (King et al., 2012; King & Laplante, 2005; Laplante et al., 2008).

There is limited information on how maternal stress can induce these changes, however, it is believed that the hormones associated with stress and anxiety play a crucial role. If these hormones are present in large quantities during sensitive periods of foetal development they are believed to influence the programming of certain systems responsible for behaviour and therefore it is possible that EF will also be influenced by these neuropsychological changes (Van den Bergh et al., 2005).

Prenatal effects on children's behaviour

The impact of natural disasters on behaviour. Research on Quebec's ice storm has shown that prenatal exposure to maternal stress can impact internalizing and externalizing behaviour of the child. Tests conducted at ages four, five and a half, six and a half, eight and a half, nine and a half, and 11 ½ showed a low to moderate association between objective stress (severity of the storm exposure for the mothers) and internalising problems, and strong association between subjective stress (the woman's psychological reactions to the storm) and internalising problems (King et al., 2012). When controlling for maternal anxiety and depression post ice storm, subjective stress accounted for an additional 8-12% of unique variance in internalising behaviour problems. When controlling for maternal mood, subjective stress could account for an additional 8-20% of unique variance in externalising behaviour problems. The behavioural problems experienced by these children were found to be long lasting, with the internalising problems at four years old being predicted by subjective maternal stress. The severity of internalising problems experienced by the children exposed to prenatal stress was found to be increasing over time compared to a normative sample. There was also a timing of exposure effects with children whose mothers experienced high levels of stress during the last month of pregnancy being two to three times more likely to show more emotional and behavioural problems at age four, than those children whose mothers experienced low stress levels (King et al., 2012).

When these children were six years old, the mothers completed an autism-screening questionnaire. Significant associations were found between subclinical autism symptoms and objective stress (severity of the storm exposure for the mothers), $r = 0.43$, and subjective stress (the woman's psychological reactions to the storm), $r = 0.45$. When rated by the mother, 23% of the variance in subclinical autism symptoms could be accounted for by objective and subjective stress (King et al., 2012). They also found further interactions between objective and subjective stress. High levels of subjective stress were associated with higher scores on the autism screening questionnaire independent of objective stress. However, objective stress was only associated with high scores on the autism screening questionnaire when experienced in conjunction with low or moderate subjective stress. They also found a timing of exposure effect. They found that there were higher reports of autistic-like traits if the mother experienced high levels of objective stress during the early stages of pregnancy. Early exposure to high levels of objective stress accounted for 42.7% of the variance in autism scores (King et al., 2012; Walder et al., 2014).

Research in line with the foetal origins hypothesis shows that a mother's exposure to traumatic or chronic life stressors, such as bereavement or natural disasters, is associated with significant changes in children's neurodevelopment, which included the increased risk of autism and increase in autistic related symptoms (Talge et al., 2007). Additional support for the association between prenatal disaster exposure and an increase in autistic symptoms comes from a study on the prenatal effects of severe storms that hit Louisiana between 1980 and 1995. This study found that the prevalence of autism significantly increased with the severity of prenatal exposure to the storms. This increase had a timing of exposure effect, with the highest prevalence rates found in children exposed to severe storms during months five, six, nine or ten of gestation. The prevalence rates of autism for children exposed to storms during these four sensitive months was 14.15 per 10,000 compared to only 3.72 per 10,000 for children exposed to storms during the other six months of gestation (Kinney, Miller, Crowley, Huang, & Gerber, 2008).

The impact of maternal stress on behaviour. Children born to mothers who experienced high levels of cortisol in late pregnancy exhibited significantly more crying, fussing, and negative facial expressions when compared to children whose mothers experienced low levels of cortisol (de Weerth et al., 2003). At seven weeks of age children in the high cortisol group had significantly more difficult temperaments, although at 18 weeks, the differences between groups were not significant. However, at four to five months, those children in the high cortisol group still fussed more and typically spent more time displaying negative facial expressions (de Weerth et al., 2003). This is supported by further findings that show high levels of maternal cortisol at 30 to 32 weeks of gestation was significantly associated with negative reactivity in infants (Davis et al., 2007). The measure in this study assessed reactivity to novel stimuli. Children who are easily aroused by various stimulation are more likely to become behaviourally inhibited as young children, showing that maternal stress can have long term effects on children (Davis et al., 2007).

Stress related to high levels of daily problems or, minor but frequent problems, in early gestation, and pregnancy anxiety in mid-pregnancy were associated with an average decrease of eight points on the Mental Developmental Index (MDI) and the Psychomotor Developmental Index (PDI) at eight months old (Huizink, Robles de Medina, Mulder, Visser, & Buitelaar, 2003). The children who experienced high levels of stress *in utero* are at an increased risk of getting developmental scores below the lowest quartile. Maternal cortisol levels were only significantly related to PDI scores at three and eight months of age and MDI scores at eight months of age, if the exposure occurred during late pregnancy. Cortisol levels in early and mid-pregnancy had no significant effect on the behaviour and developmental outcomes of infants (Huizink et al., 2003). These findings are supported by O'Connor, Heron, Golding, Beveridge, and Glover (2002) who found that children whose mothers experienced high levels of anxiety at 32 weeks gestation were more than twice as likely to have more emotional and behavioural problems at age four. These effects were maintained when controlling for demographic risk factors, birth complications and postnatal anxiety and depression. High levels of anxiety late in pregnancy were also associated with hyperactivity and inattention in boys (O'Connor et al., 2002).

In contrast to most literature, a recent study including 119 mothers found that higher cortisol levels during pregnancy was not related to problem behaviour in the children at three, eight, or 27 months of age and higher levels of perceived stress were associated with less restless and disruptive behaviour (Gutteling et al., 2005). However, some aspects of this study support findings by O'Connor et al. (2002), such as the correlation between mothers' perceived stress and mothers' pregnancy specific anxiety with problem behaviour in the children. Gutteling et al. (2005) found that higher levels of perceived stress was correlated with problem behaviour at 27 months. These children experienced more externalizing problems, were easily frustrated, cried more often, and had angrier moods. This study also found that higher pregnancy specific anxiety was related to children experiencing more restless and disruptive behaviour, and more attention regulation problems.

Elsewhere, one study found that exposure to high levels of cortisol early in gestation was associated with a slower rate of development over the first year and lower scores on mental development index of the Bayley Scales of Infant Development (Bayley MDI) at 12 months (Davis & Sandman, 2010). However, in contrast to other findings, high levels of cortisol late in gestation were associated with accelerated development over the first year, and higher Bayley MDI scores at twelve months. Although these findings directly contradict most of the research regarding cortisol exposure(Huizink et al., 2003; O'Connor et al., 2002), they provide an explanation of their findings. They suggest their findings are consistent with the natural role cortisol plays in the development of the foetus. Early during gestation the foetus is protected from naturally occurring increases in cortisol, however, near the end of gestation there is a naturally occurring increase in the level of cortisol that reaches the foetus in order for maturation of lungs and preparation for birth. They suggest this is because moderate increases in cortisol levels can facilitate brain development resulting in improved cognitive functioning (Davis & Sandman, 2010).

Prenatal effects on children's psychological functioning

Studies have shown that prenatal exposure to increased levels of maternal stress can result in long-term mental health problems. Research has shown that prenatal exposure to adverse environmental factors, such as natural disasters, stress, and maternal exposure to death, is associated with increased risk of psychiatric disorders such as depression, schizophrenia and ADHD in children (Huizink et al., 2007; Huttunen & Niskanen, 1978; Watson et al., 1999).

Research on the 1976 earthquake in Tangshan, China, found increased levels of depression in the children who were prenatally exposed. The earthquake was a 7.8 on the Richter scale, and resulted in 240,000 deaths, thousands of injuries and the destruction of infrastructure and basic services (Watson et al., 1999). Those in the exposure group had significantly higher rates of depression at 18 years old than the matched controls (13.3% compared to 5.5%), with this effect being more powerful for boys. Boys who were prenatally exposed to the earthquake during the second trimester showed the largest proportion of depression compared to boys exposed during the first or third trimester, girls exposed at any time during gestation, and the controls. Although, the rate of severe depression for boys exposed during the first trimester (14.1%), second trimester (19%), and the third trimester (13.9%), were all significantly higher than the matched controls (6.8%) (Watson et al., 1999).

The increased levels of depression are thought to be the result of the maternal release of stress hormones (increased levels of glucocorticoids) following the earthquake. It is suspected that this physiological reaction to the earthquake had a negative influence on the hypothalamic–pituitary–adrenal (HPA) axis or glucocorticoid receptors of the foetus, placing these children at an increased risk for depression later in life (Watson et al., 1999). According to the life cycle model the HPA axis can be particularly susceptible to maternal reactions to natural disasters because of the vast amount of neurodevelopment occurring during gestation (Raikkonen et al., 2012). Maternal stress has been found to increase plasma levels of cortisol and corticotrophin, which could contribute to the development of behaviour disorders, attention difficulties, learning difficulties, anxiety, and depression in the children (Weinstock, 2008).4

Research on prenatal exposure to the Chernobyl disaster in 1986, found that maternal anxiety related to exposure had a significant impact on behaviour disorder at 14 years old (Huizink et al., 2007). Although this was a nuclear disaster, it is emphasized that the results are due to the maternal stress associated with the threat of exposure to radiation, rather than a result of radiation exposure. Those children prenatally exposed to the disaster were more than twice as likely to have lifetime depression symptoms (21.1% of exposed adolescents compared to 10.7% of the control adolescents), and were also at an increased risk of meeting the DSM III criteria for Major Depressive Disorder. Furthermore, adolescents prenatally exposed to the disaster were at a significantly increased risk of having attention-deficit/hyperactivity disorder (ADHD) symptoms (31.6% compared to 21.5% of the control adolescents) (Huizink et al., 2007).

Children with ADHD often exhibit problems with their EF. In a review of 18 studies Pennington and Ozonoff (1996) found that children with ADHD consistently perform worse on some cognitive and EF measures, particularly measures of inhibition. Problems in EF were found to be more common among adolescents with ADHD than control adolescents. Additionally, for the adolescents with ADHD, problems in EF increased the likelihood of repeating a grade, the presence of a learning disability, and lower academic achievement (Biederman et al., 2004). Out of the 18 studies reviewed by Pennington and Ozonoff (1996), 15 of the studies reported significant differences in EF between participants with ADHD and participants without ADHD. These differences remained when controlling for confounding variable such as age, gender, IQ and socioeconomic status.

Schizophrenia is a serious, chronic illness that is linked to abnormalities of brain structure and function. It is influenced by environmental factors interacting with genetic susceptibility. As the foetal origins hypothesis and the life cycle model suggest, the prenatal maternal environment is crucial as schizophrenia is believed to be a result of early brain development influenced by environmental factors (Khashan et al., 2008). Huttunen and Niskanen (1978) found that those children who were *in utero* when their father died were significantly more likely to have schizophrenia than matched controls whose fathers died when they were infants. These children were in weeks 9-20 or 33-40 of gestation when their fathers' past away, suggesting these are periods of significant vulnerability to maternal stress (Huttunen & Niskanen, 1978). A larger Danish Study found that the death of one of the mother's close relatives during the first trimester of pregnancy was associated with a statistically significant increase in rates of schizophrenia compared to those who do not have experience the death of a close relative, and those who experience the death of a close relative during the second trimester, third trimester, or six months before pregnancy (Khashan et al., 2008).

Further research shows that the rate of schizophrenia more than doubled for the children whose mothers were in their second month of pregnancy for the Arab-Israeli war in June 1967. An increased rate of other mental health concerns, including affective disorder, anxiety, personality and eating disorders, and substance abuse, was found amongst children who were in their third month of gestation for the war

(Malaspina et al., 2008). van Os and Selten (1998) found that those children *in utero* for the German invasion of the Netherlands in 1940 were significantly more likely to have schizophrenia, especially if they were exposed to the maternal stress during the second trimester.

Prenatal effects on children's cognitive functioning

The impact of natural disasters on cognitive processing and language. Studies conducted on the Quebec ice storm provide evidence for the negative impact natural disasters can have on cognitive and language functioning of those prenatally exposed. Weinstock (2005) found a significant relationship between prenatal maternal stress and cognitive and language outcomes of the children at two years of age, with higher exposure to maternal stress was associated with greater impairments. However, there was a timing of exposure effect, with a significant relationship being found if the mother experienced the ice storm during her first or second trimester of pregnancy. Additional studies carried out on the Quebec ice storm provide support for the negative effects of prenatal exposure at two years old. King and Laplante (2005) found that those children whose mothers experienced moderate to high stress in the first trimester of pregnancy had, on average, Bayley MDI scores 14 points lower than their counterparts in the low stress group. Those children who were exposed to moderate to high levels of stress during the second trimester had an average score 19.5 points lower than those children exposed to only low stress. These children also understood and spoke fewer words compared to the children in the low stress group (King & Laplante, 2005).

Investigating whether there was a difference in the aspects of toy play that reflect general cognitive abilities for children exposed to high levels of prenatal maternal stress as a result of the ice storm, Laplante et al. (2007) found that higher levels of stress were associated with more immature play. Those children that experience high levels of objective prenatal stress played with the toys in a limited way, were more likely to engage in stereotypical play, and spent less time directly playing with the toys. Their findings indicated that children in the high stress group had a developmental delay of more than nine months, which can be attributed to prenatal maternal stress (Laplante et al., 2007).

These impacts on cognitive and language functioning from prenatal exposure to the ice storm remained relatively stable into late childhood. The differences in cognitive and language abilities between those exposed to high levels of stress compared with those exposed to moderate and low levels of stress were halved between testing at age two, and retesting at age five and a half. However, between five and a half and 11 ½ years old the differences stayed fairly stable, particularly in boys. Prenatal exposure to the ice storm was also associated with poorer verbal intelligence and language skills at five and a half years of age, although it was found that prenatal stress was not associated with the children's performance intelligence at five and a half years old, suggesting that prenatal maternal stress may have greater, enduring effects on the brain structures involved in language functioning (Laplante et al., 2008).

The impact of maternal stress on other cognitive processes. Studies on maternal anxiety show that exposure to high maternal anxiety while *in utero* is an independent predictor of mental development at two years old (Brouwers, van Baar, & Pop, 2001). Findings suggest that maternal anxiety may specifically influence attention related processes. At three weeks old, the babies of high anxiety mothers had lower scores on measures of ability to attend to visual and auditory stimuli and on overall alertness. At twelve months old, the children had lower scores on measures of attention and reactivity. Furthermore, findings from testing done at two years old showed that 22% of the children prenatally exposed to maternal anxiety late in pregnancy had developmental delays of at least three months, compared to only 6% of the children not exposed to maternal anxiety (Brouwers et al., 2001).

Prenatal effects on birth outcomes

The impact of natural disasters on gestation and birth outcomes. There is a growing body of evidence showing the importance of early life conditions on health, behaviour, education, and socioeconomic outcomes. However, a lot of this research emphasizes the first year of life (Torche, 2011). According to the foetal origins hypothesis, poor health at birth could be a sign of negative developmental adaptions, which could significantly impact health and development later in life (Fuller, 2014). The effects of natural disasters and stress on gestation and birth outcomes is important as this is an early marker of health, and has been shown to have effects on development and well-being through life. Additionally, an adverse association has been found between birth weight and cognitive performance, educational outcomes, employment, and earnings (Boardman, Powers, Padilla, & Hummer, 2002).

Recent research has suggested that prenatal exposure to natural disasters can have a negative impact on the gestation length and birth weight of the foetus (Dancause et al., 2011; Glynn et al., 2001; King et al., 2012). Research on the 1998 Quebec ice storms has found that those babies prenatally exposed had lower birth weights and the gestation lengths were, on average, one third of a standard deviation shorter than those not exposed to the storm (Dancause et al., 2011). Higher subjective prenatal maternal stress predicted lower birth weights, with the largest effect resulting from exposure during mid-pregnancy. Length at birth was the shortest for those children of mothers who experienced a discrepancy between objective and subjective prenatal maternal stress. However, these findings differed between genders. The effect on length at birth was highest for boys when the mother had low levels of subjective stress and high levels of objective stress. Whereas, the effect on length was highest for girls when the mother had high levels of subjective stress and low levels of objective stress (King et al., 2012).

Research on other natural disasters shows similar findings. Investigation of the prenatal effects of exposure to hurricane Katrina on birth weight and preterm births, found no significant increase in the overall rate of low birth weight and preterm births. However, women who experienced severe exposure to the hurricane were found to be at an increased risk of having babies with a low birth weight, and delivering prematurely (Xiong et al., 2008). Research on a 7.9 earthquake that struck Chile in 2005 found that those infants who were prenatally exposed to the earthquake in the first trimester had significantly reduced birth weights and gestation lengths compared to those infants not exposed, or exposed later in gestation (Torche, 2011). Research on this earthquake found that there was an average decrease in gestation by 0.18 weeks when exposed to the earthquake in the second month of pregnancy, and a decrease of 0.27 weeks when exposure occurred in the third month of pregnancy. Earthquake exposure during the second or third month of pregnancy also increased the risk of delivering preterm. This effect was significant for girls, who had a 3.8% increase in the probability of being born prematurely, which puts these children at a higher risk of negative long-term outcomes (Torche & Kleinhaus, 2012).

Simeonova (2011) conducted a study investigating the effects of various natural disasters and extreme weather conditions in the USA on pregnancy outcomes. A small, but statistically significant reduction in gestation was found when mothers were exposed to natural disasters within the last six months of pregnancy, (the second and third trimesters). A small but statistically significant negative effect was also found on birth weight, when the mother was exposed to a natural disaster during the second trimester. Simeonova (2011) suggests that the reason the result were only small in magnitude could be because of adaption. The areas that were looked at in this study are often repeatedly exposed to the natural disasters, for example, the Mid-Western states are prone to tornadoes and flash flooding. It is likely that over time the mothers may have adapted to the increased risk of these disasters, resulting in smaller health outcomes when they do occur.

The impact of low birth weight on psychological functioning. Studies have also shown a connection between low birth weight/small body size and the prevalence of sub-clinical symptoms of mental disorders (Heinonen et al., 2011) and higher internalizing and externalizing behaviour problems in children aged 7-9 (Schlotz, Jones, Godfrey, & Phillips, 2008). In a sample of 893 Finnish children Heinonen et al. (2011) found that at 56 months of age those children who were born smaller were found to have higher ADHD scores on the Conners' Hyperactivity Index parent version. Lower birth weight has also been linked to increases in the frequency and severity of depressive symptoms in adults. In a large population based British study, researchers found that girls who weighed less than 3000 grams had an increased risk of being depressed at age 26. This trend was not significant for boys, however boys weighing less than 2500 grams were more likely to report a history of depression at age 26 when compared to normal birth weight boys (Gale & Martyn, 2004). Additionally, Lahti et al. (2010) found that low birth weight/small body size was associated with higher trait anxiety in participants that were aged 69 to 71. These studies provide evidence for the foetal origins hypothesis and the life cycle model, showing that prenatal effects can be maintained into adulthood.

The impact of preterm birth on EF and learning. Given that past research has shown an association between prenatal exposure to natural disasters and maternal stress with increased rates of preterm birth (Dancause et al., 2011; Glynn et al., 2001), it is important to note the effects of preterm birth on EF and learning. Health at birth is an important predictor of life-long outcomes, such as school achievement and socioeconomic outcomes. Therefore, the following sections looks at research showing how prenatal exposure to stress could affect EF and learning, when mediated by birth outcomes.

Premature birth is often associated with a range of developmental difficulties. Recent research indicates that children born prematurely (gestational age ≥ 32 weeks) have difficulties in EF, including inhibition, working memory, switching and attention (Aarnoudse-Moens, Smidts, Oosterlaan, Duivenvoorden, & Weisglas-Kuperus, 2009; Bayless & Stevenson, 2007; Marlow, Hennessy, Bracewell, Wolke, & Group, 2007). These studies have shown that very premature children with IQ scores within the average range perform significantly worse on tests of EF than healthy term born controls. Although these preterm only show mild EF problems, they are significant and can be enduring. Narberhaus et al. (2008) found that those children born very prematurely (< 33 weeks gestation) had significantly worse executive functioning in adolescence. Another study found that children who were born prematurely performed significantly worse on cognitive flexibility and inhibition at 20-24 years old (Nosarti et al., 2007).

Children born very preterm (<28 weeks gestation) have been found to have worse EF at eight years old than their full-term peers. More specifically these children performed significantly worse on measures of reasoning ability, working memory, planning and organizing, and strategic decision-making (Anderson, 2002). A behavioural assessment supported the findings of the cognitive measures, with parents reporting more difficulties for children born prematurely than the parents of full-term children. This included: starting activities, developing new ideas and strategies, retaining information, planning actions in advance and organizing thoughts and facts. Although the mean scores for performance on cognitive and behavioural parameters were typically within the average range for both groups, more children from the preterm group were experiencing clinically significant behavioural problems. These preterm children were two to three times more likely to show significant difficulties with monitoring their performance, retaining information, initiating activities, and shifting attention (Anderson, 2002).

A recent meta-analysis looking at cognitive and behavioural outcomes of school aged children that were born prematurely looked at cognitive data from 15 studies and behavioural data from 16 studies (Bhutta, Cleves, Casey, Cradock, & Anand, 2002). They found that preterm birth is associated with lower cognitive scores than matched full term controls in school aged children. This analysis also showed that children who were born prematurely had increased externalizing behaviour problems and symptoms, internalising behaviour problems and symptoms, and significantly higher rates of attention problems than control children (Bhutta et al., 2002). These studies show that there is a significant developmental vulnerability for those children born prematurely. Additionally, children who were born prematurely, or weighing less than 2500 grams were found to be at an increased risk for repeating a grade, having low academic performance and for enrolling in special education than their normal birth weight peers (Corman & Chaikind, 1998).

Most of the research done on the effects of premature births looks at children born very prematurely, less than 34 weeks gestation, however late preterm birth is more common (34-36 weeks gestation) (Brumbaugh, Hodel, & Thomas, 2014). Although the risk for significantly worse outcomes is higher with those children born very prematurely (< 34 weeks), children born late preterm also experience problems in EF when compared to their full-term peers (van Baar, Vermaas, Knots, de Kleine, & Soons, 2009). Research with late preterm children has shown worse performance on verbal inhibitory control and short-term verbal memory compared to full term controls (Brumbaugh et al., 2014).

In a Dutch study of moderate to late preterm children, findings showed that eight years later 7.7% of the preterm children attended a special education school compared to 2.8% of the Dutch population for the same age group (van Baar et al., 2009). Children born preterm were also more likely to repeat a grade than their full term peers: 19% of the preterm children in mainstream schools had to repeat a grade compared to 8.8% of the full term group. There was also a significant difference between the children in the preterm group, with 30% of children born very prematurely (<34 weeks) repeating a grade compared to 17% of children born late prematurely (34-36 weeks). Preterm children also showed more internalising behaviour problems and sustained attention problems than full term children (van Baar et al., 2009).

The impact of natural disasters on learning. Natural disasters have also been shown to impact educational performance at primary school. The random and unpredictable nature of natural disaster and subsequent stress provides support for the causal relationship between prenatal health and academic outcomes (Fuller, 2014). In this study of third graders in North Carolina, there was between 1% and 5% of a standard deviation decrease in maths and reading test scores for those children prenatally exposed to hurricanes, with a 10% to 20% increase in special education placement. When controlling for other factors, they found that birth weight had a similar impact on test scores, 3% to 3.5% of a standard deviation (Fuller, 2014). A sub-group analysis in this study showed that negative effects are more concentrated among specific sub-groups, reported as children born to black mothers, and this is likely to be a socioeconomic status effect. The children reported as being born to black mothers showed significantly greater negative effects on reading and mathematics scores, with the effect sizes ranging from 2.6 % to 5.4 % of a standard deviation.

In this study by Fuller (2014) there is little evidence suggesting that exposure to hurricanes has an effect on physical birth outcomes, such as birth weight, preterm birth, gestational age, and low birth weight, which is in direct contrast to much of the literature on natural disasters. The only significant effects found were a 4.6% increase in the likelihood of low birth weight, and a 4.7% increase in the likelihood of being small for gestational age, when exposure occurred during the second trimester. Therefore, Fuller (2014) suggests it is highly unlikely birth outcomes mediated the effects found on academic performance. Fuller (2014) does suggest that the decrease in maths and reading scores and the increase in special education placement could be due to the more subtle influences on prenatal cognitive development, such as the influence of prenatal cortisol exposure.

Gender specific effects

Previous studies indicate that there are gender-specific neurodevelopmental vulnerabilities in children. A longitudinal study of Finnish children born in 1987 found that boys had more health problems during the perinatal period and they also had a higher risk of being born prematurely (Gissler, Järvelin, Louhiala, & Hemminki, 1999). Later in childhood, boys had higher rates of asthma, intellectual disability, and mortality. They also found that boys were significantly more delayed in their development when compared to girls. Special education data from one county in Finland showed that boys were almost three times at risk for delayed school entry and two times at risk of being enrolled in special education. Similarly, Hon and Nelson

(2006) looked at hospital data from 92,332 patients admitted to the general paediatric wards in Hong Kong between 1984 and 2000. Out of the seven leading causes of admission: gastroenteritis, upper respiratory tract infections, asthma/wheezy bronchitis, pneumonia, bronchiolitis, febrile convulsions, and other convulsions, there was a consistent over representation of boys for each disease.

A report released by the New Zealand Ministry of Health (Ministry of Health, 2016) looked at the major causes impacting on health outcomes for people in New Zealand. One of the measures of health loss used in the report is the disability-adjusted life years (DALYs). One DALY represents the loss of one year lived in full health. When results were adjusted for population size and age structure males experience 15% more health loss than females. The leading cause of health loss for New Zealand males is coronary hearth disease, which accounts for 10% of all health loss, compared to 8% of all health loss for females. Lung cancer and diabetes are also more common contributors to health loss for males than females (Ministry of Health, 2016).

Research Questions

Is there relationship between prenatal exposure to earthquakes and executive functioning five years later? *Hypothesis 1:* It was hypothesised that children who were prenatally exposed to the Christchurch earthquake would be more likely to display problems related to EF related behaviours than control children. This hypothesis is supported by studies showing that prenatal exposure to natural disasters results in increased behaviour problems (King et al., 2012; Walder et al., 2014; Weinstock, 2008), learning difficulties (Fuller, 2014), lower cognitive and language processing (King & Laplante, 2005; Laplante et al., 2007), and increased rates of preterm birth and lower gestational lengths (Dancause et al., 2011; Xiong et al., 2008).

Is there a timing of exposure effect? *Hypothesis 2:* It was hypothesised that exposure to the earthquakes during the first or second trimester of gestation would have more significant effects on EF than exposure during their third trimester of gestation. Previous research suggests that those children prenatally exposed to disasters during the first or second trimester have significantly worse effects than those children exposed during the third trimester (King & Laplante, 2005; Torche, 2011; Weinstock, 2005).

Does the gender of the child influence the effects of prenatal maternal stress on executive function? *Hypothesis 3:* It is hypothesised that boys who prenatally experienced the earthquake will have worse EF than girls. Investigation into the May 1940 invasion of The Netherlands by the German army found a significant gender interaction for children exposed during the second trimester, with boys being at an increased risk of developing schizophrenia (van Os & Selten, 1998). Studies have also shown boys to be at an increased risk of disease and to have more health problems during the perinatal period (Gissler et al., 1999; Hon & Nelson, 2006). It is important to analyse gender-specific patterns of response and susceptibility, as susceptibility to prenatal maternal stress may be different for boys and girls (Dancause et al., 2011).

Are executive function scores worse for children whose mothers were severely exposed to earthquake related stress? *Hypothesis 4:* It was hypothesised that children whose mothers had higher scores of perceived stress would have significantly higher scores on the BRIEF2 questionnaire, than control children, and children whose mothers had less severe perceived stress. Evidence for this hypothesis comes from Project Ice Storm research, with King and colleagues (2012) finding that larger effects on cognitive abilities of children who were exposed to high levels of prenatal stress.

Chapter 3: Methodology

The aims of this study were to determine whether EF development of Christchurch five year olds is related to prenatal exposure to the Christchurch earthquake, whether the prenatal timing of exposure to the earthquake influences these EF effects, whether there will be a difference in these EF effects relating to the gender of the children, and whether mother's perceived earthquake stress is related to the child's EF. The best approach for data collection was to use a quantitative research approach, as numerical data will best address the research aims and this approach allowed for comparisons between specific variables, such as earthquake exposure and EF outcomes.

Recruitment of participants

Emails were sent out to the principals of four primary schools in Christchurch and four control group primary schools in Timaru. As only two Timaru schools responded, two schools in Dunedin were also contacted and included, bringing the total of control schools to four, two from Timaru and two from Dunedin. The Christchurch primary schools were selected because they were on the east side of Christchurch, where the damage was worse, and had a large number of pupils. The Timaru/Dunedin schools were selected as they were of similar decile rating to the Christchurch schools and they had a large number of pupils. Attached in the email was a digital copy of the information sheet (appendix 1), consent form (appendix 2) and a letter of research support from the primary supervisor. Prior to the study starting, the principals signed the consent forms agreeing their school could participate in the study, and emailed them back.

Participants

The classes selected from each of the eight schools were new entrant classes, where the children started on their fifth birthday. The children had to have started school after February 22nd, so that they were *in utero* for the 2011 earthquake. The mothers of these children were asked to participate in the study. A total of 120 questionnaires were distributed, 60 to participants in the Christchurch group and 60 to participants in the control group.

Instruments

The aim of this study was to investigate whether prenatal exposure to the earthquake has an effect on development of EF. EF related behaviour was measured from the mother's perspective using a standardised questionnaire. Demographic information, trimester information, and information regarding severity of earthquake exposure was gathered through a self-administered questionnaire that was developed by the researcher for this study. The questions included in this questionnaire were based on questions used in Project Ice Storm (King & Laplante, 2005) research to reflect participant's experiences of exposure to the disaster.

Executive function. The Behaviour Rating Inventory of Executive Function, second edition (BRIEF 2) (Gioia et al., 2015) was used to measure the EF related behaviour of the children. The BRIEF 2 has nine scales that measure components of EF: Inhibit, Self-Monitor, Shift, Emotional Control, Initiate, Working Memory, Plan/Organise, Task Monitor, and Organization of Materials. The 63 questions are answered on a three-point scale of *Never*, *Sometimes*, or *Always.* The BRIEF 2 includes questions such as; "has explosive angry outbursts", "gets stuck on one activity or topic", and "has trouble remembering things, even for a few minutes". The nine scales combine to three indexes (Behaviour Regulation Index, Emotion Regulation Index, and

Cognitive Regulation Index) and one composite summary score (Global Executive Composite). The Global Executive Composite (GEC) provides an overall score of executive dysfunction. The Behaviour Regulation Index (BRI) is made up of scores from the Inhibit and Self-Monitor scales and shows a child's ability to monitor and regulate their own behaviour. The Emotion Regulation Index (ERI) is made up of the Shift and Emotional Control scales and shows the child's ability to regulate their emotional responses, including their response to changing situations. The Cognitive Regulation Index (CRI) is made up of the Initiate, Working Memory, Plan/Organise, Task Monitor, and Organisation of Materials scales. This index shows the child's problem solving abilities and ability to manage cognitive processes (Gioia et al., 2015). Reliability coefficients for the BRIEF 2 parent report forms are above .90 indicating the accuracy of the BRIEF 2 in measuring impairments in the EF of children (Gioia et al., 2015).

The *T scores* for each scale have a mean of 50 and a standard deviation of 10. For BRIEF 2 clinical scales, *T scores* between 60 and 64 are considered to be mildly elevated, between 65 and 69 potentially clinically elevated, and over 70 they are considered to be clinically elevated/clinically significant. As the BRIEF 2 focuses on problem behaviours the distribution in a normal population is positively skewed, as most scores in the standardised sample cluster around the lower end of the distribution (Gioia et al., 2015).

Demographic Information. Information regarding the mother's ethnicity, education, household income, work, and living arrangements was collected through a research-developed questionnaire. The demographic questions on the questionnaire were all multiple-choice questions (appendix 6).

Trimester of exposure. As part of the research-developed questionnaire, mothers were asked what trimester they were in at the time of the February earthquake, or what their expected due date was, and then the trimester was calculated using the difference in the days between the expected due date and the 22nd of February 2011. First trimester exposure corresponded to weeks 0 to 13, the second trimester was weeks 14 through to 26, and the third trimester was weeks 27 through to birth.

Severity of earthquake experiences. The research-developed questionnaire also contained items to measure the mother's experiences during the earthquake and the period directly following the disaster (appendix 6). This part of the questionnaire contained multiple-choice questions, such as 'how many days did you go without power' and questions that were answered on a five-point Likert scale (1-5), such as 'I was injured in the earthquake' or 'my residence suffered damage as a result of the earthquake'. The Likert scale had written descriptors: 'not at all', 'slightly', 'moderately', 'very', and 'extremely' to inform participants of what the numbers meant. This measure was developed by the researcher loosely based on the *'Reactions to storm questionnaire'* used in Project Ice Storm (King & Laplante, 2005).

Ethical considerations

Approval to conduct this research was received from Massey University Human Ethics Committee: Northern, Application 16/12.

Informed written consent was obtained from the principals and mothers who were involved in the study. Mothers were given the option to opt out of the research at any time. Confidentiality regarding the names of the participants, their children and the school was assured, with no identifiable characteristics being reported.

One of the ethical concerns with this study was the fact that there was the potential for mothers to feel slight distress, both through reliving memories of the earthquake, and through the potential for self-blame. Therefore, all participants in the study were provided with phone numbers of free support services they could use if needed.

Procedure

Following the recruitment of the schools, meetings were arranged with the new entrant classroom teachers at each school, in order to arrange times for the researcher to be present in the classroom to meet with parents. Information sheets (appendix 2) and consent forms (appendix 5) were distributed to the mothers either by the researcher directly, by the class teacher, or sent home in the child's reading folder. The information sheet informed parents of the nature and purpose of the research, the costs and benefits of participation, and had a detailed explanation of what would be required if they decided to participate. The information sheet also advised participants of their right to decline to answer questions, to withdraw from the research at any time without any reasons, and that any information they provided would be kept completely confidential to the researchers.

Attached to the information sheet was the consent form to be signed by the mother. The consent form provided agreement that the mother would participate in the current study under the conditions set out in the information sheet. With these forms, there was information on when the researcher would be present in the classroom, so the parents could bring their questions in, alternatively, parents could call the researcher or her primary supervisor directly for further information. The consent forms were to be returned as soon as possible so the questionnaires could be distributed.

Following the return of the consent forms, a self-administered questionnaire (appendix 6) was distributed to mothers, either in person, or sent home in the child's reading folder. Along with the questionnaire, the BRIEF 2 parent report form was sent home for the mothers to fill out. Participants were asked to complete these two questionnaires over a seven-day period. Mothers were also given the option to complete the questionnaire in an office at the school with the researcher present. Together, the questionnaires took approximately 15-20 minutes to fill out. Participants were told that if they had any questions regarding the questionnaires to contact the researcher for assistance. Participants either returned the questionnaires to the researcher in person, or via a prepaid envelope addressed to the researcher's primary supervisor.

Data Analysis

Data analysis was conducted using the Statistical Package for Social Science (SPSS version 24 for mac) computer package. Descriptive statistics, correlations, t-tests, and ANOVAs were used in the analysis for the results. Results from the questionnaire were transferred into SPSS for analysis. To test the first hypothesis, a one-sample t test was run for all the BRIEF 2 scales and indexes. The test value was 50, as this is the standardised average provided by the BRIEF 2 manual (Gioia et al., 2015).

This second results section looks at how the impact of prenatal exposure to the earthquake on EF varies across subgroups. Since previous studies (Fuller, 2014) have highlighted that foetuses may be more vulnerable at certain times during gestation, children exposed during different trimesters may experience different effects. To investigate this possibility a one-sample t test was run and the results were separated for children who experienced the earthquake in trimester one, two and three. These results were analysed for a level of significance of $p < 0.05$. A one-way ANOVA was run to identify any significant differences between the trimesters on the EF scales and EF indexes. Following the ANOVA, a Tukey post hoc analysis was run to find the exact effects. Individual ANOVA analyses were run for each BRIEF 2 scale and each index separately, in order to decreases the chances of a type I error.

Previous studies have investigated how the effects of prenatal exposure to a natural disaster can vary depending on the gender of the foetus (Torche & Kleinhaus, 2012). To investigate this possibility, the one-sample t test was rerun separately for girls and boys. This subgroup analysis was run for all scales of EF for both girls and boys and analysed for a level of significance of $p < 0.05$. An independent samples t test was also run to investigate the difference between boys and girls BRIEF 2 scores.

Further one-sample t tests were run to investigate if there were effects specific to the gender of the child and the trimester of exposure. This was done by splitting the analysis by both trimester and then gender to look at how girls and boys scores differed depending on what trimester they experienced the earthquake during.

To determine whether there were possible relationships between EF and maternal perceptions of severity, Pearson's correlations were run. Effect sizes were also calculated (r) and were considered to be small ($r = 0.1$), medium ($r = 0.3$) or large ($r = 0.5$) as recommended by Hojat and Xu (2004). Results were analysed for a level of significance of $p > 0.05$. These correlations were run for each of the severity questions (see appendix 6) and each of the BRIEF 2 scales and indexes.

A one-sample t test was carried out to investigate the mean differences between the standardised average and the average score on each BRIEF 2 scale and index for the Christchurch children, and to see if scores differed based on the mother's perception of how stressful she found the earthquake at the time.

The results section will only report results significantly higher than the mean as BRIEF 2 scores are not normally distributed, and the scores lower than the mean are not meaningful in a real-life context, as the majority of children will have results within or below the normal range.

As a result of the unequal group sizes, independent samples t tests could not be run comparing Christchurch children's BRIEF 2 scores and control children's BREIF 2 scores, as the difference in the group sizes would result in unreliable p-values (Field, 2013).

Chapter 4: Results

Of the 120 potential participants, 61 returned the questionnaires. Therefore, total number of participants for this study was 61 with 48 participants in the Christchurch group and 13 participants in the control group. In the Christchurch group, 23 (48%) of the children were girls and in the control group five (39%) of the children were girls (Table 2). In the Christchurch group, 25% were in their first trimester, 40% were in their second trimester, and 35% were in their third trimester of pregnancy during the 2011 earthquake. Of the 13 participants in the control group, 31% were in their first trimester, 38% were in their second trimester, and 31% were in their third trimester of pregnancy for the 2011 earthquake. Of the 48 mothers in the Christchurch group, 90% were identified as New Zealand European. The mothers in the control group were also primarily New Zealand European (92%). A bachelor’s degree was recorded as the highest education level in both Christchurch (27%) and control (31%) groups with the second most reported being a diploma (25% and 15% respectively). Of the mothers who answered ‘other’, majority expanded on this as referring to a post-graduate diploma. The majority of mothers in this study, both Christchurch participants and control participants, reported they worked part-time at the time they were surveyed. For Christchurch participants, most mothers reported their household income to be between 80,000 - 99,999 (25%), while most mothers in the control group reported their household income to be between 100,000 – 119,000 (table 2).

Table 2. Participant information: Child trimester and maternal ethnicity, education, employment and household income data

	Christchurch Group		Control Group	
	N	%	N	%
Girl	23	48	5	37
Boy	25	52	8	62
1st Trimester Total	12	25	4	31
Girl	6	50	1	25
Boy	6	50	3	75
2nd Trimester Total	19	40	5	39
Girl	11	58	1	20
Boy	8	42	4	80
3rd Trimester Total	17	35	4	31
Girl	6	35	3	75
Boy	11	65	1	25
Maternal Ethnicity				
NZ/European	43	90	12	92
Maori	1	2	-	-
Indian	1	2	-	-
Other	3	6	1	8
Maternal Education				
NCEA 1	2	4.2	1	7.7
NCEA 2	3	6.3	-	-
NCEA 3	1	2.1	-	-
Trade Qualification	2	4.2	-	-
Diploma	12	25	2	15.4
Bachelor’s Degree	13	27.1	4	30.8
Master’s Degree	2	4.2	1	7.7
Doctoral	-	-	1	7.7
Other	11	22.9	4	30.8
Current Maternal Employment Status				
Full Time	16	33	4	31
Part Time	22	46	7	54
None	10	21	2	15
Current Household Income				
< 19,999	1	2.1	-	-
20,000 - 39,999	3	6.3	-	-
40,000 - 49,999	8	16.7	3	23.1
60,000 - 69,999	9	18.8	2	15.4
80,000 - 99,999	12	25	2	15.4
100,000 - 119,999	7	14.6	4	30.8
> 120,000	7	14.6	2	15.4
Missing	1	2.1	-	-

Hypothesis 1 Results

It was hypothesised that children who were prenatally exposed to the earthquake would be more likely to display problems associated with EF related behaviours than control children. Children exposed to the earthquake *in utero* had significantly higher emotional control scores than the standardised mean. The average *T score* for Christchurch children was higher than the average *T score* on the Emotional Control scale (6.31, $t(47) = 4.307$, $p < .001$) (Table 3). The high emotional control score resulted in Christchurch children having significantly higher scores on the ERI (4.830, $t(46) = 3.331$, $p < .01$). No other scores were significantly higher than the standardised average. These results confirm hypothesis one. As hypothesised, prenatal earthquake exposure has resulted in higher scores on some EF measures, specifically Emotional Control and ERI.

Table 3. The effects of prenatal exposure to the Christchurch earthquake on EF compared to the standardised mean

One-Sample Test[a]

	Test Value = 50					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Inhibit	1.379	47	.174	1.89583	-.8694	4.6611
SelfMonitor	-.641	47	.524	-.79167	-3.2751	1.6918
Shift	1.587	46	.119	2.40426	-.6450	5.4535
EmotionalControl	**4.307**	**47**	**.000***	**6.31250**	**3.3640**	**9.2610**
Initiate	-3.899	47	.000*	-4.02083	-6.0953	-1.9463
WorkingMemory	-1.964	46	.056	-2.53191	-5.1264	.0625
Plan	-5.610	45	.000*	-5.50000	-7.4746	-3.5254
TaskMonitor	-4.805	46	.000*	-5.85106	-8.3022	-3.3999
Organisation	-1.685	46	.099	-1.76596	-3.8754	.3435
BRI	.794	47	.431	1.042	-1.60	3.68
ERI	**3.331**	**46**	**.002***	**4.830**	**1.91**	**7.75**
CRI	-4.209	45	.000*	-4.370	-6.46	-2.28
GEC	-.512	45	.611	-.652	-3.22	1.91

*. The mean difference is significant at the 0.05 level.

Differences between the mean emotional control score for the Christchurch children and the emotional control score for the control children were seen (Table 4). Because of the difference in group size, an independent samples t test could not be conducted to see if the difference was statistically significant. However, there is a trend towards the Christchurch children having higher scores, in particular emotional control and ERI scores, when compared to children who did not experience the earthquake *in utero*.

Table 4. Scale and Index scores with descriptive statistics for BRIEF 2 scores for Christchurch children and control children

Group		N	Minimum	Maximum	Mean	Std. Deviation
Christchurch	Inhibit	48	38.00	77.00	51.8958	9.52318
	SelfMonitor	48	38.00	68.00	49.2083	8.55261
	Shift	47	39.00	73.00	52.4043	10.38531
	EmotionalControl	48	40.00	82.00	56.3125	10.15446
	Initiate	48	38.00	67.00	45.9792	7.14438
	WorkingMemory	47	37.00	69.00	47.4681	8.83632
	Plan	46	37.00	60.00	44.5000	6.64914
	TaskMonitor	47	35.00	66.00	44.1489	8.34834
	Organisation	47	37.00	63.00	48.2340	7.18456
	BRI	48	37	73	51.04	9.088
	ERI	47	39	79	54.83	9.940
	CRI	46	37	59	45.63	7.041
	GEC	46	36	69	49.35	8.644
Control	Inhibit	13	36.00	74.00	49.7692	9.89237
	SelfMonitor	13	38.00	59.00	49.1538	7.17456
	Shift	13	39.00	64.00	51.8462	8.87737
	EmotionalControl	13	43.00	70.00	52.4615	8.09954
	Initiate	13	38.00	59.00	48.0769	6.44802
	WorkingMemory	13	40.00	59.00	46.9231	4.97429
	Plan	11	37.00	58.00	44.4545	5.78556
	TaskMonitor	12	35.00	54.00	42.1667	5.84393

Organisation	13	42.00	57.00	48.3846	5.22077
BRI	13	35	63	49.62	7.622
ERI	13	42	62	52.31	7.750
CRI	11	42	58	45.82	4.895
GEC	11	40	62	48.55	6.267

Hypothesis 2 Results

It was hypothesised that prenatal earthquake exposure during the first or second trimester would have more significant effects on EF than exposure during their third trimester or no exposure at all. Children in all trimester groups had higher emotional control scores than the standardised mean (Table 5). Exposure in trimester three resulted in the highest scores on the Inhibit scale (mean =55.77), the Emotional Control scale (mean = 61.29), the Shift scale (mean = 56.47), and the ERI (mean = 60) compared to exposure during other trimesters, or no exposure at all.

Table 5. Scale and index scores with descriptive statistics for Christchurch children's BRIEF 2 scores separated by trimester of exposure

Descriptive Statistics

Group	Trimester		N	Minimum	Maximum	Mean	Std. Deviation
Christchurch	1st trimester	Inhibit	12	38.00	62.00	51.3333	6.91945
		SelfMonitor	12	39.00	68.00	51.4167	8.09555
		Shift	12	39.00	70.00	51.0000	9.23432
		EmotionalControl	12	46.00	64.00	54.5833	6.11196
		Initiate	12	38.00	59.00	46.5833	7.10260
		WorkingMemory	12	39.00	69.00	49.2500	9.59285
		Plan	11	37.00	60.00	44.8182	6.33748
		TaskMonitor	11	35.00	66.00	46.4545	9.38471
		Organisation	11	42.00	57.00	49.0000	5.76194
		BRI	12	41.00	60.00	51.6667	6.89312
		ERI	12	44.00	67.00	53.4167	6.97343
		CRI	11	38.00	59.00	46.4545	6.99090
		GEC	11	40.00	64.00	49.5455	7.60741
	2nd trimester	Inhibit	19	38.00	68.00	48.7895	8.27029
		SelfMonitor	19	38.00	68.00	46.7368	8.77396
		Shift	18	39.00	64.00	49.5000	7.86840
		EmotionalControl	19	40.00	74.00	52.9474	10.19517

	Initiate	19	38.00	67.00	44.5263	7.63303
	WorkingMemory	18	37.00	61.00	44.2222	6.33901
	Plan	18	37.00	46.00	40.3889	3.32794
	TaskMonitor	19	35.00	61.00	41.7368	7.90107
	Organisation	19	37.00	63.00	46.3684	7.52190
	BRI	19	37.00	67.00	47.9474	8.56007
	ERI	18	39.00	65.00	50.8889	8.47063
	CRI	18	37.00	57.00	43.1667	5.92353
	GEC	18	36.00	59.00	45.1111	5.98910
3rd trimester	Inhibit	17	40.00	77.00	55.7647	11.35523
	SelfMonitor	17	38.00	63.00	50.4118	8.41174
	Shift	17	39.00	73.00	56.4706	12.53554
	EmotionalControl	17	40.00	82.00	61.2941	10.87293
	Initiate	17	38.00	59.00	47.1765	6.73828
	WorkingMemory	17	37.00	64.00	49.6471	9.96206
	Plan	17	37.00	60.00	48.6471	7.07938
	TaskMonitor	17	35.00	58.00	45.3529	7.93679
	Organisation	17	37.00	63.00	49.8235	7.53521
	BRI	17	38.00	73.00	54.0588	10.30455
	ERI	17	39.00	79.00	60.0000	11.26943
	CRI	17	37.00	59.00	47.7059	7.72791
	GEC	17	39.00	69.00	53.7059	9.77091

Christchurch children who experienced the earthquake during the first trimester had a higher mean score on the Emotional Control scale than the standardised average (4.58, $t(11) = 2.598$, $p < .05$) (Table 6). There were no significant differences between the Christchurch children and the standardised mean on any of the index scales for exposure during the first trimester. There were no scores significantly higher than the standardised average for children exposed during the second trimester.

Christchurch children who were in their third trimester for the earthquake had significantly higher scores on the Shift scale (6.47, $t(16) = 2.128$, $p < .05$) and the Emotional Control scale (11.29, $t(16) = 4.283$, $p < .01$) than the standardized mean. Those children who were exposed to the Christchurch earthquake during the third trimester of gestation had a significantly higher ERI average score than the standardised mean (10.00, $t(16) = 3.659$, $p < .01$).

Table 6. The effects of prenatal exposure during different trimesters of pregnancy compared to the standardised mean

One-Sample Test

			Test Value = 50					
							95% Confidence Interval of the Difference	
Group	Trimester		t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Christchurch	1st trimester	Inhibit	.668	11	.518	1.33333	-3.0631	5.7297
		SelfMonitor	.606	11	.557	1.41667	-3.7270	6.5603
		Shift	.375	11	.715	1.00000	-4.8672	6.8672
		EmotionalControl	**2.598**	**11**	**.025***	**4.58333**	**.7000**	**8.4667**
		Initiate	-1.666	11	.124	-3.41667	-7.9294	1.0961
		WorkingMemory	-.271	11	.792	-.75000	-6.8450	5.3450
		Plan	-2.712	10	.022*	-5.18182	-9.4394	-.9242
		TaskMonitor	-1.253	10	.239	-3.54545	-9.8502	2.7593
		Organisation	-.576	10	.578	-1.00000	-4.8709	2.8709
		BRI	.838	11	.420	1.667	-2.71	6.05
		ERI	1.697	11	.118	3.417	-1.01	7.85
		CRI	-1.682	10	.123	-3.545	-8.24	1.15
		GEC	-.198	10	.847	-.455	-5.57	4.66
	2nd trimester	Inhibit	-.638	18	.531	-1.21053	-5.1967	2.7756
		SelfMonitor	-1.621	18	.122	-3.26316	-7.4921	.9658
		Shift	-.270	17	.791	-.50000	-4.4129	3.4129

	EmotionalControl	1.260	18	.224	2.94737	-1.9665	7.8613
	Initiate	-3.126	18	.006*	-5.47368	-9.1527	-1.7947
	WorkingMemory	-3.867	17	.001*	-5.77778	-8.9301	-2.6255
	Plan	-12.253	17	.000*	-9.61111	-11.2661	-7.9562
	TaskMonitor	-4.559	18	.000*	-8.26316	-12.0714	-4.4550
	Organisation	-2.104	18	.050	-3.63158	-7.2570	-.0061
	BRI	-1.045	18	.310	-2.053	-6.18	2.07
	ERI	.445	17	.662	.889	-3.32	5.10
	CRI	-4.894	17	.000*	-6.833	-9.78	-3.89
	GEC	-3.463	17	.003*	-4.889	-7.87	-1.91
3rd trimester	Inhibit	2.093	16	.053	5.76471	-.0736	11.6030
	SelfMonitor	.202	16	.843	.41176	-3.9132	4.7367
	Shift	**2.128**	**16**	**.049***	**6.47059**	**.0254**	**12.9158**
	EmotionalControl	**4.283**	**16**	**.001***	**11.29412**	**5.7038**	**16.8845**
	Initiate	-1.728	16	.103	-2.82353	-6.2880	.6410
	WorkingMemory	-.146	16	.886	-.35294	-5.4750	4.7691
	Plan	-.788	16	.442	-1.35294	-4.9928	2.2869
	TaskMonitor	-2.414	16	.028*	-4.64706	-8.7278	-.5663
	Organisation	-.097	16	.924	-.17647	-4.0507	3.6978
	BRI	1.624	16	.124	4.059	-1.24	9.36
	ERI	**3.659**	**16**	**.002***	**10.000**	**4.21**	**15.79**
	CRI	-1.224	16	.239	-2.294	-6.27	1.68
	GEC	1.564	16	.137	3.706	-1.32	8.73

*. The mean difference is significant at the 0.05 level.

There was a difference between trimester groups on the Emotional Control scale as determined by a one-way ANOVA ($F(2,45) = 3.628$, $p = .035$). There was a difference between trimester groups on the ERI ($F(2,45) = 2.169$, $p = 0.018$) and on the GEC scale ($F(2,43) = 5.117$, $p = 0.010$) (Table 7). A Tukey post hoc (Table 8) revealed that children who experienced the earthquake in the third trimester had significantly higher scores on the Emotional Control scale than those children exposed during the second trimester by 8.35 ($p < .05$), significantly higher ERI scores than those exposed during the second trimester by 9.111 ($p < .05$) and significantly higher GEC scores than those exposed during the second trimester by 8.595 ($p < 0.01$). There were no statistically higher mean differences on any of the other EF scales or indexes. These results partially support hypothesis two, in that trimester effects were observed. However, the effects were related to the third trimester, not first or second as hypothesised.

Table 7. Between trimester analysis of the effects of prenatal earthquake exposure on EF scales and indexes

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Inhibit	Between Groups	441.596	2	220.798	2.600	0.085
	Within Groups	3820.883	45	84.909		
	Total	4262.479	47			
SelfMonitor	Between Groups	199.198	2	99.599	1.384	0.261
	Within Groups	3238.719	45	71.972		
	Total	3437.917	47			
Shift	Between Groups	456.584	2	228.292	2.23	0.12
	Within Groups	4504.735	44	102.38		
	Total	4961.319	46			
Emotional Control	**Between Groups**	**672.919**	**2**	**336.460**	**3.628**	**.035***
	Within Groups	4173.393	45	92.742		
	Total	4846.313	47			
Initiate	Between Groups	68.855	2	34.428	0.665	0.519
	Within Groups	2330.124	45	51.781		
	Total	2398.979	47			
Working Memory	Between Groups	308.459	2	154.229	2.067	.139
	Within Groups	3283.243	44	74.619		
	Total	3591.702	46			
Plan	Between Groups	597.704	2	298.852	9.233	0.00*
	Within Groups	1391.796	43	32.367		
	Total	1989.5	45			
TaskMonitor	Between Groups	193.664	2	96.832	1.414	.254

	Within Groups	3012.294	44	68.461		
	Total	3205.957	46			
Organisation	Between Groups	115.534	2	57.767	1.125	0.334
	Within Groups	2258.892	44	51.338		
	Total	2374.426	46			
BRI	Between Groups	341.361	2	170.681	2.169	0.126
	Within Groups	3540.555	45	78.679		
	Total	3881.917	47			
ERI	**Between Groups**	**757.944**	**2**	**378.972**	**4.404**	**0.018***
	Within Groups	3786.694	44	86.061		
	Total	4544.638	46			
CRI	Between Groups	189.961	2	94.98	2.001	0.148
	Within Groups	2040.757	43	47.459		
	Total	2230.717	45			
GEC	**Between Groups**	**646.4**	**2**	**323.200**	**5.117**	**0.010***
	Within Groups	2716.034	43	63.164		
	Total	3362.435	45			

*. The mean difference is significant at the 0.05 level

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Table 8. Post hoc analysis of the effects of prenatal earthquake exposure on Emotional Control, ERI and GEC

Tukey HSD

Dependent Variable	(I) Trimester	(J) Trimester	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
EmotionalControl	1st trimester	2nd trimester	1.63596	3.55101	.890	-6.9703	10.2422
		3rd trimester	-6.71078	3.63097	.166	-15.5108	2.0893
	2nd trimester	1st trimester	-1.63596	3.55101	.890	-10.2422	6.9703
		3rd trimester	**-8.34675**	**3.21505**	**.033***	**-16.1388**	**-.5547**
	3rd trimester	1st trimester	6.71078	3.63097	.166	-2.0893	15.5108
		2nd trimester	**8.34675**	**3.21505**	**.033***	**.5547**	**16.1388**
ERI	1st trimester	2nd trimester	2.528	3.457	.746	-5.86	10.91
		3rd trimester	-6.583	3.498	.156	-15.07	1.90
	2nd trimester	1st trimester	-2.528	3.457	.746	-10.91	5.86
		3rd trimester	**-9.111**	**3.137**	**.016***	**-16.72**	**-1.50**
	3rd trimester	1st trimester	6.583	3.498	.156	-1.90	15.07
		2nd trimester	**9.111**	**3.137**	**.016***	**1.50**	**16.72**
GEC	1st trimester	2nd trimester	4.434	3.042	.321	-2.95	11.82
		3rd trimester	-4.160	3.075	.374	-11.63	3.30
	2nd trimester	1st trimester	-4.434	3.042	.321	-11.82	2.95
		3rd trimester	**-8.595**	**2.688**	**.007***	**-15.12**	**-2.07**
	3rd trimester	1st trimester	4.160	3.075	.374	-3.30	11.63
		2nd trimester	**8.595**	**2.688**	**.007***	**2.07**	**15.12**

*. The mean difference is significant at the 0.05 level.

Hypothesis 3 Results

It was hypothesised that the Christchurch boys would have worse scores of EF than both the standardised average, and girls. The mean emotional control score for Christchurch girls is higher (55) than that of the control girls emotional control score (51.25) (Table 9). The maximum score seen in the Christchurch girls group was 80, which is three standard deviations above the standardised average emotional control score on the BRIEF 2. Christchurch boys also had a higher mean Emotional Control score (57.52) than the control boys (54.4). Christchurch boys also had a higher mean ERI score (56.58) compared to the control boys (51.8).

Table 9. Descriptive statistics for the Christchurch children and control children's BRIEF 2 scores separated by gender

Descriptive Statistics

Group	Gender		N	Minimum	Maximum	Mean	Std. Deviation
Christchurch	Girl	Inhibit	23	40.00	68.00	52.2174	8.73320
		SelfMonitor	23	39.00	59.00	47.0435	7.02902
		Shift	23	39.00	72.00	49.6087	9.95782
		EmotionalControl	23	40.00	80.00	55.0000	10.37479
		Initiate	23	39.00	57.00	44.6522	5.65371
		WorkingMemory	23	39.00	64.00	46.8261	6.47830
		Plan	23	37.00	58.00	43.0000	5.30866
		TaskMonitor	23	38.00	61.00	43.4783	7.34147
		Organisation	23	37.00	61.00	48.1304	7.85843
		BRI	23	38.00	67.00	50.6087	8.62206
		ERI	23	39.00	79.00	53.0000	9.86730
		CRI	23	38.00	58.00	44.6522	5.98186
		GEC	23	39.00	67.00	47.9565	6.97709
		Valid N (listwise)	23				
Control	Girl	Inhibit	8	36.00	58.00	45.5000	6.30193
		SelfMonitor	8	38.00	58.00	50.5000	7.07107
		Shift	8	42.00	64.00	53.6250	9.13295
		EmotionalControl	8	43.00	61.00	51.2500	6.96419

		Initiate	8	38.00	59.00	47.2500	7.75979
		WorkingMemory	8	40.00	59.00	46.5000	5.75698
		Plan	7	39.00	58.00	45.1429	6.09449
		TaskMonitor	8	35.00	54.00	41.6250	5.80486
		Organisation	8	42.00	57.00	47.7500	5.09201
		BRI	8	35.00	59.00	47.0000	6.84523
			8	44.00	62.00	52.6250	7.65203
		CRI	7	42.00	58.00	45.5714	5.62308
		GEC	7	40.00	62.00	48.4286	6.80336
		Valid N (listwise)	7				
Christchurch	Boy	Inhibit	25	38.00	77.00	51.6000	10.36822
		SelfMonitor	25	38.00	68.00	51.2000	9.45163
		Shift	24	39.00	73.00	55.0833	10.27414
		EmotionalControl	25	40.00	82.00	57.5200	10.00467
		Initiate	25	38.00	67.00	47.2000	8.21077
		WorkingMemory	24	37.00	69.00	48.0833	10.73360
		Plan	23	37.00	60.00	46.0000	7.58587
		TaskMonitor	24	35.00	66.00	44.7917	9.32495
		Organisation	24	38.00	63.00	48.3333	6.64416
		BRI	25	37.00	73.00	51.4400	9.65695
		ERI	24	39.00	76.00	56.5833	9.89474
		CRI	23	37.00	59.00	46.6087	7.97575
		GEC	23	36.00	69.00	50.7391	10.00553
		Valid N (listwise)	23				

Control	Boy	Inhibit	5	43.00	74.00	56.6000	11.37102
		SelfMonitor	5	39.00	59.00	47.0000	7.58288
		Shift	5	39.00	61.00	49.0000	8.60233
		EmotionalControl	5	46.00	70.00	54.4000	10.21274
		Initiate	5	43.00	52.00	49.4000	3.97492
		WorkingMemory	5	44.00	53.00	47.6000	3.91152
		Plan	4	37.00	50.00	43.2500	5.85235
		TaskMonitor	4	38.00	53.00	43.2500	6.65207
		Organisation	5	42.00	57.00	49.4000	5.85662
		BRI	5	45.00	63.00	53.8000	7.52994
		ERI	5	42.00	61.00	51.8000	8.78635
		CRI	4	42.00	51.00	46.2500	4.03113
		GEC	4	44.00	57.00	48.7500	6.18466
		Valid N (listwise)	4				

The mean Emotional Control scale score for Christchurch girls was higher than the standardised mean (5.0, $t(22) = 2.311$, $p < .05$) (Table 10). There were no other significantly higher scores on the other BRIEF 2 scales or indexes for girls.

Christchurch boys had higher scores on the Shift scale (5.08, $t(23) = 2.424$, $p < .05$), and the Emotional Control scale (7.51, $t(24) = 3.758$, $p < .01$) than the standardised mean. Christchurch boys had a significantly higher average ERI score than the standardised mean (6.583, $t(23) = 3.259$, $p < .01$).

An independent sample t-test found no significant differences between boys and girls scores on each of the EF scales and indexes (data not shown). However, as hypothesised, the one-sample t test showed different results for boys and girls compared to the standardised average, boys had higher scores on the shift scale and ERI while girls did not.

Table 10. The effects of prenatal earthquake exposure on EF for boys and girls

One-Sample Test

		Test Value = 50					
						95% Confidence Interval of the Difference	
Gender		t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Girl	Inhibit	1.218	22	.236	2.21739	-1.5591	5.9939
	SelfMonitor	-2.017	22	.056	-2.95652	-5.9961	.0831
	Shift	-.188	22	.852	-.39130	-4.6974	3.9148
	EmotionalControl	**2.311**	**22**	**.031***	**5.00000**	**.5136**	**9.4864**
	Initiate	-4.536	22	.000*	-5.34783	-7.7927	-2.9030
	WorkingMemory	-2.350	22	.028*	-3.17391	-5.9753	-.3725
	Plan	-6.324	22	.000*	-7.00000	-9.2956	-4.7044
	TaskMonitor	-4.260	22	.000*	-6.52174	-9.6964	-3.3470
	Organisation	-1.141	22	.266	-1.86957	-5.2678	1.5287
	BRI	.339	22	.738	.609	-3.12	4.34
	ERI	1.458	22	.159	3.000	-1.27	7.27
	CRI	-4.288	22	.000*	-5.348	-7.93	-2.76
	GEC	-1.405	22	.174	-2.043	-5.06	.97
Boy	Inhibit	.772	24	.448	1.60000	-2.6798	5.8798
	SelfMonitor	.635	24	.532	1.20000	-2.7014	5.1014
	Shift	**2.424**	**23**	**.024***	**5.08333**	**.7449**	**9.4217**
	EmotionalControl	**3.758**	**24**	**.001***	**7.52000**	**3.3903**	**11.6497**

Initiate	-1.705	24	.101	-2.80000	-6.1892	.5892
WorkingMemory	-.875	23	.391	-1.91667	-6.4491	2.6157
Plan	-2.529	22	.019*	-4.00000	-7.2804	-.7196
TaskMonitor	-2.736	23	.012*	-5.20833	-9.1459	-1.2708
Organisation	-1.229	23	.232	-1.66667	-4.4723	1.1389
BRI	.746	24	.463	1.440	-2.55	5.43
ERI	**3.259**	**23**	**.003***	**6.583**	**2.41**	**10.76**
CRI	-2.039	22	.054	-3.391	-6.84	.06
GEC	.354	22	.727	.739	-3.59	5.07

*. The mean difference is significant at the 0.05 level.

Other Results

Christchurch girls who were exposed to the earthquake during the third trimester had the highest shift mean score (56.33), the highest emotional control mean score (61.67), and the highest ERI score (60.17) when compared to first trimester girls and second trimester girls. Boys who were exposed to the earthquake during the third trimester also had the highest shift mean score (56.55), the highest emotional control mean score (61.09), and the highest ERI score (59.91) (Table 11). Boys exposed in the third trimester scored significantly higher on the scale measuring emotional control (11.09, $t(10) = 3.737$, $p < .01$) and on the ERI (9.909, $t(10) = 3.170$, $p < .05$) compared to the standardised average (Table 12).

Table 11. Descriptive statistics for Christchurch children and control children's BRIEF 2 scores separated by trimester and gender

Descriptive Statistics

Group	Gender	Trimester		N	Minimum	Maximum	Mean	Std. Deviation
Christchurch	Girl	1st trimester	Inhibit	6	43.00	62.00	53.5000	7.76531
			SelfMonitor	6	39.00	54.00	47.3333	6.83130
			Shift	6	39.00	56.00	45.5000	5.75326
			EmotionalControl	6	48.00	59.00	54.3333	5.08593
			Initiate	6	39.00	48.00	44.0000	3.46410
			WorkingMemory	6	39.00	50.00	44.8333	3.97073
			Plan	6	37.00	48.00	42.8333	3.97073
			TaskMonitor	6	38.00	57.00	45.5000	6.97854
			Organisation	6	42.00	57.00	49.8333	4.99667
			BRI	6	41.00	60.00	51.6667	7.96660
			ERI	6	44.00	57.00	50.8333	4.70815
			CRI	6	40.00	50.00	44.6667	3.50238
			GEC	6	42.00	53.00	47.5000	3.93700
			Valid N (listwise)	6				
		2nd trimester	Inhibit	11	40.00	68.00	49.7273	8.60338
			SelfMonitor	11	39.00	59.00	45.8182	7.50757
			Shift	11	39.00	56.00	48.1818	6.79438
			EmotionalControl	11	40.00	70.00	51.7273	9.64459

	Initiate	11	39.00	57.00	43.3636	6.29719
	WorkingMemory	11	39.00	61.00	46.1818	6.64557
	Plan	11	37.00	46.00	40.2727	3.40855
	TaskMonitor	11	38.00	61.00	42.0000	7.72010
	Organisation	11	37.00	58.00	46.4545	8.02949
	BRI	11	38.00	67.00	48.3636	8.28580
	ERI	11	39.00	65.00	50.2727	8.10051
	CRI	11	38.00	55.00	42.9091	5.82159
	GEC	11	40.00	59.00	45.6364	5.92069
	Valid N (listwise)	11				
3rd trimester	Inhibit	6	40.00	68.00	55.5000	9.93479
	SelfMonitor	6	39.00	59.00	49.0000	7.07107
	Shift	6	39.00	72.00	56.3333	15.22717
	EmotionalControl	6	40.00	80.00	61.6667	13.57449
	Initiate	6	43.00	57.00	47.6667	5.85377
	WorkingMemory	6	42.00	64.00	50.0000	7.92465
	Plan	6	43.00	58.00	48.1667	6.04704
	TaskMonitor	6	38.00	57.00	44.1667	7.67898
	Organisation	6	37.00	61.00	49.5000	10.29077
	BRI	6	38.00	67.00	53.6667	10.13246
	ERI	6	39.00	79.00	60.1667	13.83353
	CRI	6	40.00	58.00	47.8333	7.65289
	GEC	6	39.00	67.00	52.6667	9.47980
	Valid N (listwise)	6				

Boy	1st trimester	Inhibit	6	38.00	55.00	49.1667	5.81091
		SelfMonitor	6	48.00	68.00	55.5000	7.58288
		Shift	6	49.00	70.00	56.5000	9.04986
		EmotionalControl	6	46.00	64.00	54.8333	7.49444
		Initiate	6	38.00	59.00	49.1667	9.10860
		WorkingMemory	6	40.00	69.00	53.6667	11.82652
		Plan	5	39.00	60.00	47.2000	8.22800
		TaskMonitor	5	35.00	66.00	47.6000	12.50200
		Organisation	5	42.00	57.00	48.0000	7.03562
		BRI	6	41.00	59.00	51.6667	6.40833
		ERI	6	47.00	67.00	56.0000	8.29458
		CRI	5	38.00	59.00	48.6000	9.81326
		GEC	5	40.00	64.00	52.0000	10.55936
		Valid N (listwise)	5				
	2nd trimester	Inhibit	8	38.00	61.00	47.5000	8.17662
		SelfMonitor	8	38.00	68.00	48.0000	10.69045
		Shift	7	39.00	64.00	51.5714	9.50188
		EmotionalControl	8	40.00	74.00	54.6250	11.35074
		Initiate	8	38.00	67.00	46.1250	9.38749
		WorkingMemory	7	37.00	49.00	41.1429	4.70562
		Plan	7	37.00	45.00	40.5714	3.45722
		TaskMonitor	8	35.00	58.00	41.3750	8.66747
		Organisation	8	38.00	63.00	46.2500	7.30460
		BRI	8	37.00	64.00	47.3750	9.47082

	ERI	7	39.00	63.00	51.8571	9.59911
	CRI	7	37.00	57.00	43.5714	6.52833
	GEC	7	36.00	54.00	44.2857	6.47339
	Valid N (listwise)	7				
3rd trimester	Inhibit	11	41.00	77.00	55.9091	12.52561
	SelfMonitor	11	38.00	63.00	51.1818	9.29320
	Shift	11	39.00	73.00	56.5455	11.63928
	EmotionalControl	11	46.00	82.00	61.0909	9.84332
	Initiate	11	38.00	59.00	46.9091	7.43579
	WorkingMemory	11	37.00	64.00	49.4545	11.28152
	Plan	11	37.00	60.00	48.9091	7.85436
	TaskMonitor	11	35.00	58.00	46.0000	8.36660
	Organisation	11	45.00	63.00	50.0000	6.14817
	BRI	11	39.00	73.00	54.2727	10.88201
	ERI	11	45.00	76.00	59.9091	10.36778
	CRI	11	37.00	59.00	47.6364	8.13969
	GEC	11	41.00	69.00	54.2727	10.33529
	Valid N (listwise)	11				

Table 12. The effects of prenatal earthquake exposure on EF scales for boys and girls separated by trimester of exposure

One-Sample Test

			Test Value = 50					
							95% Confidence Interval of the Difference	
Gender	Trimester		t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Girl	1st trimester	Inhibit	1.104	5	.320	3.50000	-4.6492	11.6492
		SelfMonitor	-.956	5	.383	-2.66667	-9.8357	4.5023
		Shift	-1.916	5	.114	-4.50000	-10.5377	1.5377
		EmotionalControl	2.087	5	.091	4.33333	-1.0040	9.6707
		Initiate	-4.243	5	.008*	-6.00000	-9.6354	-2.3646
		WorkingMemory	-3.187	5	.024*	-5.16667	-9.3337	-.9996
		Plan	-4.421	5	.007*	-7.16667	-11.3337	-2.9996
		TaskMonitor	-1.580	5	.175	-4.50000	-11.8235	2.8235
		Organisation	-.082	5	.938	-.16667	-5.4103	5.0770
		BRI	.512	5	.630	1.667	-6.69	10.03
		ERI	.434	5	.683	.833	-4.11	5.77
		CRI	-3.730	5	.014*	-5.333	-9.01	-1.66
		GEC	-1.555	5	.181	-2.500	-6.63	1.63
	2nd trimester	Inhibit	-.105	10	.918	-.27273	-6.0526	5.5071
		SelfMonitor	-1.847	10	.094	-4.18182	-9.2255	.8618
		Shift	-.888	10	.396	-1.81818	-6.3827	2.7463
		EmotionalControl	.594	10	.566	1.72727	-4.7521	8.2066

		Initiate	-3.495	10	.006*	-6.63636	-10.8669	-2.4059
		WorkingMemory	-1.906	10	.086	-3.81818	-8.2827	.6464
		Plan	-9.465	10	.000*	-9.72727	-12.0172	-7.4374
		TaskMonitor	-3.437	10	.006*	-8.00000	-13.1864	-2.8136
		Organisation	-1.464	10	.174	-3.54545	-8.9397	1.8488
		BRI	-.655	10	.527	-1.636	-7.20	3.93
		ERI	.112	10	.913	.273	-5.17	5.71
		CRI	-4.040	10	.002*	-7.091	-11.00	-3.18
		GEC	-2.444	10	.035*	-4.364	-8.34	-.39
	3rd trimester	Inhibit	1.356	5	.233	5.50000	-4.9259	15.9259
		SelfMonitor	-.346	5	.743	-1.00000	-8.4206	6.4206
		Shift	1.019	5	.355	6.33333	-9.6466	22.3133
		EmotionalControl	2.105	5	.089	11.66667	-2.5789	25.9122
		Initiate	-.976	5	.374	-2.33333	-8.4765	3.8098
		WorkingMemory	.000	5	1.000	.00000	-8.3164	8.3164
		Plan	-.743	5	.491	-1.83333	-8.1793	4.5126
		TaskMonitor	-1.861	5	.122	-5.83333	-13.8919	2.2253
		Organisation	-.119	5	.910	-.50000	-11.2995	10.2995
		BRI	.886	5	.416	3.667	-6.97	14.30
		ERI	1.800	5	.132	10.167	-4.35	24.68
		CRI	-.693	5	.519	-2.167	-10.20	5.86
		GEC	.689	5	.521	2.667	-7.28	12.62
Boy	1st trimester	Inhibit	-.351	5	.740	-.83333	-6.9315	5.2648
		SelfMonitor	1.777	5	.136	5.50000	-2.4577	13.4577

	Shift	1.759	5	.139	6.50000	-2.9972	15.9972
	EmotionalControl	1.580	5	.175	4.83333	-3.0316	12.6983
	Initiate	-.224	5	.832	-.83333	-10.3922	8.7256
	WorkingMemory	.759	5	.482	3.66667	-8.7445	16.0778
	Plan	-.761	4	.489	-2.80000	-13.0164	7.4164
	TaskMonitor	-.429	4	.690	-2.40000	-17.9233	13.1233
	Organisation	-.636	4	.560	-2.00000	-10.7359	6.7359
	BRI	.637	5	.552	1.667	-5.06	8.39
	ERI	1.772	5	.137	6.000	-2.70	14.70
	CRI	-.319	4	.766	-1.400	-13.58	10.78
	GEC	.424	4	.694	2.000	-11.11	15.11
2nd trimester	Inhibit	-.865	7	.416	-2.50000	-9.3358	4.3358
	SelfMonitor	-.529	7	.613	-2.00000	-10.9374	6.9374
	Shift	.438	6	.677	1.57143	-7.2163	10.3592
	EmotionalControl	1.152	7	.287	4.62500	-4.8645	14.1145
	Initiate	-1.168	7	.281	-3.87500	-11.7231	3.9731
	WorkingMemory	-4.980	6	.003*	-8.85714	-13.2091	-4.5052
	Plan	-7.216	6	.000*	-9.42857	-12.6260	-6.2312
	TaskMonitor	-2.815	7	.026*	-8.62500	-15.8712	-1.3788
	Organisation	-1.452	7	.190	-3.75000	-9.8568	2.3568
	BRI	-.784	7	.459	-2.625	-10.54	5.29
	ERI	.512	6	.627	1.857	-7.02	10.73
	CRI	-2.605	6	.040*	-6.429	-12.47	-.39
	GEC	-2.335	6	.058	-5.714	-11.70	.27

3rd trimester	Inhibit	1.565	10	.149	5.90909	-2.5057	14.3239
	SelfMonitor	.422	10	.682	1.18182	-5.0614	7.4251
	Shift	1.865	10	.092	6.54545	-1.2739	14.3648
	EmotionalControl	**3.737**	**10**	**.004***	**11.09091**	**4.4781**	**17.7037**
	Initiate	-1.379	10	.198	-3.09091	-8.0863	1.9045
	WorkingMemory	-.160	10	.876	-.54545	-8.1245	7.0336
	Plan	-.461	10	.655	-1.09091	-6.3675	4.1857
	TaskMonitor	-1.586	10	.144	-4.00000	-9.6208	1.6208
	Organisation	.000	10	1.000	.00000	-4.1304	4.1304
	BRI	1.302	10	.222	4.273	-3.04	11.58
	ERI	**3.170**	**10**	**.010***	**9.909**	**2.94**	**16.87**
	CRI	-.963	10	.358	-2.364	-7.83	3.10
	GEC	1.371	10	.200	4.273	-2.67	11.22

*. The mean difference is significant at the 0.05 level.

Hypothesis 4 Results

This section looks at the analysis results from the severity section of the questionnaire for the Christchurch participants. Table 13 displays the descriptive statistics for this group. Majority of the participants from this group (71%) lived on the east side of Christchurch for the February 2011 earthquake. This was the side of the city that that had the most significant damage, along with the city centre (McSaveney, 2014). 94% of the Christchurch participants reported they had some damage to their home, with 75% reporting moderate to extreme damage. All of the Christchurch mothers reported feeling at least slightly stressed at the time of the earthquake. More than half, 54%, reported feeling very or extremely stressed at the time of the earthquake. See table 13 for a complete description of Christchurch mother's experiences of the Christchurch earthquake.

Table 13. Descriptive statistics for maternal earthquake experiences showing location, injury, household damage, and income disruption

Descriptive Statistics

		Frequency	Percent			Frequency	Percent
Area	North	7	15	Liquefaction	Not at all	11	23
	South	2	4		Slightly	11	23
	East	34	71		Moderately	9	19
	West	4	8		Very	5	10
	Rural	1	2		Extremely	12	25
Injured Self	Not at all	41	85	Days Without Power	0 Days	10	21
	Slightly	7	15		1-2 Days	12	25
Injured Other	Not at all	38	79		3-5 Days	7	15
	Slightly	5	11		5-7 Days	3	6
	Moderately	4	8		>7 Days	15	31
	Extremely	1	2	Left Home	Yes	25	52
Damaged Residence	Not at all	3	6		No	22	46
	Slightly	9	19	Left ChCh	Yes	12	25
	Moderately	21	44		No	36	75
	Very	5	10	Red Zoned	Yes	4	8
	Extremely	10	21		No	44	92
Loss of Income	Not at all	38	80	Rebuild	Yes	9	19
	Slightly	3	6		No	39	81
	Moderately	4	8	Overall Stress Perception	Slightly	7	15
	Very	1	2		Moderately	15	31
	Extremely	2	4		Very	16	33
					Extremely	10	21

It was hypothesised that children whose mothers had higher scores of perceived stress would have significantly higher scores on the EF measures, than control children, or than children whose mothers had less severe perceived stress. There was a moderate, positive correlation between how severely someone close to the mother was injured and children's Inhibit scores ($r = 0.365$, $n = 48$, $p < 0.05$), Organisation scores ($r = 0.307$, $n = 47$, $p < 0.05$), Emotional Control scores ($r = 0.345$, $n = 48$, $p < 0.05$), and BRI scores ($r = 0.350$, $n = 48$, $p < 0.05$) (Table 14). There was also a moderate, positive correlation between how significantly the mother was injured in the earthquake and children's ERI scores ($r = 0.305$, $n = 47$, $p < 0.05$). There was a moderate, positive correlation between mother's loss of income as a result of the earthquake and children's Working Memory scale scores ($r = 0.328$, $n = 47$, $p < 0.05$).

Table 14. Correlations between all earthquake experiences and EF scores

		Injured Self	Injured Other	Damaged residence	Loss of Income	Liquefaction	Days Without Power	Stress Perception
Inhibit	Pearson Correlation	.550	**.365***	-.061	.040	-.067	-.160	-.043
	Sig. (2-tailed)	.712	.011	.679	.789	.651	.283	.771
	N	48	48	48	48	48	47	48
Self Monitor	Pearson Correlation	.206	.179	-.124	.163	.135	-.045	-.187
	Sig. (2-tailed)	.160	.223	.401	.269	.362	.763	.203
	N	48	48	48	48	48	47	48
Shift	Pearson Correlation	.170	.082	-.039	.149	.017	.052	-.145
	Sig. (2-tailed)	.245	.583	.794	.317	.911	.730	.330
	N	48	48	48	48	48	46	47
Emotional Control	Pearson Correlation	**.345***	.244	.086	.258	-.031	.254	.102
	Sig. (2-tailed)	.016	.094	.561	.077	.832	.085	.409
	N	48	48	48	48	48	47	48
Initiate	Pearson Correlation	.126	.177	-.107	.175	.021	-.141	-.137
	Sig. (2-tailed)	.392	.228	.470	.235	.885	.344	.352
	N	48	48	48	48	48	47	48
Working Memory	Pearson Correlation	.237	.277	-.070	**.328***	.083	-.119	-.046
	Sig. (2-tailed)	.108	.060	.639	.024	.579	-.430	-.758
	N	47	47	47	47	47	46	47
Plan	Pearson Correlation	.133	.261	.061	.239	.052	.027	.031
	Sig. (2-tailed)	.377	.080	.687	.110	.730	.857	.838
	N	46	46	46	46	46	46	46
Task	Pearson Correlation	.202	.014	-.216	.210	.061	-.081	-.244

Monitor	Sig. (2-tailed)	.173	.924	.145	.157	.686	.589	.098
	N	47	47	47	47	47	47	47
Organisation	Pearson Correlation	-.047	**.307***	-.027	.195	.035	-.146	-.100
	Sig. (2-tailed)	.752	.036	.855	.190	.815	.328	.502
	N	47	47	47	47	47	47	47
BRI	Pearson Correlation	.123	**.350***	-.087	.102	.003	-.132	-.091
	Sig. (2-tailed)	.406	.015	.556	.489	.982	.377	.539
	N	48	48	48	48	48	47	48
ERI	Pearson Correlation	**.305***	.219	.050	.248	.004	.204	.011
	Sig. (2-tailed)	.037	.140	.741	.093	.981	.173	.942
	N	47	47	47	47	47	46	47
CRI	Pearson Correlation	.162	.276	.035	.280	.153	-.022	-.107
	Sig. (2-tailed)	.283	.063	.817	.059	.311	.883	.479
	N	46	46	46	46	46	46	46
GEC	Pearson Correlation	.252	.287	-.035	.271	.060	-.009	-.051
	Sig. (2-tailed)	.091	.054	.820	.069	.693	.952	.734
	N	46	46	46	46	46	46	46

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.001 level (2-tailed).

For those children with mothers who reported they were only slightly stressed at the time of the earthquake, there was a significant increase in Shift scores (8.14, $t(6) = 2.801$, $p < .05$) and ERI scores (7.571, $t(6) = 2.624$, $p < .05$) compared to the standardised mean (Table 15). Children in the group whose mothers reported being very stressed had significantly higher Emotional Control scores (4.68, $t(15) = 2.700$, $p < .050$). Those children who had mothers who rated their stress as extreme had an average mean difference of 10 on the Emotional Control scale, however, this did not quite reach significance (2.214, $t(9) = 10$, $p = .054$). There were no statistically significantly higher results for the BRIEF 2 indexes in the moderate, very, or extreme stress subgroups. As hypothesised, higher maternal stress was associated with higher EF scores on the BRIEF 2 (Table 15).

Table 15. The effects of prenatal earthquake exposure on EF separated by maternal reports of stress experienced at the time of the earthquake

One-Sample Test

StressPerception		t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference: Lower	95% Confidence Interval of the Difference: Upper
		Test Value = 50					
Slightly	Inhibit	.744	6	.485	2.14286	-4.9092	9.1949
	SelfMonitor	.488	6	.643	2.00000	-8.0322	12.0322
	Shift	**2.801**	**6**	**.031***	**8.14286**	**1.0304**	**15.2553**
	EmotionalControl	1.930	6	.102	6.28571	-1.6829	14.2543
	Initiate	-.616	6	.560	-1.42857	-7.1011	4.2439
	WorkingMemory	-.137	6	.895	-.57143	-10.7427	9.5999
	Plan	-1.317	5	.245	-2.83333	-8.3632	2.6966
	TaskMonitor	-.642	5	.549	-3.16667	-15.8543	9.5209
	Organisation	.077	5	.942	.16667	-5.4029	5.7363
	BRI	.701	6	.510	2.143	-5.34	9.63
	ERI	**2.624**	**6**	**.039***	**7.571**	**.51**	**14.63**
	CRI	-.929	5	.395	-2.833	-10.67	5.00
	GEC	.624	5	.560	2.000	-6.24	10.24
Moderately	Inhibit	1.040	14	.316	3.13333	-3.3311	9.5978
	SelfMonitor	.295	14	.772	.73333	-4.6008	6.0675
	Shift	1.000	13	.336	2.78571	-3.2325	8.8039
	EmotionalControl	1.994	14	.066	5.60000	-.4222	11.6222

	Initiate	-1.246	14	.233	-2.73333	-7.4392	1.9725
	WorkingMemory	-.676	13	.511	-1.71429	-7.1891	3.7606
	Plan	-3.523	13	.004*	-6.50000	-10.4858	-2.5142
	TaskMonitor	-1.142	14	.273	-2.73333	-7.8666	2.4000
	Organisation	-.127	14	.901	-.26667	-4.7825	4.2491
	BRI	.857	14	.406	2.400	-3.60	8.40
	ERI	1.441	13	.173	4.071	-2.03	10.18
	CRI	-1.196	13	.253	-2.357	-6.62	1.90
	GEC	.000	13	1.000	.000	-5.65	5.65
Very	Inhibit	.205	15	.840	.43750	-4.1131	4.9881
	SelfMonitor	-1.684	15	.113	-2.68750	-6.0896	.7146
	Shift	-.648	15	.527	-1.50000	-6.4339	3.4339
	EmotionalControl	**2.700**	**15**	**.016***	**4.68750**	**.9869**	**8.3881**
	Initiate	-4.756	15	.000*	-7.00000	-10.1374	-3.8626
	WorkingMemory	-2.705	15	.016*	-5.37500	-9.6106	-1.1394
	Plan	-4.798	15	.000*	-7.31250	-10.5609	-4.0641
	TaskMonitor	-6.795	15	.000*	-9.06250	-11.9053	-6.2197
	Organisation	-3.973	15	.001*	-4.75000	-7.2981	-2.2019
	BRI	-.286	15	.779	-.563	-4.76	3.63
	ERI	1.208	15	.246	2.250	-1.72	6.22
	CRI	-5.229	15	.000*	-7.563	-10.64	-4.48
	GEC	-2.416	15	.029*	-3.563	-6.71	-.42
Extremely	Inhibit	.714	9	.493	2.20000	-4.7667	9.1667
	SelfMonitor	-.739	9	.479	-2.00000	-8.1260	4.1260

Shift	1.038	9	.326	4.10000	-4.8313	13.0313
EmotionalControl	2.214	9	.054	10.00000	-.2173	20.2173
Initiate	-1.392	9	.197	-3.00000	-7.8752	1.8752
WorkingMemory	-.204	9	.843	-.50000	-6.0539	5.0539
Plan	-1.198	9	.261	-2.80000	-8.0870	2.4870
TaskMonitor	-3.037	9	.014*	-7.00000	-12.2133	-1.7867
Organisation	-.139	9	.892	-.40000	-6.8971	6.0971
BRI	.263	9	.799	.800	-6.09	7.69
ERI	1.900	9	.090	8.100	-1.54	17.74
CRI	-1.286	9	.231	-3.000	-8.28	2.28
GEC	.438	9	.672	1.500	-6.25	9.25

*. The mean difference is significant at the 0.05 level.

Control Group Outcomes

Overall, the control group children showed no scores that were significantly higher than the mean standardised scores for all BRIEF 2 scales and indexes (Table 16). The control group was too small to investigate any subgroup trends.

Table 16. Control children's EF scores compared to the BRIEF 2 standardised average

One-Sample Test[a]

	Test Value = 50					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Inhibit	-.084	12	.934	-.23077	-6.2087	5.7471
SelfMonitor	-.425	12	.678	-.84615	-5.1817	3.4894
Shift	.750	12	.468	1.84615	-3.5184	7.2107
EmotionalControl	1.187	12	.258	2.61538	-2.1845	7.4152
Initiate	-1.075	12	.303	-1.92308	-5.8196	1.9734
WorkingMemory	-2.230	12	.046	-3.07692	-6.0829	-.0710
Plan	-3.179	10	.010*	-5.54545	-9.4322	-1.6587
TaskMonitor	-4.643	11	.001*	-7.83333	-11.5464	-4.1203
Organisation	-1.116	12	.286	-1.61538	-4.7703	1.5395
BRI	-.182	12	.859	-.385	-4.99	4.22
ERI	1.074	12	.304	2.308	-2.38	6.99
CRI	-2.833	10	.018*	-4.182	-7.47	-.89
GEC	-.770	10	.459	-1.455	-5.66	2.76

*. The mean difference is significant at the 0.05 level.

Chapter 5: Discussion

Natural disasters have the potential to disrupt communities. Since the February 2011 Christchurch earthquake, there have been other parts of New Zealand that have suffered large earthquakes and significant damage to the community. These types of natural disasters have the potential to lead to long-term effects for children who experienced the disaster during a vulnerable period of prenatal development. Within the education community in Christchurch there have been concerns expressed over increasingly challenging behaviour of recent new entrants, who would have been *in utero* during the 2011 earthquake. The extent of school concerns was exemplified by the principal from one of the participating schools, which typically has a ‘no research within the school policy’. The principal agreed to the school participating in this study as he, and the teaching staff, have had concerns and difficulties with the new entrant children and considered this research to be of importance to the community.

This study aimed to investigate the long-term effects of prenatal exposure to the Christchurch earthquake on EF related behaviour. Only BRIEF 2 scores that are significantly higher than standardised or comparison scores will be discussed, as these are the scores that are resulting in noticeable differences in everyday life and low scores are not thought to have any meaningful interpretation (Gioia et al., 2015).

The findings from this study suggest that prenatal exposure to a natural disaster, such as the Christchurch earthquake has a negative effect on the emotional functioning component of EF related behaviour. The findings from this study concur with other studies on the prenatal effects of natural disaster and how this exposure can result in greater behaviour problems (King et al., 2012; Walder et al., 2014; Weinstock, 2008), lower cognitive processing (King & Laplante, 2005; Laplante et al., 2007), and learning difficulties (Fuller, 2014). The results indicate that not all aspects of EF are influenced by prenatal exposure to maternal stress, with Emotional Control and emotional regulation the most affected EF components. These findings support the foetal origins hypothesis, which suggests *in utero* exposure to stress can result in long-term changes to behaviour and brain development (Kinsella & Monk, 2009). Furthermore, these results are supported by other reports of ongoing emotional difficulties being witnessed in Christchurch schools (O'Callaghan, 2015). It is likely that the behavioural difficulties faced in Christchurch school with this cohort of children are due to their difficulties with control and regulating their emotional responses.

More specifically, children who were exposed to the earthquake during their third trimester had worse emotional control then those children not exposed at all, or those children exposed during the second trimester. Difficulties with shift skills, and emotional regulation were also more likely to be experienced by these children who were exposed to the earthquake during the third trimester. However, children exposed during the first trimester were also found to have difficulties with Emotional Control. This finding was unexpected as previous studies on prenatal exposure to natural disasters have typically found that exposure during the first or second trimester often results in a more negative outcome for the child, such as: increased behavioural difficulties, lower cognitive and language function, and worse academic performance (Fuller, 2014; King & Laplante, 2005; Torche, 2011; Weinstock, 2005). However, the results of this study are consistent with one study that found exposure to high levels of prenatal stress during the last month of pregnancy resulted in the child being two to three times more likely to have an emotional or behavioural problem at the age of four (King et al., 2012). This is consistent with the life cycle model of stress, which places importance on the timing of exposure to an adverse event (Lupien et al., 2009). However, this study also found children who were *in utero* in first and second trimester had slightly higher than average scores on the Emotional Control scale and so it is likely that difficulties in these areas can be observed in some of the children exposed during the first and second trimester as well.

Similar to other studies that have found a gender-specific pattern of response to prenatal maternal stress (Torche & Kleinhaus, 2012; van Os & Selten, 1998), this study found differing effects for boys and girls. Boys had a mean shift score higher than the standardised mean. This shows that some of these boys are likely to have difficulties moving from one situation to another, do not tolerate change as well as would be expected for their age group, and have difficulty switching attention and changing their mindset when necessary (Gioia et al., 2015), potentially indicating reduced cognitive flexibility. This is consistent with index scores that show boys had a significantly higher ERI score, a combination of emotional control and shift scores, while girls did not. Therefore, boys' shift abilities could be more susceptible to prenatal maternal stress than girls'. These difficulties experienced by boys would be noticeable by parents and teachers. An independent sample t test was carried out to investigate if there was a difference between boys and girls BRIEF 2 scores, however, these results did not reach a level of statistical significance. This is likely the result of the small sample size of the control group, and the difference in the group sizes. However, the one-sample t tests and the observable differences in the descriptive statistics shows there are differences in some areas of EF between boys and girls.

Earthquake exposure during the third trimester of gestation resulted in both boys and girls having higher emotional control and ERI scores. This effect did not reach significance for girls', despite this subgroup having a similar or a higher mean score than boys who were exposed in the third trimester. The small group sizes (5 – 11) in this subgroup analysis likely had an impact on the results. However, these results show a trend for girls to have worse emotional control and emotional regulation if they were exposed to the earthquake during the third trimester, similar to the boys exposed during the third trimester.

To understand possible associations with the severity of exposure, similar questions were used as those used in Project Ice Storm research (King & Laplante, 2005), however, a different rating scheme was used. Rather than one severity score, as in the Project Ice Storm research, BRIEF 2 scores were analysed with individual severity question scores. Correlations were run for each of the maternal scores on severity questions (appendix 6, questions 12-17) and their child's scores on each BRIEF 2 scale and index. These results showed that the worse someone close to the mother was injured, the higher the child's scores on the Inhibit, Organisation, and Emotional Control scales and BRI were. Also, children of mothers who reported more significantly injuring themselves in the earthquake had higher ERI scores. These different outcomes suggest that there are different *in utero* processes when someone close to the mother is injured compared to when the mother herself is injured. Consistent with previous research (Hackman & Farah, 2009), this study found that children's working memory abilities were correlated with income, or more specifically a loss of income related to the earthquake resulted in the child having higher scores on the Working Memory scale. Overall these findings support the general findings of this study, that prenatal exposure to the earthquake affects EF. The correlations, although moderate, show that stress related to earthquake injury, of the mother or someone close to the mother, and the after effects of the earthquake, such as loss of income, are making differences to the children's EF five years later. It is important to note that some children would have been exposed to a combination of these stressors and hence there is the possibility of an additive effect for some children.

The average emotional control and emotional regulation scores from each stress perception subgroup (slightly, moderately, very, and extremely stressed) showed a pattern of worse functioning compared to the standardised average, despite the small subgroup sample size. The average emotional control and ERI scores for the Christchurch children for every stress group was higher than the standardised mean indicating the possibility of even small amounts of earthquake related stress resulting in decreased emotional control and regulation abilities. However, children in the extreme stress subgroup have the largest mean difference on the Emotional Control scale and the ERI. Similar to results from Project Ice Storm (King et al., 2012; King & Laplante, 2005) the trend found in this study indicates that the more stressful the earthquake was as perceived by mothers, the more difficulties with emotional control and regulation. The children in the group for extreme maternal earthquake stress had emotional control scores and emotional regulation score that indicate mild clinical significance, and the difficulties these children have are likely noticeable in the classroom.

Despite the small size of the control group in this study, analysis was conducted to investigate whether the control group results were similar to the expected outcomes on the BRIEF 2 questionnaire. There were no significant differences between control group and standardised scores, therefore, these results support the use of the BRIEF 2 as a measure of EF abilities in a New Zealand population.

Although there is a growing body of literature on the prenatal effects of natural disasters, this is the first study to investigate the prenatal effects of earthquake exposure on EF in Oceania. While other studies have looked at behaviours that are associated with one specific aspect of EF, no studies have investigated the effect on overall EF. The results from this study suggest that prenatal exposure to maternal stress does not impact all EF components, as BRI and CRI and the overall GEC scores were not elevated in this sample, but has a more specific impact on children’s emotional function, and regulation. The children who were exposed to the earthquake *in utero*, especially those in the third trimester of gestation for the disaster, may have disproportionate reactions to seemingly small events and may struggle to control their emotions. Teachers and parents may notice these children cry easily, laugh hysterically or inappropriately, or have temper tantrums. These emotional difficulties can have an adverse effect on schooling as emotional regulation has been found to be an important factor in school readiness, academic achievement, and successful peer interaction (Graziano et al., 2007; Shields et al., 2001).

The findings from this research are important, as early childhood is crucial time for the development of emotions and emotional understanding. Lacking age appropriate development of emotional regulation and competence puts children at risk for a range of developmental problems, such as disruptive behaviours and impaired social functioning (Shields et al., 2001). Emotional regulation involves efforts to adjust emotional arousal in order to promote positive outcomes such as: normative social, cognitive, and language development, the capacity to deal with daily tasks and change, and, for children, academic functioning (Graziano et al., 2007). Age-appropriate emotional regulation is important for successful transition to school (Shields et al., 2001). This study indicates the need for additional support for these children around their emotional functioning.

Policy and Community Implications

Looking at the long-term effects of prenatal earthquake exposure is important, as results might indicate the need for more specific targeting of resources following an earthquake (or other natural disaster) to include more of a focus on pregnant women. The negative impact on children of experiencing prenatal stress associated with a significant earthquake suggests the need for more resources and additional support for mothers immediately following the disaster. The results of this study show that there is the potential for long-term effects of prenatal development, therefore, it would be beneficial in the long term to invest resources into helping reduce the stress faced by pregnant women immediately following the disaster and preventing or minimizing the difficulties faced by the children, schools and communities in the long-term. Additionally, in the years following a natural disaster, the children that were *in utero* could benefit from additional support around developing emotional regulation and emotional management skills. Providing this extra support to children with emotional regulation difficulties has been shown to help children adjust better to the school environment and minimise social and academic difficulties (Shields et al., 2001).

Limitations

One of the limitations of this study was that the results for the Christchurch group could not be compared to the results of same age peers at other schools in New Zealand. This was a result of the poor response rate from mothers outside of Christchurch. The Christchurch parents had a vested interest in the study, and were more likely to return their questionnaires than parents in other cities. If another study like this was to be done again, further incentives may need to be given to parents in the control group to get a better response rate. However, as the BRIEF 2 is a standardised questionnaire the results could still be analysed.

Initially, this study was intended to measure the severity of stress experienced by each individual mother and investigate the relationship between severity and EF outcomes. The severity questions were modelled on severity questions in the Project Ice Storm research (King & Laplante, 2005). However, the scoring method could not be found in any of the articles. Therefore, severity was looked at for each individual question, rather than as a whole, and may have provided a more useful level of detail with this approach.

Another limitation of this study was experienced when analysing subgroup results. When looking at subgroups within the Christchurch group some of the subgroups had only a small number of participants. This resulted in some results not making statistical significance because of the sample size. For example, Project Ice Storm research found that severity of exposure effects were moderated by the timing of the exposure (King & Laplante, 2005). However, this could not be analysed in this study, as the subgroups were too small to get meaningful results.

Years on, Christchurch is still experiencing aftershocks and it is well-recognised that stress levels in many Christchurch families is still high, therefore, it is possible that the ongoing stress is contributing to some of the developmental concerns expressed by school staff. However, the variations in trimester and maternal perception of stress indicate that *in utero* effects on EF are present.

In spite of these limitations these findings contribute to an increasing body of evidence showing that prenatal exposure to natural disasters/maternal stress can have a significant effect on child development. However, more research is needed in this area, in particular to evaluate intervention methods for children and families affected by natural disaster.

Future Research

More research is needed on the long-term effects of prenatal exposure to natural disasters, especially in the New Zealand/Oceania population. It is important to gain more of an understanding of how natural disasters can impact pregnant women, how to better support this group, and how to reduce the potential effects early on, rather than when the children reach school age.

Conclusion

This study looked at the way in which *in utero* exposure to a significant natural disaster can impact on the child years later. The findings show that prenatal exposure to the Christchurch earthquake resulted in children having worse EF functioning than both the control children, and the standardised average. More specifically, those children who were exposed to the earthquake performed worse on measures of emotional control and emotional regulation than would be expected for their age. These children have difficulties being able to regulate their own emotional responses; meaning they likely to overreact to events and have sudden outbursts. Children who have problems with their emotional control are often reported to cry easily, or/and have temper tantrums that aren't age appropriate. These are the problems that are being reported by junior schoolteachers, principals, and parents in the community in Christchurch, and underlie the initial decision to conduct this research. Furthermore, boys appear to be more greatly affected than girls, having more problematic inhibitory behaviour. This shows the potential long-term costs of natural disasters, which should be considered by communities and governments when they prepare for and respond to earthquakes and other natural disasters in the future.

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Appendices

Appendix 1: Information Sheet for Principals

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Educational Psychology Programme
Institute of Education
Massey University
Private Bag 102904
North Shore, Auckland 0745
New Zealand

The Prenatal Effects of the Christchurch Earthquake on Executive Function

My name is Erin Dobson and I am currently completing my Masters of Educational Psychology at Massey University. I would like to invite your school to take part in a research study. Before you decide you need to understand why the research is being done and what it would involve for your school. Please take time to read the following information carefully. Ask questions if anything you read is not clear or if you would like more information. Take time to decide whether or not to take part.

This study is looking at the prenatal effects of the February 2011 Christchurch earthquakes on executive function. Executive function is defined as a set of mental processes crucial for behavioural and cognitive regulation.

This project has been reviewed and approved by the Massey University Human Ethics Committee: Northern, Application 16/12. If you have any concerns about the conduct of this research, please contact Dr Andrew Chrystall, Chair, Massey University Human Ethics Committee: Northern, telephone 09 414 0800 x43317 email humanethicsnorth@massey.ac.nz.

What is the purpose of this study?
This study is being carried out as part of a Masters degree in Educational Psychology. The purpose of this research is to have a better understanding of the long-term effects of the Christchurch earthquake, especially on vulnerable populations, such as children.

Do we have to take part?
It is up to you to decide whether you would like to take part in this study. It is entirely voluntary. The study will be described and information is provided on this sheet. You will then be asked to sign a consent form to show you agreed to have the school take part in this research. You are free to withdraw at any time, without giving a reason.

What will happen if I agree for the school to be involved?
If you agree for your school to be involved, the researcher will meet with parents of the children in the new entrant classrooms. Consent forms and information sheets will be provided for all parents who qualify for the research.

What will be done?
Parents will be asked to complete two questionnaires, screening questionnaire, and a Behaviour Rating Inventory of Executive Function parent report questionnaire. The Behaviour Rating Inventory of Executive Function questionnaires should take no longer than 10 minutes to complete, and the screening questionnaire should take no longer than 10 minutes to complete.

Erin Dobson | Massey University
E-mail: erin-dobson@hotmail.co.nz| phone: 0273716251

What are the possible benefits of taking part?
We cannot promise the study will help you and your school but the information we get from this study will help to increase the understanding of the long-term effects of natural disasters on executive function. In the event of another severe natural disaster, this research could help understand what happens to the children, and prepare the community with ways to help them. Finding out if there are long term effects on executive function is important, as improvements can be made in the executive function of school aged children with early intervention.

What if there is a problem?
If you have a concern about any aspect of this study, you should make contact with me, the researcher, and I will do my best to answer your questions (erin-dobson@hotmail.co.nz. 0273716251). Alternatively, you may contact my supervisor, Judith Ansell (J.M.Ansell@massey.ac.nz).

Will the schools participation in the study be kept confidential?
All schools will remain anonymous and will not be named in the research. All information that is collected from your school and parents during the course of the research will be kept strictly confidential, and any information about your school leaves the university will have names removed so that the participants cannot be identified.

All questionnaires will be stored in a locked cupboard, only accessible by the researcher. The data collected will only be viewed by the researcher and the two university supervisors of this research.

What will happen to the results of the research study?
The data collection and results of this study will be used for my Masters thesis, with the intention of being submitted for publication in a relevant journal in the future. You may also request to have a copy of the results from this study for you and your staff to read. If you wish to receive a copy of the results, please select this option on the consent form.

Erin Dobson | Massey University
E-mail: erin-dobson@hotmail.co.nz| phone: 0273716251

Appendix 2: Principal Consent Form

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Educational Psychology Programme
Institute of Education
Massey University
Private Bag 102904
North Shore, Auckland 0745
New Zealand

The Prenatal Effects of the Christchurch Earthquake on Executive Function

PRINCIPAL CONSENT FORM

I have read the information sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I consent to this school participating in the study under the conditions set out in the information sheet.

I wish/do not wish to request a copy of the results from this study.

Signature: .... **Date:** ....

Full Name - printed ....

Erin Dobson | Massey University
E-mail: erin-dobson@hotmail.co.nz| phone: 0273716251

Appendix 3: Christchurch Parent Information Sheet

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Educational Psychology Programme
Institute of Education
Massey University
Private Bag 102904
North Shore, Auckland 0745
New Zealand

The Prenatal Effects of the Christchurch Earthquake on Executive Function

Kia ora, my name is Erin Dobson. I currently live in Christchurch and have lived here for most of my life. I was in my final year of high school for the February 2011 earthquake and have been in Christchurch for most of the past five years. As well as completing my Masters of Educational Psychology at Massey University, I also work at as a teacher aid at a primary school in Christchurch, and I have worked at a Christchurch after-school care program since 2010. My personal experiences with the earthquake and within the education community in Christchurch make this research very important to me, so I really appreciate you taking the time to participate.

I would like to invite you to take part in a research study that I am completing as part of my degree. Before you decide whether or not to participate, you need to understand why the research is being done and what participation would involve for you. Please take time to read the following information carefully. Ask questions if anything you read is not clear or if you would like more information. Take time to decide whether or not to take part.

This study is investigating whether the Christchurch earthquake has had any effect on the children whose mothers were pregnant with them at the time of the February 2011 earthquake. Nobody knows whether there have been any effects so now that these children are starting school we are interested to see if there are any subtle differences in behaviour. The study is looking at subtle executive function behaviours. Executive function is defined as a set of mental processes that are important for learning and behaviour.

This project has been reviewed and approved by the Massey University Human Ethics Committee: Northern, Application 16/12. If you have any concerns about the conduct of this research, please contact Dr Andrew Chrystall, Chair, Massey University Human Ethics Committee: Northern, telephone 09 414 0800 x43317 email humanethicsnorth@massey.ac.nz.

What is the purpose of this study?
This study is being carried out as part of a Masters degree in Educational Psychology. The purpose of this research is to have a better understanding of the long-term effects of the Christchurch earthquake, especially on children. The aims of this research are to find out if there is an effect of prenatal exposure to the earthquake on executive function five years later, and whether or not the timing of the earthquake during pregnancy has an effect on executive function.

Why have I been invited?

Erin Dobson | Massey University
E-mail: erin-dobson@hotmail.co.nz| phone: 0273716251

The principal of your school has given consent for this school to be involved in this research. You have been invited to participate in this study because you were pregnant with your child during the February 2011 earthquake.

Do I have to take part?
It is up to you to decide whether you would like to take part in this study. It is entirely voluntary and confidential. All the information you need to know is provided on this sheet. Once you have read this sheet you will then be asked to sign a consent form to show you agreed to take part in this research. You are free to withdraw at any time, without giving a reason. Withdrawing or declining to participate will have no impact on your child's education.

Will my taking part in the study be kept confidential?
All information that is collected about you and your child during the course of the research will be kept strictly confidential. Any information about you or your child that leaves the university will have names removed so that you cannot be recognised.

All questionnaires will be stored in a locked cupboard, only accessible by the researcher. My supervisors and I will be the only people to view the data that is collected. Following the completion of the study the data will be securely stored for ten years.

What will I have to do?
You will only be required to fill out two brief questionnaires. A screening questionnaire, and a questionnaire on your child's behaviour that relates to executive function. Together these forms should take no longer than 20-25 minutes to complete.

What are the possible benefits of taking part?
I cannot promise the study will help you personally but the information we get from this study will help to increase the understanding of the long-term effects of natural disasters. Understanding that natural disasters can have long-term effects on children will help prepare communities to deal with these effects, as improvements can be made in the executive function of school-aged children with early intervention.

What if there is a problem?
If you have a concern about any aspect of this study, you should make contact with me, the researcher, and I will do my best to answer your questions (erin-dobson@hotmail.co.nz). Alternatively, you may contact my supervisor, Judith Ansell (J.M.Ansell@massey.ac.nz).

What will happen if I don't carry on with the study?
If you withdraw from the study all the information and data collected from you will be disposed of securely.

What will happen to the results of the research study?
The data collection and results of this study will be used for my Masters thesis, with the intention of being submitted for publication in a relevant journal in the future. You may also request a copy of the results from this study. If you wish to receive a copy of the results, please select this option on the consent form.

Free support services

Erin Dobson | Massey University
E-mail: erin-dobson@hotmail.co.nz| phone: 0273716251

If you feel as though this research has brought up any anxiety for you, you can contact either of the free support services listed below to talk to someone about how you are felling.

- Canterbury support line: 0800 777 846
- Lifeline New Zealand: 0800 543 354

Following the research, if you have any concerns about your child, please talk to your classroom teacher first.

Erin Dobson | Massey University
E-mail: erin-dobson@hotmail.co.nz| phone: 0273716251

Appendix 4: Control Schools Information Sheet

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Educational Psychology Programme
Institute of Education
Massey University
Private Bag 102904
North Shore, Auckland 0745
New Zealand

The Prenatal Effects of the Christchurch Earthquake on Executive Function

Kia ora, my name is Erin Dobson. I currently live in Christchurch and have lived there for most of my life. I was in my final year of high school for the February 2011 earthquake and have been in Christchurch for most of the past five years. As well as completing my Masters of Educational Psychology at Massey University, I also work at as a teacher aid at a primary school in Christchurch, and I have worked at a Christchurch after-school care program since 2010. My personal experiences with the earthquake and within the education community in Christchurch make this research very important to me, so I really appreciate you taking the time to participate.

I would like to invite you to take part in a research study that I am completing as part of my degree. Before you decide whether or not to participate, you need to understand why the research is being done and what participation would involve for you. Please take time to read the following information carefully. Ask questions if anything you read is not clear or if you would like more information. Take time to decide whether or not to take part.

This study is investigating whether the Christchurch earthquake has had any effect on the children whose mothers were pregnant with them at the time of the February 2011 earthquake. Nobody knows whether there have been any effects so now that these children are starting school we are interested to see if there are any subtle differences in behaviour. The study is looking at subtle executive function behaviours. Executive function is defined as a set of mental processes that are important for learning and behaviour.

This project has been reviewed and approved by the Massey University Human Ethics Committee: Northern, Application 16/12. If you have any concerns about the conduct of this research, please contact Dr Andrew Chrystall, Chair, Massey University Human Ethics Committee: Northern, telephone 09 414 0800 x43317 email humanethicsnorth@massey.ac.nz.

What is the purpose of this study?
This study is being carried out as part of a Masters degree in Educational Psychology. The purpose of this research is to have a better understanding of the long-term effects of the Christchurch earthquake, especially on children. The aims of this research are to find out if there is an effect of prenatal exposure to the earthquake on executive function five years later, and whether or not the timing of the earthquake during pregnancy has an effect on executive function. Having a comparison group of children from out of Christchurch allows me to compare the executive function of children exposed to the earthquake, with children who were not exposed to see whether there is a difference.

Erin Dobson | Massey University
E-mail: erin-dobson@hotmail.co.nz| phone: 0273716251

Why have I been invited?
The principal of your school has given consent for this school to be involved in this research. The reason you have been invited to participate in this research is that I am looking for a comparison group of participants who were pregnant for February 22nd 2011 but did not experience the Christchurch earthquake.

Do I have to take part?
It is up to you to decide whether you would like to take part in this study. It is entirely voluntary and confidential. All the information you need to know is provided on this sheet. Once you have read this sheet you will then be asked to sign a consent form to show you agreed to take part in this research. You are free to withdraw at any time, without giving a reason. Withdrawing or declining to participate will have no impact on your child's education.

Will my taking part in the study be kept confidential?
All information that is collected about you and your child during the course of the research will be kept strictly confidential. Any information about you or your child that leaves the university will have names removed so that you cannot be recognised.

All questionnaires will be stored in a locked cupboard, only accessible by the researcher. My supervisors and I will be the only people to view the data that is collected. Following the completion of the study the data will be securely stored for ten years.

What will I have to do?
You will only be required to fill out two brief questionnaires. A screening questionnaire, and a questionnaire on your child's behaviour that relates to executive function. Together these forms should take no longer than 10-15 minutes to complete.

What are the possible benefits of taking part?
I cannot promise the study will help you personally but the information we get from this study will help to increase the understanding of the long-term effects of natural disasters. Understanding that natural disasters can have long-term effects on children will help prepare communities to deal with these effects, as improvements can be made in the executive function of school-aged children with early intervention.

What if there is a problem?
If you have a concern about any aspect of this study, you should make contact with me, the researcher, and I will do my best to answer your questions (erin-dobson@hotmail.co.nz). Alternatively, you may contact my supervisor, Judith Ansell (J.M.Ansell@massey.ac.nz).

What will happen if I don't carry on with the study?
If you withdraw from the study all the information and data collected from you will be disposed of securely.

What will happen to the results of the research study?
The data collection and results of this study will be used for my Masters thesis, with the intention of being submitted for publication in a relevant journal in the future. You may also request a copy of the results from this study. If you wish to receive a copy of the results, please select this option on the consent form.

Erin Dobson | Massey University
E-mail: erin-dobson@hotmail.co.nz| phone: 0273716251

Free support services:
If you feel like as though this research has brought up any anxiety for you, you can contact either of the free support services listed below to talk to someone about how you are felling.

- Lifeline New Zealand: 0800 543 354

Following the research, if you have any concerns about your child, please talk to your classroom teacher first.

Erin Dobson | Massey University
E-mail: erin-dobson@hotmail.co.nz| phone: 0273716251

Appendix 5: Participant Consent Forms for Parents

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Educational Psychology Programme
Institute of Education
Massey University
Private Bag 102904
North Shore, Auckland 0745
New Zealand

The Prenatal Effects of the Christchurch Earthquake on Executive Function

PARENT CONSENT FORM

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I wish/do not wish to request a copy of the results from this study.

I agree to participate in this study under the conditions set out in the Information Sheet.

Signature: .... **Date:** ....

Full Name - printed ....

Phone number ....

Email (if you would like a copy of the results) ....

Erin Dobson | Massey University
E-mail: erin-dobson@hotmail.co.nz | phone: 0273716251

Appendix 6: Participant Questionnaire

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Educational Psychology Programme
Institute of Education
Massey University
Private Bag 102904
North Shore, Auckland 0745
New Zealand

Name: ID number:
(This is required for matching this with the questionnaires. Your name will not be included in the study)

Please circle the answer that best describes you. Try to answer all the questions, however, you may leave questions blank if you do not wish to answer them.

1. Which ethnic group (or groups) do you belong to? *Circle the group or groups that apply to you.*
   a. New Zealand European
   b. Mäori
   c. Samoan
   d. Cook Island Maori
   e. Tongan
   f. Niuean
   g. Chinese
   h. Indian
   i. Other, such as Dutch, Japanese, Tokelauan. Please state: ____________

2. What is your highest level of education?
   a. NCEA level 1
   b. NCEA level 2
   c. NCEA level 3
   d. Trade qualification
   e. Diploma
   f. Bachelors degree
   g. Masters Degree
   h. Doctoral Degree
   i. Other (please specify) ____________

3. Are you employed outside of the home?
   a. Fulltime
   b. Part time
   c. No

4. What is your current household income?
   a. Less than 19,999
   b. 20,000 – 39,999
   c. 40,000 – 59,999

Erin Dobson | Massey University
E-mail: erin-dobson@hotmail.co.nz| phone: 0273716251

d. 60,000 – 79,999
e. 80,000 – 99,999
f. 100,000 – 119,999
g. > 120,000

5. Did your child attend any early childhood education?
   a. Yes, what type? ___________
   b. No

6. What adults currently live in your household?
   a. Just you
   b. You and one or more other adults
   c. You and this child's other parent (or stepparent)
   d. Two parents and one or more other adults

7. How many weeks pregnant were you on February 22nd 2011?
   ________ weeks
   Or, what was your expected due date? _______________

8. What date was your child born? ____/____/2011

9. Were you in Christchurch for the Feburary 22nd 2011 earthquake?
   a. Yes
   b. No

If you answered *no* to the previous question, please go to question 28

10. During your pregnancy, at the time of the earthquake, who lived in your household?
    a. Just you
    b. You and one or more other adults
    c. You and this child's other parent (or stepparent)
    d. Two parents and one or more other adults

11. Which area of Christchurch were you living in at the time?
    a. North
    b. South
    c. East
    d. West
    e. Rural

For questions 12 – 16 please circle the best answer that suits your experiences with the earthquake.

Erin Dobson | Massey University
E-mail: erin-dobson@hotmail.co.nz| phone: 0273716251

	Not at all	Slightly	Moderately	Very	Extremely
12. I was injured in the earthquake	1	2	3	4	5
13. Someone close to me was injured in the earthquake	1	2	3	4	5
14. My residence suffered damage as a result of the earthquake	1	2	3	4	5
15. I suffered a loss of personal income as a result of the earthquake	1	2	3	4	5
16. My street had liquefaction	1	2	3	4	5

17. How many days did you go without power
   a. 0
   b. 1-2
   c. 3-5
   d. 5-7
   e. >7

18. Did you have to leave your home following the quake?
   a. Yes, for how long? ______
   b. No

19. If yes, how long after the earthquake did you leave your home?
   a. Within 12 hours
   b. 12-24 hours after
   c. 1-3 days after
   d. 3-5 days after
   e. 5+ days after

20. Did you leave Christchurch following the earthquake?
   a. Yes, for how long? ______
   b. No

21. Was your house red-zoned?
   a. Yes
   b. No

22. Was your house a rebuild?
   a. Yes

Erin Dobson | Massey University
E-mail: erin-dobson@hotmail.co.nz| phone: 0273716251

b. No

23. How many times have you moved house since the earthquake?
    a. 0
    b. 1-2
    c. 3-5
    d. 5-7
    e. >7

For questions 25 and 26 please circle the best answer the best suits your experience.

	Not at all	Slightly	Moderately	Very	Extremely
25. How personally stressful did you find the earthquake at the time?	1	2	3	4	5
26. How personally stressful do you consider the earthquake to be now?	1	2	3	4	5

27. Is there any further information regarding your experience with the earthquake you think could be important for this research?

Life Experiences Since the Earthquake/February 22nd 2011

Listed below are a number of events which sometimes bring about change in the lives of those who experience them. Please provide an answer for those events which you have experienced in the past five years (since the earthquake).

Please indicate the extent to which you viewed the event as having either a positive or negative impact on your life at the time the event occurred. That is, indicate the type and extent of impact that the event had. A rating of —3 would indicate an extremely negative impact. A rating of 0 suggests no impact either positive or negative. A rating of +3 would indicate an extremely positive impact.

Erin Dobson | Massey University
E-mail: erin-dobson@hotmail.co.nz| phone: 0273716251

	Extremely negative	Moderately negative	Somewhat negative	No impact	Slightly positive	Moderately positive	Extremely positive
28. Major change in living conditions of family (building new home, remodeling, deterioration of home, neighborhood, etc.)	-3	-2	-1	0	1	2	3
29. Marital separation from partner	-3	-2	-1	0	1	2	3
30. Major change in financial status (a lot better off, or a lot worse off)	-3	-2	-1	0	1	2	3
Other experiences which have had an impact on your life since the earthquake/Feb 22nd 2011. List and rate							
31. ______________________	-3	-2	-1	0	1	2	3
32. ______________________	-3	-2	-1	0	1	2	3
33. ______________________	-3	-2	-1	0	1	2	3
34. ______________________	-3	-2	-1	0	1	2	3

35. Is there any information regarding your child that you think could be important for this research?

Erin Dobson | Massey University
E-mail: erin-dobson@hotmail.co.nz| phone: 0273716251

36. Is there anything you wish to add, or comment on?

Thank you very much for taking the time to complete this questionnaire. Your responses are important to our research.

Erin Dobson

Erin Dobson | Massey University
E-mail: erin-dobson@hotmail.co.nz| phone: 0273716251