Prenatal Maternal Stress and Infant Development as Assessed by Maturity of Play Behavior: A QF2011 Queensland Flood Study

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Abstract

Background: Prenatal maternal stress (PNMS) may influence the cognitive development of children. However, it is very difficult to examine this variable because the child's temperament, which can also be affected by PNMS, often limits the child from performing at their best. This association between PNMS and cognitive development was observed in a study by Laplante et al. (2007), which followed Zelazo and Kearsely's (1980) 15-minute play protocol to test the play maturity in 2-year-old infants whose mothers were affected by the Ice Storm in Quebec during pregnancy. Although Laplante et al. found a relationship between PNMS and impaired cognitive outcomes in the offspring, especially for children exposed in early pregnancy, barely any other studies have been conducted using observational methods that are unbiased by variables (like the child's temperament) to arrive at definitive conclusions about play maturity in children. To date, no replications of the Laplante et al. (2007) study have been published using a different cohort affected by a different disaster during pregnancy.

Objective(s): The main goal was to replicate findings from Laplante et al., 2007 using subjects from a different disaster. The first objective of this study was to determine if PNMS and timing of exposure influence play maturity in children affected by a different disaster: the 2011 Queensland Flood (QF2011). The second objective was to determine if in-utero exposure to the flood in the 1st and 2nd trimester is a critical time period for creating a sensitivity to PNMS and impacting play maturity. The study also tested whether the associations between PNMS and play maturity would be affected by adjusting for variables such as child's birth order, sex, temperament, and daycare enrollment.

Hypothesis: It was hypothesized that exposure to higher levels of disaster-related PNMS would predict higher levels of immature stereotypical play along with lower levels of mature functional play and play diversity in children at both 16 and 30 months of age. It was also anticipated that the effects of PNMS on play behavior will be greatest for children exposed to the flood during the 1st or 2nd trimester and that the effect of PNMS on the child's play maturity will still be significant even after adjusting for the child's birth order, sex, temperament, and daycare enrollment.

Method: The 230 women who had been exposed to the 2011 flooding in Queensland, Australia during their 1st, 2nd, or 3rd trimester of pregnancy were recruited shortly after the flood in order to assess their PNMS. The study used videos available from their children whose play behavior was assessed at 16 months (n = 142) and 30 months (n = 135). The Mangold Observer video coding software was used to code the play behavior.

Results: For children at the ages of 16 and 30 months, a trimester effect was visible where early exposure to the disaster rendered the children sensitive to the effects of PNMS. At 16 months, early exposure was associated with greater sensitivity to PNMS such that the higher the PNMS the better cognitive development (interactions); however, late exposure was generally associated with worse cognitive outcomes (especially main effects). At 30 months, no significant main effects were found between PNMS and play maturity. However, a similar timing-by-PNMS interaction trend was found where early exposure was sensitive to PNMS.

Discussion: These findings lend support to the idea that timing influences the relationship between PNMS and child cognitive outcomes.

Résumé

Contexte: Le stress prénatal maternel (SPM) peut influencer le développement cognitif des enfants. Cependant, il est très difficile d'examiner cette variable, car le tempérament de l'enfant, qui peut également être affecté par le SPM, empêche souvent l'enfant de livrer sa meilleure performance. Ce lien entre le SPM et le développement cognitif a été observé dans une étude de Laplante *et al.* (2007) ayant suivi le protocole de jeu de 15 minutes de Zelazo et Kearsely (1980) pour tester la maturité de jeu chez les enfants de 2 ans dont les mères avaient été touchées par la tempête de verglas au Québec pendant leur grossesse. Bien que Laplante et al. (2007) ont trouvé une relation entre le SPM et un développement cognitif altéré chez les enfants, surtout chez ceux qui étaient exposés au désastre tôt dans la grossesse, presque aucune étude n'a utilisé des méthodes d'observation qui considèrent les variables confondantes (comme le tempérament de l'enfant) afin d'arriver à une conclusion définitive sur la maturité de jeu chez les enfants. À ce jour, aucune réplication de l'étude de Laplante et al. (2007) n'a été publiée en utilisant un nouvel échantillon de femmes affectées par une catastrophe pendant leur grossesse.

Objectif(s): L'objectif principal était de reproduire les résultats de Laplante et al., 2007 en utilisant des individus ayant vécu une situation similaire. Le premier objectif de cette étude était de déterminer si le SPM et le moment de l'exposition influencent la maturité de jeu chez les enfants affectés par une catastrophe différente : l'inondation de Queensland en 2011 (QF2011). Le deuxième objectif était de déterminer si l'exposition *in utero* à l'inondation au cours des 1er et 2e trimestres est une période critique pouvant rendre sensibles les jeunes enfants au SPM et avoir un impact sur la maturité de jeu. L'étude a aussi testé si les associations entre le SPM et la maturité de jeu seraient affectées en ajustant pour des variables contrôles (p.ex. rang de naissance de l'enfant, sexe, tempérament et inscription à la garderie).

Hypothèse: Notre hypothèse était que l'exposition à des niveaux plus élevés de SPM liés à une catastrophe permettrait de prédire des niveaux plus élevés de jeu stéréotypé ainsi que des niveaux inférieurs de jeu fonctionnel et de diversité de jeu chez les enfants à 16 et 30 mois. Nous prévoyions également que les effets du SPM sur le comportement de jeu seraient les plus importants pour les enfants exposés à l'inondation au cours des 1^{er} et 2^{e} trimestres et que l'effet du SPM sur la maturité de jeu resterait significatif même après ajustement pour les variables contrôles.

Méthode: 230 femmes ayant été exposées aux inondations de 2011 dans le Queensland, en Australie, au cours de leur 1^{er}, 2^{e} ou 3^{e} trimestres de grossesse, ont été recrutées peu de temps après l'inondation afin d'évaluer leur SPM. L'étude a utilisé des vidéos de leurs enfants dont le comportement de jeu a été évalué à 16 mois (n=142) et à 30 mois (n=135). Le logiciel de codage vidéo Mangold Observer a été utilisé pour coder les comportements de jeu.

Résultats : Pour les enfants âgés de 16 et 30 mois, un effet de trimestre a été observé : une exposition précoce à la catastrophe a accru la sensibilité des enfants aux effets du SPM. À 16 mois, une exposition précoce était associée à une plus grande sensibilité au SPM, de sorte que plus le SPM était élevé, meilleur était le développement cognitif ; en revanche, une exposition tardive était généralement associée à de pires résultats cognitifs (en particulier les effets principaux). À 30 mois, aucun lien significatif n'a été trouvé entre le SPM et la maturité de jeu. Cependant, une tendance similaire d'interaction entre le moment d'exposition et le SPM a été observée : une exposition précoce rendait les enfants sensibles au SPM.

Discussion: Ces résultats soutiennent l'idée que le moment de l'exposition influence la relation entre le SPM et le développement cognitif de l'enfant.

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This journey of completing my master's degree has been the most strenuous yet the most rewarding experience of my life. There are a lot of people without whose assistance I would not have been able to accomplish this goal.

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Contribution of Authors

The thesis is built on the collaborative work done by many researchers that have successfully contributed to the 2011 Queensland Flood study as part of the Stress in Pregnancy International Research Alliance (www.mcgill.ca/spiral).

Dr. Suzanne King took the initiative to collaborate with researchers including Dr. Marie Paule Austin and Dr. Sue Kilda to build upon the ongoing studies. Queensland Flood was added as another source for collecting data on the effects of PNMS from natural disasters. Thus, before I joined the King lab, measures had already been taken to collect data on the ongoing project. This includes the measures of prenatal maternal stress and the videos of the children's play sessions at both ages.

Researchers Dr. Belinda Lequertier, Dr. Katrina M. Moss, Donna Amaraddio, and Dr. Gabrielle Simcock were responsible for observing and video recording the children's play behavior at both ages, 16 and 30 months. Additionally, Dr. Donna Amaraddio was also responsible for participant recruitment and bookings.

My contribution to the ongoing study was viewing the videotapes and coding the play behavior of children at both ages, 16 and 30 months. Undergraduate McGill Student, Xiao Xia Zhang, also contributed in this process to assure good inter-rater reliability. I was also primarily responsible for the statistical analysis and data interpretation for this study, where I was assisted by our lab statistician, Guillaume Elgbeili.

My supervisor, Dr. Suzanne King, and advisory committee members Dr. Ashley Wazana and Dr. Phyllis Zelkowitz, were involved throughout the project and assisted with manuscript edits.

List of Abbreviations and Acronyms

EDI	Early Development Instrument
IES-R	Impact of Event Scale - Revised
COSMOSS	Composite Score for Mothers' Subjective Stress
M@NGO	Midwives @ New Group Practice Options
PNMS	Prenatal Maternal Stress
PTSD	Post-Traumatic Stress Disorder
QFOSS	Queensland Flood Objective Stress Score
QFOSS_lg	Queensland Flood Objective Stress Score Log Transformed
PDI	Peritraumatic Distress Inventory
PDEQ	Peritraumatic Dissociative Experiences Questionnaire
QF2011	2011 Queensland Flood Study
SPIRAL	Stress in Pregnancy International Research Alliance
SES	Socio-economic Status
SEIFA	SEIFA score: Australian Socio-Economic Indexes for Area
STST	Short Temperament Scale for Toddlers

Cognitive Development

Jean Piaget in 1936 defined intelligence to be more than just a static concept. According to him, children move through four different stages of mental development: sensorimotor, preoperational, concrete operational, and formal operational stage (Huitt & Hummel, 2003). Each stage shows a cognitive transition from conception to adulthood highlighting the maturity of the human brain in terms of how people process and make sense of the world around them. Furthermore, it is the cognitive development in early childhood that can be predictive of lifelong success. Studies have found first grade reading ability to be a strong predictor for the child's 11th grade outcomes (Cunningham & Stanovich, 1997) with early math skills having the greatest predictive power, followed by reading and then attention skills (Duncan et al., 2007). However, there can be many factors that affect this normal transition, thereby leading to variations within the population. Both genetics and environmental factors have an equally important role to play in influencing cognitive development (D'Onofrio et al., 2010); Voss et al., 2012).

Twin studies have proven cognitive abilities to be amongst the most heritable behavioral traits, with 50% of the variation in cognitive abilities attributable to genes (Bouchard & McGue, 1981). In a longitudinal study following Swedish same-sex twin pairs (approximately 80 years old), developmental comparisons yielded that heritability for cognitive abilities increased from 20% in infancy to about 40% in childhood to 50% and 60% in adolescence and adulthood, respectively (McClearn et al., 1997). Additionally, in another longitudinal study conducted on 209 twin pairs, genetic influences were found to be the main driving force for determining continuity in cognitive skills in 5, 7, 10, and 12-year-old children respectively (Bartels et al., 2002).

Meanwhile, although the aforementioned studies convey the influence of genetics on cognition, there is strong evidence suggesting that children's cognitive abilities are also affected by their environment. One study (Engelhardt et al., 2019) found that shared environmental influences explained 100% of the variability in cognitive abilities in children between 7-20 years of age, which was accounted for by combining measures of parents' socioeconomic status (SES), neighborhood SES and the child's school demographic composition with race (Engelhardt et al., 2019). Previous studies have also found family income and poverty status as the two most powerful correlates of children's cognitive development and behavior (Duncan et al., 1994). The lack of resources and economic deprivation are even known to diminish the cognitive development of 3-year-old children (Kiernan & Huerta, 2008). Additionally, there have been more studies to establish the prevalence of the consequence of 'deprivation', confirming that children with low SES along with low intellectual ability at 22 months of age are likely to show similar low intellectual skills as late as age 10 (Feinstein, 2003). This was assessed by asking the 22-month-old children to complete a range of different tasks, like pointing to their eyes to illustrate understanding of language; putting on their shoes, as an indication of personal development; drawing lines and stacking cubes as indicators of locomotor ability, etc.)

Among the other environmental teratogens, nicotine use during pregnancy is also associated with cognitive delays (Pauly & Slotkin, 2008). Maternal smoking has been associated with lower scores in arithmetic and spelling tasks among children between 5.5 and 11 years of age (Bastra et al., 2003) as well as lower cognitive developmental scores in 3-year-old children (Fox et al., 1990). Moreover, the use of other substances like alcohol and cannabis are also linked to developmental problems (Willford et al., 2004; Bailey et al., 2004) However, there has been considerable attention paid in recent decades to another non-genetic risk factor which is most relevant to the current area of research for its effects on altered fetal development, commonly known as prenatal maternal stress.

Prenatal Maternal Stress

The prenatal period is considered a time of rapid changes when fetal organs are at a vulnerable stage of organizing and disorganizing influences (Davis & Sandman, 2010). Influences on the fetus have been defined as fetal programming, a process whereby prenatal insults can have long-lasting effects on the developing fetus (Barker, 2004) via the Hypothalamic Pituitary Adrenal (HPA) axis (Davis et al., 2011). During the foetal period, the brain grows rapidly. This fast growth rate makes the fetal brain extremely vulnerable to hormones that reach it in excess amounts as a consequence of maternal stress (Weinstock, 2008). These hormones can then further impede the formation of appropriate neural connections and reduce plasticity and neurotransmitter activity levels which can lead to subtle changes in cognitive functioning and behavior (Weinstock, 2008). In general, *in utero* exposure to high levels of prenatal maternal stress (PNMS) is linked to deficits in cognitive/language, motor, and behavioral development (Huizink et al., 2002). Furthermore, children exposed *in utero* to high levels of PNMS also show altered HPA functioning (Yong Ping et al., 2015; Gutteling et al., 2005).

These effects of PNMS on offspring have been significantly studied across laboratory animals in controlled settings. Animal studies have an advantage over human studies because of the possibility of randomization. Moreover, animal studies involving random assignment to stressful conditions during pregnancy have shown to increase fear responses to novel, intimidating environments (Poltyrev et al., 1996) as well as higher startle responses among rats (Tazumi et al., 2005). Among squirrel monkeys, PNMS has also been found to decrease motor maturity leading to shorter attention spans, reduced motor activity, and slower reaction time (Schneider & Coe, 1993). Similarly, rhesus monkeys exposed to prenatal stress have also displayed reduced attention spans and neuromotor capabilities as early as the first month of life (Schneider et al., 2002). While many animal studies have established that prenatal stress leads to alterations in the functioning of the HPA axis and further lifelong problems, it has also been shown to cause major cognitive deficits (Schneider et al., 1999).

Although this period of fetal programming is easier to test on animals, the results of animal studies cannot be easily generalized to humans due to the possibility of both protective and risk factors operating between the objective hardship and the subjective distress following an event (Laplante et al., 2004). It is also not ethical to subject pregnant women to stressful conditions, which is why many human studies lack internal validity (Laplante et al., 2004). Objective stress refers to the external forces of an event acting upon an individual whereas subjective distress represents the psychological reactions (anxiety, depression, panic) associated with the experience of an event. For example, hyperarousal, intrusive thoughts, avoidance etc. are all different ways in which some people react to a potentially traumatic experience. The majority of human studies have, however, laid more emphasis on studying the associations between non-objective stress and the developing fetus. Related studies found that by 18 months of age, prenatal maternal depression was associated with cognitive development independent of postnatal depression (Koutra et al., 2013). It even correlated with lower IQ scores as early as 8 years of age. Additionally, in both boys and girls between 6 to 9 years of age, high levels of pregnancy-specific anxiety were associated with lower visuospatial working memory performance and inhibitory control (Buss et al., 2011). However, other studies report a discrepancy with the above findings with no correlation established between the mother's emotional state during pregnancy and the child's cognitive performance around 3 years of age (Kiernan & Huerta, 2008).

While these studies show the harmful consequences of PNMS on the developing fetus, the real challenge associated with these studies is the complexity of uncovering the processes that are responsible for the effects of PNMS on the child's developmental outcomes (King et al., 2015). How much of an outcome caused by PNMS is associated with the objective severity of the mother's exposure to the stressful event? What magnitude is caused by the mother's subjective level of distress? How much of it is because of her physiological response? And how can these different variables interact to increase the developmental risks of the unborn child? Furthermore, the stressful situations recorded in these studies lacked randomization and did not take into account a measure of objective stress, thus challenging the reliability of these studies for measuring the impact of PNMS. But for those that did take 'objective stressors' into account, classifying these stressors as completely 'independent' was complex. Studies related to naturally occurring life events found that children of mothers who underwent divorce or instances of 'partner cruelty' were more susceptible to lower cognitive maturity scores (Talge et al., 2007), while maternal prenatal family stress was found to be associated with children's low word comprehension and poorer non-verbal cognitive skills (Henrichs et al., 2011). Additional studies reported otherwise, with vocabulary development at 10 years of age having no association with mothers' experience of different stressful life events during pregnancy (Whitehouse et al., 2010).

However, most naturally occurring events cannot be classified as ‘independent’ stressors because of the inability to disentangle the influence of a woman’s own personality traits, which may also be genetically passed on to the child. To eliminate this problem, the ‘sudden onset’ of a natural disaster is completely independent of the ‘control’ of an individual (King et al., 2014) and serves as a prominent ‘independent’ stressor to study the effects of PNMS affecting pregnant women on a large scale. Natural and man-made disasters, thus, act as “natural experiments” helping to randomize the distribution of stress exposure without harming the internal validity of such experiments.

Natural Experiments

“Natural hazards are threatening events, capable of producing damage to the physical and social space where they take place not only at the moment of their occurrence, but on a long-term basis due to their associated consequences” (Alcántara-Ayala, 2002). With temperatures gradually increasing every year, climate change can have disastrous impacts such as an increase in the global mean sea level, retreat of glaciers, shifts of plant and animal ranges, and an increase in the frequency and severity of severe weather events, etc. (Van Aalst, 2006). Natural disasters, with their sudden onset and ability to randomize the distribution of stress exposure, are an appropriate means of obtaining data to assess the impact of PNMS. Thus, initiatives have been taken to use natural disasters as independent stressors to study their influence on child development.

SPIRAL

The Stress in Pregnancy International Research Alliance (www.mcgill.ca/spiral) is a collection of studies investigating the consequences and mechanisms of PNMS on child development, using natural disasters as the quasi-randomized stressor. The program takes into account the different categories of stress and combines different methods such as assessing pregnant women's self-reported information related to their levels of objective hardship or exposure, as well as their subjective distress level, and also by examining stress hormones such as cortisol to get a complete understanding of the impact. The fundamental goal is to determine how such factors come to play a role in influencing the child's cognitive, behavioral, motor, and physical functioning across development. So far, the program has covered many disasters like Quebec's Ice storm, Iowa Flood and Queensland Flood, collecting useful data for further research on the consequences of natural disasters.

An example of catastrophic consequences of global warming can be attributed to Quebec's 1998 Ice Storm which led to power outages lasting up to 6 weeks and affecting more than 1.4 million households. Rated as the most expensive natural disaster in Canadian history, the event resulted in $3 billion worth of lost income to businesses and another $1 billion to hydroelectric infrastructural repairs (Laplante et al., 2008). With around 700 municipalities affected, this storm was the source of enormous data for the ongoing research on the impact of natural disasters on pregnant women and the development of their fetuses.

Following on the aforementioned disaster, another source of data related to PNMS and associated child outcomes was the flood that broke out in Queensland. In early January 2011, severe floods devastated the state of Queensland, Australia affecting nearly 70 towns. The majority of the state was declared a disaster zone, with the flooding reaching its peak in the state capital of Brisbane. Furthermore, with damages worth one billion dollars, 2100 streets were evacuated, 20,000 homes were flooded and approximately 40 deaths were associated with the floods (King et al., 2015). While both these disasters accounted for major economic and ecological damages, it was also the primary focus of SPIRAL researchers to study PNMS among women pregnant during that time.

The SPIRAL alliance aims to study the consequences and mechanisms of PNMS inflicted by these disasters by incorporating different methods. One of the methods was a screening instrument to measure ‘objective hardship’ influenced by the work of Norris in 1990. SPIRAL measures objective stress by assessing these aspects of a natural disaster: Loss, Threat, Scope, as well as Change. ‘Loss’ is defined as the loss of both people and property. ‘Threat’ indicates any event that puts the life or integrity of an individual at stake. ‘Scope’ refers to the degree and duration to which individuals were exposed to the disaster which includes the duration of loss of electricity and communication services. Lastly, the degree of deviation as a result of the disaster is seen as a measure of ‘Change’.

Subjective distress, which is the psychological reaction (anxiety, depression, panic) associated with the experience of an event, was recorded by distributing questionnaires.

SPIRAL also assesses the effects of PNMS experienced by the mother by evaluating their cognitive appraisal of the event. Cognitive appraisal is how an individual evaluates the experience of a stressful event. It can range from very positive, to neutral to very negative. Depending upon the degree to which they experience the event, it can be an important predictor variable in an infant's developmental problems (although its association with cognitive development has not yet been tested).

The timing of the stressor is also seen as an important moderator of PNMS effects on the fetus. Most of the SPIRAL studies thus reported a trimester effect associated with developmental outcomes.

Objective Stress and Cognitive Development

The physical hardship caused by a stressful event has been known to have some long-term consequences. SPIRAL studies reported negative correlations between mothers' objective hardship and infant problem-solving skills in 6-month-old children impacted by the Queensland Flood before birth (Simcock et al., 2017). Similar studies conducted on 2-year-old children affected by the ice storm disaster also found objective hardship to be negatively correlated with Bayley MDI scores and language abilities (Laplante et al., 2004), and again at 5 ½ years of age, objective hardship was found to be negatively correlated with verbal IQs and language abilities (Laplante et al., 2008). However, for children affected by the Queensland Flood, objective hardship was not associated with fine motor skills and gross motor development at around 16 months of age (Moss et al., 2017).

Subjective Distress and Cognitive Development

The psychological reactions following the stressful event are also known to have many detrimental outcomes. The mother's Post Traumatic Stress Disorder (PTSD) symptoms from the Queensland Flood had a negative correlation with the child's fine motor skills at 16 months of age, which was measured with the Bayley Scales (Moss et al., 2017). Furthermore, in mothers affected by the 1998 Quebec Ice Storm, similar results were found in 2-year-old children: PTSD symptoms were negatively correlated with Bayley MDI scores and productive language abilities (Laplante et al., 2004). Similarly, for the Iowa flood study, long term effects of maternal subjective distress were observed in 5.5-year-old children affected by the event. The children received lower Bayley scores as well as lower receptive (understanding) and productive (speaking) language scores (Laplante et al., 2018).

Cognitive Appraisal and Other Findings

The way a person evaluates a stressful event also affects the way that event impacts their life. Significant findings show pregnant women's cognitive appraisal of Quebec's Ice storm having effects on the genome-wide DNA methylation of the child at 13 years of age (Cao-Lei et al., 2015). Additionally, mothers' cognitive appraisal has been found to moderate the effects of timing on motor development in infancy (Moss et al., 2017; Moss et al., 2018).

Timing of Exposure and Cognitive Development

The timing of a stressor during pregnancy can influence a variety of outcomes according to the structure or system in the fetus that is being developed, or is in ascendance, at that time. SPIRAL studies have often found that the timing of the disaster in gestation moderates the effects of PNMS on child outcomes. Children whose mothers reported experiencing severe objective hardship from the ice storm during the 1st and 2nd trimester, showed lower cognitive development, as assessed by the Bayley scales, and language development, as assessed by a maternal report, at 24 months of age (Laplante et al., 2004). Similarly, for children exposed to the Iowa flood before birth, decreased cognitive functioning skills (i.e., lower Bayley scores) were observed in 5-year-old children if the exposure occurred early in gestation (Laplante et al., 2018). Conversely, no effects of stress severity on the MDI scores were found for children exposed to the ice storm in the 3rd trimester of pregnancy (Laplante et al., 2004), but the same children showed no trimester effect at all at age 5 (Laplante et al., 2008). Although early-mid-gestation exposure seems to be associated with cognitive development, third-trimester exposure appears to be associated with lower motor development as seen in Project Ice Storm (Cao-Lei et al., 2014) and for children in QF2011 (Moss et al., 2017).

Although these studies were conducted to measure performance on structured tasks such as the Bayley Scales, a child's performance on these tasks might also reflect temperamental or behavioral characteristics rather than purely cognitive skills due to the presence of the experimenter; that is, children who are inhibited or oppositional due to the effects of PNMS may not perform at their best in testing situations involving an unfamiliar tester. Publications from the QF2011 study found similar associations, where high levels of maternal anxiety and depression were associated with negative infant temperament: in general, higher levels of subjective PNMS were associated with more irritability, whereas objective stress was only associated with heightened irritability in boys as compared to girls (Simcock et al., 2017). This hampers the validity of the test, therefore requiring the introduction of a different method of assessment without compromising the true essence of the experiment. Thus, videotaping a non-structured free play session, that is, in the absence of an unfamiliar research assistant, helps to circumvent potential confounding factors such as the child's temperament.

Play Behavior

A non-structured free play session is independent of confounding variables like temperament and other behavioral characteristics that can interfere with the validity of a test intended to measure a child's cognitive skills (Zelazo and Kearsley, 1980). Play maturity is a construct that represents a non-verbal and non-social measure of cognitive development (Laplante et al., 2007). In 1980, Zelazo and Kearsley conducted a study examining a 15-minute free play session of 64 infants belonging to age groups of 9.5, 11.5, 13.5, and 15.5 months. The protocol included 28 individual objects belonging to 3 different categories: neutral and those considered to be preferred by males, and females. This free play setting not only allowed the children to freely access each category of toys, but also aided the display of non-directed preferences (Zelazo and Kearsley, 1980). "*It was reasoned that the availability of realistic toys that lent themselves to object-specific, functionally appropriate uses would provide a vehicle for the infant's expressions of his/her capacity to generate specific associations relevant to those toys*" (Zelazo and Kearlsey, 1980, p. 2). Three types of play behavior were coded from this free play session (stereotypical, relational, and functional) along with 36 previously defined adult-like acts also known as displayed hypotheses. Stereotypical play consists of actions such as fingering, mouthing, banging, and waving. It was regarded as the most immature form of play behavior and was dominant at 9.5 months of age. Relational play, which was the inappropriate association of toys, involved the child bringing two different toys together without serving any useful function.

This type of play became more evident by 13.5 months. Lastly, functional play, which was viewed as the most mature form of play, involved the infant appropriately using the toys in a previously determined adult-like manner. This play type was dominant among 15.5-month-old children (Zelazo & Karsley, 1980).

The study found that stereotypical play behavior decreased rapidly from an average of 87% of total play acts at 9.5 months to an average of 22% total play acts at 15.5 months of age. Furthermore, functional play increased from an average of 1.5% of total play acts at 9.5 months to an average of 52% of total play acts at 15.5 months. "*This shift from stereotypical to functional play reflects a shift from reflexive action to conscious manipulation of mental representations of real-world objects*" (Laplante et al., 2007, p. 2). A parallel increase was also found in the breadth of functional acts (displayed hypotheses) exhibited by the infants increasing from an average of 0.32 acts per 15 minutes at 9.5 months to an average of 10.38 acts per 15 minutes at 15.5 months. This increase in terms of both quantity of play (number of different displayed hypotheses) and quality of play (time spent engaging in functional play) represents a period of cognitive metamorphism that occurs at the beginning of a child's second year (Zelazo & Leonard, 1983).

The Laplante et al., (2007) Project Ice Storm Study: Effects of Prenatal Maternal Stress

The Zelazo study prompted the initiation of the Ice Storm assessments undertaken by Dr. David Laplante (2007) who used this same procedure for testing cognitive development in infants. The sample was from Project Ice Storm, a longitudinal study that examined the effects of PNMS on outcomes of children exposed to the ice storm while in utero (Laplante et al., 2004;

King & Laplante, 2005; King et al., 2000). The aim was to measure the play abilities of 2-year-old children and to examine if the in-utero exposure to varying degrees of PNMS has an impact on the play maturity of the child. The study found that the greater the mothers' objective hardship the lower their children's levels of mature play and higher their levels of immature play. While Zelazo had found that at 15.5 months of age children engaged in functional play about 52% of the time, 24-month old children exposed to high objective PNMS from the Quebec ice storm spent only 42% of the time in functional play. This suggests a delay of greater than 9 months in cognitive maturity. Similarly, higher levels of subjective PNMS were also associated with higher levels of stereotypical play and significantly lower number of displayed hypotheses. However, subjective stress reactions were marginally associated with lower levels of functional play. There was also a decline in the number of displayed functional acts associated with more subjective PNMS. Twenty-four-month-old in-utero stress-exposed children displayed 10 different functional acts (Laplante et al., 2007) as compared to younger 15-month-old children who displayed 10.4 number of appropriate functional acts (Zelazo & Kearsley, 1980). This points towards a developmental delay in the ice storm cohort greater than 8 months. The timing of exposure was also taken into consideration to analyze if a certain trimester had more profound effects as compared to others. It was found that the effects of PNMS were greatest when the infants were exposed during the 1st or 2nd trimester.

However, although these results imply that objective PNMS has a negative impact on children's cognitive development, no replications of the Laplante et al., 2007 study have been conducted to verify if the results can be repeated. And even though there is ample research on the relationship between Prenatal Maternal Stress (PNMS) and impaired cognitive outcomes in the offspring, very few studies using observational methods that are unbiased by potentially confounding variables (like the child's temperament and other variables) have been published to arrive at definitive conclusions about play maturity in children. Moreover, extraneous factors like birth order, temperament, daycare enrollment and sex of the child might play a confounding role in influencing the role of PNMS on the cognitive development of the child that were not taken into account, as described below.

Potential Covariates

Over the years, many social scientists have studied the relationship between intelligence and birth order. While some claim it is an important factor in accounting for intellectual development (Belmont & Marolla, 1973; Zajonc and Markus, 1975; Heiland, 2009) this is not a common consensus. Later studies suggest that this assumption of birth order affecting intelligence is a result of an indirect measure of several potential biases like parent's education level, socio-economic status (SES), quality of schooling and many other factors that have no significance once these factors are controlled for (Wichman et al., 2006). Nonetheless, the belief in the effect of birth order on play maturity, where younger children may be influenced by observing older siblings playing, persists, and needs to be considered.

Enrollment at a daycare facility may also influence the child's cognitive abilities. Children are presented with the opportunity to interact with other children and learn other motor or gross skills through observation or modelling. "Daycare is any type of institutional out of home care for children younger than five years of age, independent of who provided the daycare (government, private or a combination of both)" (Leroy et al., 2012, p. 473). A study focusing on

Latin American countries such as Columbia used a community-based approach to study the impact of daycare facilities on child development. The Hogares Comunitarios de Bienestar (HCB) intervention, targeting children under the age of 6, found noticeable effects of the program on cognitive development. Using the Early Development Instrument (EDI), positive impacts on cognitive development were recorded in children older than 49 months, with longer exposure to the program resulting in larger impacts (if exposure lasted for 2 to 4 months, or 5 to 15 months or more than 16 months). A similar daycare program in Bolivia had a positive effect on gross and fine motor, language, and psycho-social skills (Behrman et al., 2004). The program led to an increase in all the skills by 2-6% in children between the age group of 37 and 58 months (Leroy et al., 2012).

Another potential factor that should be controlled for includes the child's sex. A study conducted on a large sample (438 girls and 350 boys) between the age of 5 and 16 years reported gender differences in oral language (language expression and language comprehension) spatial abilities (recognition of pictures seen from different angles), and visual (Object Integration Test) and tactile perceptual tasks, with boys outperforming girls in every other scenario except for the tactile tasks (Ardila et al., 2011). The majority of these gender studies found that females outperform males on sub-tests of verbal ability (Eccles et al., 1983; Wigfield et al., 2002). However, in terms of play behavior, males are more likely to be engaged in activities that involve navigation whereas the activities of females involve fine-motor coordination. This highlights the sexual division of labor that can have a significant impact on the course of action for play behavior (Silverman and Eals, 1992). As such, sex should be controlled for in any study of PNMS and play behavior.

The child's temperament can also be a confounding factor. Zelazo suggested that because oppositional and non-compliant behavior in at-risk children may interfere with standardized testing procedures (Zelazo, 1982; Zelazo, 2001), the results can be indicative of their level of oppositional behavior rather than what the test is standardized to measure. In a study of free-play sessions, even though the task is not directly administered by an unfamiliar tester, the presence of the tester and the unfamiliar environment could make a difference in children of different temperaments.

The fact that the majority of the PNMS and child development research studies the associations between potentially non-independent life events or maternal mood and child cognitive development, makes it difficult to determine the extent to which their results reflect the effects of the prenatal environment, the postnatal environment, or the genetic transmission of maternal traits. Thus, natural experiments such as Project Ice Storm, which can tease apart the effects of the objective degree of maternal hardship due to exposure to a purely independent stressor, from the mothers' non-independent subjective distress and cognitive appraisal, advance our understanding of the role of different aspects of the maternal stress experience. Next, the fact that PNMS has been associated with more difficult temperaments in children, who may be less compliant with the administration of standardised cognitive tests, also compromises confidence in the results of most studies. As such, the observational method developed by Zelazo et al. (1980) and used by Laplante et al. (2007) in Project Ice Storm is also a methodological advantage that allows for greater confidence in conclusions. What is lacking to date is a replication of this method in the context of a different disaster.

Objectives and Hypotheses

The SPIRAL program, with its data from different disasters, provides the opportunity to replicate the methods used in Project Ice Storm with a different sample exposed to a different disaster during pregnancy. The main objective of this study was to determine the extent to which PNMS and timing of exposure influence play maturity in children exposed to the 2011 Queensland Flood. The second objective was to determine if the timing of the stressor moderates the effects of PNMS on the cognitive development of the child by play analysis. Additionally, it also fills in the gap of previous studies by determining whether the associations between PNMS and play maturity would change when adjusting for other variables such as birth order, sex, temperament, and daycare enrollment. Moreover, since daycare is seen as any type of institutional out of home care for children younger than age 5, the variable that was selected for the present study only pertained to ‘out of home’ daycare services. The reason for this selection is that the institutional set up offers the opportunity to be present amongst other children, which facilitates the process of development by observing and modelling behavior.

It was hypothesized that exposure to higher levels of disaster-related PNMS would lead to lower levels of functional play and play diversity, along with higher levels of stereotypical play at both 16 and 30 months of age. It was anticipated that the effects of PNMS on play behavior at 16 and 30 months will be greatest for children exposed to the flood during the 1st and 2nd trimester. It was also predicted that the effect of PNMS on the child’s play maturity will still hold significant even after adjusting for the child’s temperament, birth order, and daycare enrollment as covariates.

Article 1: Timing of a Natural Disaster in Pregnancy Influences Infant Cognitive Development as Reflected in Play Maturity: The QF2011 Queensland Flood Study

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Timing of a Natural Disaster in Pregnancy Influences Infant Cognitive Development as Reflected in Play Maturity: The QF2011 Queensland Flood Study

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Abstract

The Laplante et al. (2007) study found that effects of PNMS from a disaster on child cognitive development at 2 years of age, as assessed by play maturity, was greatest for those exposed to the Quebec Ice storm in early pregnancy. To date, no replications of the Laplante (2007) study have been published using a different cohort affected by a different disaster during pregnancy. The present study assessed the PNMS in mothers (n =230) affected by the 2011 Queensland Flood in Australia while pregnant. Their children's play maturity was assessed at the ages of 16 (n = 142) and 30 months (n = 135) by coding videotapes of a 10-minute free play session. At 16 months, early exposure was associated with greater sensitivity to PNMS such that the higher the PNMS the better the cognitive development (PNMS-by-Timing interactions); however, late exposure was generally associated with worse cognitive outcomes (especially Timing main effects). At 30 months, no significant main effects were found between PNMS and play maturity. However, a similar timing-by-PNMS interaction trend was found where early exposure rendered children sensitive to PNMS: the more positive the mothers' cognitive appraisal, the greater the child's displayed hypotheses at 30 months; while late exposure predicted lower displayed hypotheses for any level of appraisal of the event. In conclusion, the results partially replicated those of Laplante et al. (2007) where early exposure was found to render the children sensitive to the degree of PNMS, while late exposure was associated with worse cognitive outcomes irrespective of the level of PNMS.

Cognitive Development

Cognitive development in early childhood can be predictive of future success. Research has shown how genetics and environmental factors can play a major role in influencing a child's development (Engelhardt et al., 2019). Although many factors influence a child's cognitive development, over the years, more attention has been paid to studying the effects of prenatal maternal stress (PNMS), an environmental risk factor, on fetal development.

The prenatal period is a vulnerable time during which exposure to high levels of stress can have long-lasting detrimental effects on the fetus, a process known as fetal programming (Barker et al., 1989; Van Den Bergh et al., 2017). Effects of PNMS on offspring have been studied extensively across laboratory animals in controlled settings with findings including significant associations between PNMS and cognitive deficits (Poltyrev et al., 1996; Tazumi et al., 2005; Schneider & Coe, 1993; Schneider et al., 1999). Animal studies have an advantage over human studies due to the ease of randomization. However, results of animal studies cannot be easily generalized to humans due to the protective and risk factors operating between the objective hardship and the subjective distress following an event (Laplante et al., 2004). Objective hardship refers to the external forces of an event acting upon an individual, whereas subjective distress represents the psychological reactions (anxiety, depression, panic) associated with the experience of an event (Laplante et al., 2004).

Although many animal and human studies show the harmful consequences of PNMS on the developing fetus, the biggest challenge associated with these studies is uncovering the processes that are responsible for the effects of PNMS on child development (King et al., 2015), and understanding how different variables interact to the developmental risks to the unborn child. Moreover, the stressful situations recorded in many human studies lacked randomization and did not take into account the extent of objective hardship endured, thus challenging the reliability of these studies for measuring the impact of PNMS. But for those that did take 'objective stressors' into account, classifying these stressors as completely 'independent' of the pregnant woman's own agency is complex (Talge et al., 2007; Henrichs et al., 2011). This is because of the inability to disentangle the influence of a woman's personality traits, which may also be passed on to the child. Furthermore, it is not ethical to subject pregnant women to stressful conditions intentionally (Laplante et al., 2004). To eliminate both these problems, a natural disaster can be used as a prominent 'independent' stressor to study the effects of PNMS on pregnant women as it is completely independent of the 'control' of the individual (King et al., 2015). Natural disasters act as 'natural experiments' helping to randomize the distribution of stress exposure without harming the internal validity of such experiments. This kind of stressor is known to affect pregnant women at all stages of gestation while allowing the precise recording of the timing of in utero exposure (Simcock et al., 2017). For these reasons, several studies use natural disasters as independent stressors to better study the influence of PNMS on child development.

SPIRAL

The Stress in Pregnancy International Research Alliance (www.mcgill.ca/spiral) is a collection of studies investigating the consequences and mechanisms of PNMS on child development with natural disasters as the quasi-randomized stressor. The projects in this research program assess the pregnant women's disaster experience by assessing their objective hardship, cognitive appraisal, and subjective distress related to the event. They also consider the timing of the stressor in gestation as an important factor in moderating the effects of PNMS on the fetus (Laplante et al., 2004; Laplante et al., 2018; Cao et al. 2014; Moss et al., 2017). The fundamental goal is to determine the extent to which these factors influence, individually and in combination, the unborn child's cognitive, behavioral, motor and physical development across development.

Although these studies found significant effects of PNMS on children's performance on structured tasks (Simcock et al., 2017; Laplante et al., 2004; Moss et al., 2017; Laplante et al., 2004; Laplante et al., 2018) a child's performance on these tasks might have also reflected the effects of PNMS on their temperamental characteristics (Simcock et al., 2017; Laplante et al., 2016) rather than purely cognitive skills; children who are inhibited or oppositional due to the effects of PNMS may not perform at their best in testing situations involving an unfamiliar tester. Thus, videotaping a non-structured free play session, in the absence of an unfamiliar research assistant, helps circumvent potential confounding factors (Zelazo and Kearsley, 1980).

Play Behavior

Play maturity is a non-verbal and non-social measure of cognitive development (Laplante et al., 2007). In 1980, Zelazo and Kearsley published a study examining a 15-minute free play session of 64 infants belonging to age groups of 9.5, 11.5, 13.5, and 15.5 months. The protocol included 28 individual objects belonging to 3 different categories: male, female, and neutral. This free play setting not only allowed the children to freely access each category of toys, but also aided the display of non-directed preferences (Zelazo and Kearsley, 1980). Three types of play behavior (stereotypical, relational, and functional) were coded from videos of this free play session along with 36 previously defined adult-like acts also known as "displayed hypotheses".

Stereotypical play includes actions such as fingering, mouthing, banging, and waving toys. It is regarded as the most immature form of play behavior and was dominant at 9.5 months of age. Relational play, which is the inappropriate association of two toys, involves the child bringing two different toys together without serving any useful function, became more evident by 13.5 months. Lastly, functional play, viewed as the most mature form of play, involves the infant appropriately using the toys in a previously determined adult-like manner (Zelazo & Karsley, 1980). This play type was dominant among 15.5-month-old children.

The study found that from the age of 9.5 months to 15.5 months, the amount of stereotypical play behavior decreased rapidly (from 87% to 22% of total play acts) and that the child's functional play increased from 1.5% to 52% of total play acts. Furthermore, an increase was also found in the child's displayed hypotheses, increasing from an average of 0.32 acts per 15 minutes at 9.5 months to an average of 10.38 acts per 15 minutes at 15.5 months. This increase in terms of both quantity and quality of play represents a period of cognitive metamorphism that occurs at the beginning of a child's second year (Zelazo & Leonard, 1983).

The Laplante et al., (2007) Project Ice Storm Study: Effects of Prenatal Maternal Stress

The Zelazo study inspired the initiation of Project Ice Storm assessments undertaken by Laplante (2007) who used the same procedure to measure the play abilities of 2-year-olds whose mothers had been pregnant during the devastating 1998 ice storm in Quebec, Canada. The ice storm was one of the worst natural disasters in Canadian history, knocking out power for 1.5 million households, some for as long as 45 days in the peak of winter. Laplante et al. assessed the PNMS of women pregnant during the disaster and then determined the extent to which the in-utero exposure to varying degrees of PNMS has an impact on the play maturity of the child. They found that higher levels of mothers' objective hardship were associated with lower levels of functional play and higher levels of stereotypical play. While Zelazo and Kearsely (1980) found that, at 15.5 months of age, children engaged in functional play about 52% of the time, 24-month-old children exposed to high objective PNMS from the Quebec ice storm spent only 42% of the time in functional play. This suggests a delay of greater than 9 months in cognitive maturity. Similarly, while higher levels of subjective PNMS from the ice storm were associated with higher levels of stereotypical play and a significantly lower number of displayed hypotheses, subjective stress reactions were only marginally associated with lower levels of functional play. Interestingly, the effects of objective PNMS on stereotypical and functional play were strongest in children exposed in the first or second trimesters, with a significant timing interaction in predicting displayed hypotheses. However, no replications of the Laplante (2007) study have been conducted to verify if the results can be repeated. Additionally, very few studies using observational methods that are unbiased by potentially confounding variables have been published to arrive at definitive conclusions about PNMS and play maturity in children.

Objectives and Hypotheses

In early January 2011, a series of severe floods devastated the state of Queensland, Australia affecting nearly 70 towns. Most of the area was declared a disaster zone, with the flooding reaching its peak in the state capital of Brisbane (King et al., 2015). The main objective of the present study was to determine the extent to which PNMS, and timing of exposure influence cognitive development as assessed by play maturity in children affected by the Queensland flood. The second objective was to determine if the timing of the stressor moderates the effects of PNMS on play maturity. Additionally, the third objective was to determine whether the associations between PNMS and play maturity would be affected by adjusting for variables such as birth order, sex, temperament, and daycare enrollment. It was hypothesized that exposure to higher levels of disaster related PNMS would lead to lower levels of functional play and displayed hypotheses, along with higher levels of stereotypical play at both 16 and 30 months of age. It was anticipated that the effects of PNMS on play behavior would be greatest for children exposed to the flood during the 1st and 2nd trimester. It was also predicted that the effect of PNMS on the child's play maturity will still be significant even after adjusting for the child's temperament, birth order, and daycare enrollment as covariates.

Method

Sample

Women who agreed to participate in the study provided written informed consent. The inclusion criteria for this study involved women being fluent in English, at least 18 years of age at recruitment, pregnant with a singleton at the peak of the disaster (Jan. 10th, 2011), and residing in the vicinity of Brisbane, Australia. Recruitment began on April 4, 2011, as soon as the ethics approval was granted and continued until 12 months post-flood (January 2012). Women who were enrolled in a different study (Midwives @ New Group Practice Options, M@NGO; Tracy et al., 2011) were also invited to participate in the study. Flyers and other advertisements were put out through the internet, radio, and newspapers inviting eligible women to participate.

A total of 230 women (n=230) accepted to participate in the Queensland Flood Study (QF2011), a prospective longitudinal study. For the current study, there were 158 mothers of 86 boys and 72 girls in total. The children were observed for their play behavior twice, once when 16 months old (142 infants studied) and again when 30 months old (135 infants studied), with 119 participants being assessed at both time points.

Table 1 presents descriptive statistics for the whole sample of 158 dyads, while Tables 2 and 3 present descriptive statistics for dyads assessed at 16 and 30 months respectively.

Table 1

General Descriptive Table

	N	Minimum	Maximum	Mean	Standard Deviation
Mother's age at flood	158	19.10	46.88	31.386	5.027
QFOSS_lg	158	1.10	4.41	2.806	0.777
COSMOSS	158	-1.078	4.649	0.069	1.062
Cognitive Appraisal	157	1.00	4.00	2.751	0.748
Timing of Exposure	158	-2.02	267.98	122.143	76.706
Parity	151	0	4	0.77	0.934
	N	Category	Code	n	%
Sex of the Child		Male	0	86	54.4
	158	Female	1	72	45.6

Note. Descriptive Variables include: Mothers Age at Flood (as of January 11, 2011) , QFOSS_lg (Objective Hardship), COSMOSS (Subjective Distress) and CONSEQ (Cognitive Appraisal), Timing of Exposure = Pregnancy days on Jan 10, 2011 based on 280 days: <0 = Preconception; 0-280 Pregnancy; > 280=Postpartum exposed, Parity = Number of previous births

Table 2

Descriptive Statistics for Prenatally Exposed Children at 16-Month-Old.

	N	Minimum	Maximum	Mean	Standard Deviation
STER16	142	0	21.77	3.802	3.954
RELAT16	142	0	11.49	2.038	2.488
FUNC16	142	0	32.45	8.801	6.958
Displayed Hypotheses at 16 Months	142	0	16	5.690	3.279
QFOSS_lg	142	1.1	4.41	2.849	0.764
COSMOSS	142	-1.07764	4.64924	0.072	1.085
Cognitive Appraisal	141	1	4	2.744	0.769
Timing of Exposure	142	-2.02	267.98	124.822	77.569
Mother's age at flood	142	19.78	46.88	31.797	4.839
Age of child at 16 months assessment (in months)	142	14.78	18.1	16.516	0.574
Short Temperament Scale for Toddlers - Easy-Difficult Factor Scale for 16 months	123	2.06	4.87	3.370	0.569
Parity	136	0	4	0.79	0.946

	N	Category	Code	n	%
Sex of the Child	142	Male	0	77	54.2
		Female	1	65	45.8
DAYC16	133	No	0	72	50.7
		Yes	1	61	43.0

Note. STER16 = Stereotypical play at 16 months, RELAT16 = Relational Play at 16 months, FUNC16 = Functional Play at 16 months, Timing of Exposure = Pregnancy days on Jan 10, 2011 based on 280 days: <0 = Preconception; 0-280 Pregnancy; > 280=Postpartum exposed, Mothers Age at Flood = Age as of January 11, 2011, DAYC16 = Enrollment in a day care at 16 months, Parity = Number of previous births.

Table 3

Descriptive Statistics for Prenatally Exposed 30-Month-Old Children.

	N	Minimum	Maximum	Mean	Standard Deviation
STER30	135	0	7.29	1.346	1.553
RELAT30	135	0	16.12	4.545	3.695
FUNC30	135	1.52	47.6	19.513	8.879
Displayed Hypotheses at 30 Months	135	3	19	11.111	3.611
QFOSS_lg	135	1.1	4.41	2.848	0.767
COSMOSS	135	-1.077	3.441	0.090	1.021
Cognitive Appraisal	134	1	4	2.7463	0.752
Timing of Exposure	135	-2.02	267.98	122.783	76.870
Mother's age at flood	135	19.1	46.88	31.598	5.095
Age of child at 16 months assessment (in months)	124	14.78	18.76	16.517	0.613
Short Temperament Scale for Toddlers -	106	2.1	4.8	3.209	0.531

Easy-Difficult Factor Scale for 30 months					
Parity	129	0	3	0.77	0.931
	N	Category	Code	n	%
Sex of the Child	135	Male	0	74	54.8
		Female	1	61	45.2
DAYC16	119	No	0	44	32.6
		Yes	1	75	55.6

Note. STER30 = Stereotypical play at 30 months, RELAT30 = Relational Play at 30 months, FUNC30 = Functional Play at 30 months, Timing of Exposure = Pregnancy days on Jan 10, 2011 based on 280 days: <0 = Preconception; 0-280 Pregnancy; > 280=Postpartum exposed , Mothers Age at Flood = Age as of January 11, 2011,DAYC30 = Enrollment in a day care at 30 months, Parity =Previous number of births.

Instruments/Measures

Maternal Stress Predictor Variables

Objective Flood Stress Exposure (recorded at recruitment and/or 12 months post flood). At recruitment, the women's objective hardship due to the flooding was assessed with a specially-designed 55-item questionnaire that reflected their objective flood-related experiences according to four categories of exposure (Appendix1): Threat (e.g., "Incurred any injury?"), Loss (e.g., "Did you experience loss of property or income?"), Scope (e.g., "How long were you out of your home"), and Change (e.g., "Did you spend any time in a temporary shelter?"). This questionnaire was adapted from another one used in a previous study of flood related PNMS (Yong Ping et al., 2015; Brock et al., 2015). Points were assigned to every item such that each category was allotted up to 50 possible points with a maximum overall hardship score of 200 resulting in the total score called QFOSS (Queensland Flood Objective Stress Scale). This scale was administered to all women at recruitment. It was re-administered at 12 months post flood (January 2012) to women who had not been recruited recently to update their values on the different domains of loss, threat, scope, and change.

Subjective Distress. The women's emotional or subjective reactions to the Queensland Flood were assessed by using 3 different scales that were then combined into a single score known as the COSMOSS (Composite Score for Mother's Subjective Stress).

Post-Traumatic Stress Disorder (PTSD) - like symptoms. The women's PTSD-like symptoms at recruitment were assessed using the 22-item Impact of Event Scale – Revised (IES-R) (Weiss & Marmar, 1997). This scale yields a total score as well as scores for three categories of PTSD symptoms: intrusive thoughts, avoidance, and hyperarousal. The women rated the items on a Likert scale ranging from 0 (not true) to 4 (extremely true) for their symptoms related to the flood. Total scores above 22 were suggestive of possible PTSD (Rash et al., 2008), while scores above 32 suggested probable PTSD (Creamer et al., 2003).

Peritraumatic Experiences. The women's peritraumatic distress, that is, their level of distress 'at the time of the flood' as recalled at recruitment, was assessed using the 13-item Peritraumatic Distress Inventory (PDI) (Brunet et al., 2001). It has items about the severity of their initial emotional distress which are rated in severity on a 0 (not true) to 4 (extremely true) scale. Additionally, the women's dissociative experiences (e.g., "What was happening seemed unreal, like it was a dream or a movie") were assessed using the 10-item Peritraumatic Dissociative Experiences Questionnaire (PDEQ) (Marmar et al., 1997).

Composite Score for Mothers' Subjective Stress (COSMOSS). A composite subjective stress score was calculated in order to reduce the number of predictor variables in the regression analyses. The Composite Score for Mothers' Subjective Stress (COSMOSS) is a standardized score with a mean of 0, where positive and negative scores represent levels of subjective distress that are higher or lower than the mean, respectively. It was computed using Principal Component Analysis (PCA) on the total scores of the three traumatic stress measures (IES-R, PDI, and PDEQ) for all the women who provided PNMS data when they were recruited for the study (n=230). The final algorithm used to compute mothers' composite subjective distress for QF2011 was: 0.36 x IES-R + 0.40 x PDI + 0.39 x PDEQ.

Cognitive Appraisal (CONSEQ). The women's cognitive appraisal of the flood was assessed using a single item at recruitment: "Overall, what were the consequences of the flood on you and your family?"; response options were on a five-point scale of "Very negative" (1), "Negative" (2), "Neutral" (3), Positive (4), and "Very positive" (5). This item was categorized into 'Negative' and 'Neutral/Positive' due to the limited range of responses on the scale and to isolate the role of a negative cognitive appraisal.

Timing of Exposure. Timing of in utero flood exposure was the number of days between the estimated date of conception and January 10, 2011, the date at which the flooding was at its peak. To calculate the estimated date of conception, 280 days (40 weeks) was subtracted from each woman's due date (King et al., 2015). Higher flood exposure days indicated flood exposure later in pregnancy. 0-91 days was the first trimester of pregnancy, 92-182 days was the 2nd trimester and 182-280 days was the 3rd trimester.

Child Covariates

Short Temperament Scale for Toddlers (16 months, 2.5 years). Short Temperament Scale for Toddlers (STST; Pedlow et al., 1993) is a 30-item questionnaire. Mothers rated their children's behavior with scores relating to 6 dimensions of temperament: Approach, Rhythmicity, Cooperation-Manageability, Activity-Reactivity, Persistence, and Distractibility. An easy/difficult scale score was calculated by combining the Approach, Cooperation/Manageability and Activity-Reactivity dimensions, where scores >1 SD above the mean indicated that a child is 'Difficult' (Gray et al., 2013).

Daycare Enrollment (16 months and 2.5 years). At 16 and 30 months, mothers were asked about their child's enrollment in any daycare facility. Some of the questions asked included "Does your child have regular child minding or child-care with grandparents or any other family members?" or 'child-care with a paid-in-house Nanny?". Thus, this item reflects current enrollment in any type of daycare (scored 1) or not (scored 0).

Sex of the child and Parity. Information about the 'sex of the child' and 'parity' (i.e., number of biological children before the participant child*)* was gathered by asking the mothers directly and collecting information from hospital records. Sex was coded as 0 for Males, and 1 for Females.

Maternal Covariates

Mothers completed questionnaires at recruitment, at 12-months post-flood, and at other times during the first year postpartum. Their demographic data were collected at recruitment. Their socio-economic status was assessed with the Australian Socio-Economic Indexes for Area (SEIFA) score based on the family's postal code at recruitment. The mean score is 1000 (SD = 100), with a higher score indicating that an area is more privileged compared to areas with lower scores.

When their children were 16 and 30 months of age, mothers again completed questionnaires and brought their children to the Mater Mothers' Hospital in Brisbane, Queensland for assessments. These meetings included the play session described below.

Play maturity

Play Behavior Observation. The infants' play was assessed using a 10-minute protocol, similar to what was developed by Zelazo and Kearsley (1980). Zelazo recognized that reducing the play session from 15 to 10 minutes would not change the results in terms of analyzing play maturity. Each QF2011 infant was presented with the 28 toys listed in Appendix#2. The toys were from three gender-specific categories to control for possible sex-typed preferences: 2 gender-neutral toys (including a tea set and telephone); 2 female-oriented toys (including one large and one small doll set); and 2 male-oriented toys (including one baseball set and one truck set). The toys were presented in a semi-circle in front of the infants in a specific pattern (baseball set, large doll set, telephone, truck set, small doll set, tea set). A timer was set, and the infants were left to play on their own while the session was video recorded. As a way to prevent them from interfering with the child's play session, the mothers (who were in the same room) were asked to complete a parent-rated language inventory about their child's language abilities. They were also asked to redirect the child back to the toys if he/she tried to engage with them during the session**.**

The play session usually lasted for about 10 minutes but was prolonged if the toddler took a bathroom/ water break; time lost while out of the room for the break was not taken into account.

Video recordings of the play assessment were available for 142 infants at 16 months of age (69 males) who were exposed either during the 1st (49 infants; 30 males), 2nd (49 infants; 22 males), or 3rd (29 infants; 17 males) trimester of pregnancy. At 30 months of age, there were 135 infants (70 males) who were exposed either during the 1st (50 infants; 29 males), 2nd (50 infants; 21 males), or 3rd (30 infants; 20 males) trimester of pregnancy.

Play Behavior Coding. Play behaviors of the children at both ages were coded from the videotapes of the free play sessions using the Mangold Interact video coding software. A Cronbach Alpha of 0.966 to 0.996 was obtained for all forms of play behavior at 16 and 30 months. The coding focused on the percentage of time spent in the three mutually-exclusive categories of maturity (stereotypical, relational, and functional), and breadth of play. Stereotypical play was defined as any action that involved mouthing, fingering, waving, or banging the toys (Zelazo & Kearsley, 1980). Relational play was defined by the simultaneous association of two or more toys in a non-functional manner. For instance, forming inappropriate associations between a 'toy truck' and a 'teacup' was coded as 'relational' because of its non-functionality. Functional play was coded whenever the infant used the toys in a manner characteristic of the 36 previously determined adult-like actions (Zelazo & Kearsley, 1980) as listed in Appendix 2. For instance, drinking from the cup, placing the unisex doll in bed/chair, pushing the truck, etc. were considered functionally appropriate acts. But ambiguous actions such as inserting the spoon or bottle in one's own mouth while taking a swing at the baseball bat were excluded because it remained uncertain whether they were stereotypical actions or functional ones. A fourth variable, defined as "displayed hypotheses" was the number of different functional, adult-like actions, as listed in Appendix 2, that the child exhibited during the session. Thus, a child who spent the entire play session playing appropriately with the tea set received a 100% score on the functional play, but only a score of 1 on displayed hypotheses. On the other hand, a child who played appropriately with 4 different toys but only played during a quarter of the time received a functional play score of 25% but a score of 4 on displayed hypotheses. The duration of time the child spent in non-play activity was also recorded. To determine whether there were differences in the overall time spent playing with the toys, two additional variables were calculated: total length of session and duration of non-play activity (Zelazo & Kearsley, 1980).

Statistical Analyses

Pearson product-moment correlations were first conducted between the four outcome variables at each age (stereotypical play, relational play, functional play, and displayed hypotheses), the predictors (objective and subjective PNMS) and cognitive appraisal), and potential covariates (sex of the child, daycare enrollment, temperament, birth order). Hierarchical multiple regressions were then conducted for each outcome to determine the association between PNMS and play maturity. Each dependent variable was examined against the 3 independent variables (IV): objective hardship, subjective distress, and cognitive appraisal. The final step was to examine whether there were any interactions between timing and any of the three PNMS variables. Interactions were first examined without controlling for the covariates, and then re-examined with the covariates to determine whether controlling for them would make a difference in any of the previously significant associations. Of note, however, the adjusted model had 25 fewer participants than the unadjusted model because of missing values among the covariates. If results changed when controlling for the covariates, the FILTER command was used to temporarily select cases with complete data on all covariates to determine the reason behind the different results. Thus, when there was a difference in significance for the effects of PNMS between the two models, the unadjusted model was rerun using the smaller sample with the FILTER command to better determine whether the cause of the difference was either the covariates or the change in sample size.

Furthermore, a non-linear regression model was used to estimate the confidence interval (CI) of the cross-over point and was then used to compare the CI to the range of values of the predictor (Widaman et al., 2012). An interaction was regarded as disordinal and supportive of the differential susceptibility model if the confidence interval of the cross-over point was within the range of the predictor (i.e., PNMS). Conversely, if the cross-over point was outside the range of the predictor, the interaction was regarded as ordinal and potentially supportive of the diathesis-stress model instead.

The 'objective hardship' variable, QFOSS, was positively skewed and was thus log-transformed (Tabachnik and Fidell, 2013). Consequently, all objective hardship analyses used the log-transformed objective hardship variable i.e., QFOSS_lg.

Outliers were also found for stereotypical, relational, and functional play scores at 16 and 30 months. As such, those variables were winsorized to reduce the impact of extreme values. No outliers were found for displayed hypotheses at 16 and 30 months and thus were not winsorized.

In the hierarchical multiple regressions 'objective hardship' was added as the predictor in step 1, and then 'timing' was added in step 2 while controlling for objective hardship. Covariates such as 'birth order', 'daycare enrollment', 'parity', 'temperament', and 'sex of the child' were then added to the model while controlling for objective hardship and timing. The interaction between objective hardship and timing was entered into the model as the fourth step. The PROCESS macro (Hayes, 2017), a regression path analysis tool in SPSS, was used to analyze interactions. The tool provided conditional simple effects at the 16^{th} and 84^{th} percentile.

To test for the effects of subjective distress on each outcome, objective hardship was added in step 1, and composite subjective distress was entered in step 2. Timing was then added in step 3. The covariates were then added in step 4 to determine if their addition would change any significant associations from the previous step. The PROCESS tool was then used in step 5 to determine if 'timing' had any moderating effect on the relationship between composite subjective distress and a specific outcome variable.

Similar steps were taken to examine the effects of cognitive appraisal (CONSEQ) on the outcomes, by replacing 'composite subjective distress' with 'cognitive appraisal' in step 2 and step 5 and following the rest of the steps as mentioned above. In all the analyses, objective hardship was consistently controlled for.

Results

Intercorrelations between Outcome Variables and Potential Covariates

Correlations between the four outcome variables and potential covariates were examined at 16 months of age (Table 4). Mothers' subjective PNMS (COSMOSS) was negatively correlated with functional play ($r = -.176, p =.036$). As expected, the 3 PNMS variables: objective hardship, subjective distress, and cognitive appraisal were correlated with each other. Another positive trend was found between the 'displayed hypotheses' at 16 months and 'functional play' ($r = .416, p < .001$), where a higher percentage of time spent in functional play was associated with more diversity in play behavior. The timing of exposure to the flood also had significant associations, with earlier exposure being associated with more relational play ($r = -.198, p = .018$) and displayed hypotheses ($r = -.179, p = .033$). In the sample available at 30 months of age (Table 5) the three PNMS variables were still correlated as expected. As at 16 months, a positive correlation was also found between the ‘displayed hypotheses’ at 30 months and ‘functional play’ (r = .295, p = .001). Among the covariates, enrollment at daycare had a negative correlation with Objective hardship (r = -.208, p = .015), such that those who had experienced more objective hardship in pregnancy were less likely to be enrolled in daycare at 30 months. None of the remaining potential covariates were significantly correlated with any of the four outcome variables.

Table 4

Pearson Correlation Table of Children at 16 Months of Age.

	STER 16	REL 16	FUNC 16	DH16	Sex	Timing of Exp.	DAY C16	STST	Parity	QFOSS lg	COSM OSS	CONSEQ
STER16	1	-.041	-.128	-.156	-.050	.031	.027	.071	-.126	-.092	-.084	.005
RELAT16	-.041	1	.089	.143	.038	-.198*	-.026	-.097	-.105	.093	-.047	.068
FUNC16	-.128	.089	1	.416**	.058	-.145	-.072	-.115	-.061	-.073	-.176*	.060
DH16	-.156	.143	.416**	1	-.008	-.179*	-.090	-.128	-.026	.082	-.146	.083
Sex of the child	-.050	.038	.058	-.008	1	-.007	.036	-.143	.028	-.058	-.083	-.019

Timing of Exp.	.031	-.198*	-.145	-.179*	-.007	1	.057	.110	.022	.003	.009	-.068
DAYC16	.027	-.026	-.072	-.090	.036	.057	1	.169	-.141	-.061	.107	.004
STST	.071	-.097	-.115	-.128	-.143	.110	.169	1	-.172	.083	.092	.024
Parity	-.126	-.105	-.061	-.026	.028	.022	-.141	-.172	1	-.131	-.051	.018
QFOSS_lg	-.092	.093	-.073	.082	-.058	.003	-.061	.083	-.131	1	.497**	-.361**
COSMOSS	-.084	-.047	-.176*	-.146	-.083	.009	.107	.092	-.051	.497**	1	-.269**
CONSEQ	.005	.068	.060	.083	-.019	-.068	.004	.024	.018	-.361**	-.269**	1

Note. * $p < 0.05$, two-tailed. ** $p < 0.01$, two-tailed. Dependant Variables: STER16 = Stereotypical Play at 16 months, RELAT16 = Relational Play at 16 months, FUNC16 = Functional Play at 16 months, DH16 NW = Not Winsorized Displayed Hypotheses values exhibited by 16-month-old children, Sex = Sex of the child.
Predictor Variables: Timing of Exp = Pregnancy days on Jan 10, 2011 based on 280 days: <0 = Preconception; 0-280 Pregnancy; > 280=Postpartum exposed, DAYC30 = Day Care Enrollment at 30 months, STST = Short Temperament Scale for Toddlers - Easy-Difficult Factor Scale for 30 months, PARITY = Number of previous births, QFOSSlg = Objective Hardship, COSMOSS= Subjective Distress, CONSEQ = If you think about all of the consequences of the flood on you and your household, would you say the flood has been??

Table 5

Pearson Correlation Table of Children at 30 Months of Age.

	STER30	REL 30	FUNC 30	DH30	Sex	Timing of Exp.	DAY C 30	STST	Parity	QFOSS_ lg	COSM OSS	CONSEQ
STER30	1	-.014	-.088	-.054	.018	-.013	-.147	-.165	-.005	-.143	.053	.059
RELAT30	-.014	1	-.124	-.121	.020	-.151	.023	.061	-.102	.070	.019	-.166
FUNC30	-.088	-.124	1	.295**	-.092	.113	.042	-.168	.061	.036	-.005	.009
DH30	-.054	-.121	.295**	1	-.003	-.137	.077	.037	.143	.002	.001	.091
Sex of the child	.018	.020	-.092	-.003	1	-.007	.063	-.085	.028	-.058	-.083	-.019
Timing of Exp.	-.013	-.151	.113	-.137	-.007	1	-.046	.070	.022	.003	.009	-.068
DAYC30	-.147	.023	.042	.077	.063	-.046	1	.026	-.129	-.208*	-.006	.143
STST	-.165	.061	-.168	.037	-.085	.070	.026	1	-.141	.162	.007	-.034
Parity	-.005	-.102	.061	.143	.028	.022	-.129	-.141	1	-.131	-.051	.018

QFOSS_lg	-.143	.070	.036	.002	-.058	.003	-.208*	.162	-.131	1	.497**	-.361**
COSMOSS	.053	.019	-.005	.001	-.083	.009	-.006	.007	-.051	.497**	1	-.269**
CONSEQ	.059	-.166	.009	.091	-.019	-.068	.143	-.034	.018	-.361**	-.269**	1

Note. * $p < 0.05$, two-tailed. ** $p < 0.01$, two-tailed.
Dependant Variables: STER30 = Stereotypical Play at 30 months, REL30 = Relational Play at 30 months, FUNC30 = Functional Play at 30 months, DH30 NW = Not Winsorized Displayed Hypotheses values exhibited by 30-month-old children, Sex = Sex of the child. Predictor Variables: Timing of Exp. = Pregnancy days on Jan 10, 2011 based on 280 days: <0 = Preconception; 0-280 Pregnancy; > 280=Postpartum exposed, DAYC30 = Day Care Enrollment at 30 months, STST = Short Temperament Scale for Toddlers - Easy-Difficult Factor Scale for 30 months, PARITY = Number of previous births, QFOSSlg = Objective Hardship, COSMOSS= Subjective Distress, CONSEQ = If you think about all of the consequences of the flood on you and your household, would you say the flood has.

Hierarchical Regressions

Children at 16-Months of Age

Stereotypical Play and Objective Hardship. As shown in Table 6, exposure to objective hardship during pregnancy had no significant effect on the percentage of time spent in stereotypical play at 16 months. There were also no significant effects of the timing of exposure. Timing had a marginally significant moderating effect on the relationship between objective hardship and stereotypical play at 16 months ($p = .098$) and the interaction explained an additional 1.9% of the variance. When examining the same interaction with covariates in the model, the interaction was no longer significant ($p =.314$) (Appendix 3). Using FILTER, it was found that the reduced sample size led the interaction to become non-significant, rather than the influence of the covariates themselves. As illustrated in Figure 1A and 1B, when the flood occurred early in pregnancy (i.e., before 43 days), there was a significant, negative association between objective hardship and stereotypical play; when the flood occurred later in pregnancy (>43 days) there was no association between objective hardship and this form of play. Additionally, the cross-over point was 2.806 with CI= [1.943; 3.669], which lies within the range of the objective hardship values (1.101; 4.41). As such, it can be interpreted as a disordinal interaction, that is, with early-exposed children being differentially susceptible to the effects of objective hardship.

Table 6

Summary of Hierarchical Regression Analyses of All Objective Hardship Variables for Stereotypical Play at 16 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
16 Months								
STEP 1				0.092	0.008	0.008	1.194	1.194
QFOSS_lg	-0.092	-0.475	0.435					
STEP 2				0.098	0.010	0.001	0.667	0.148
QFOSS_lg	-0.093	-0.478	0.436					
TIMING	0.032	0.002	0.004					
STEP 3				0.171	0.029	0.020	1.378	2.783~
QFOSS_lg		-1.715*	0.859					
TIMING		-0.028	0.018					
QFOSS x Timing		0.010~	0.006					

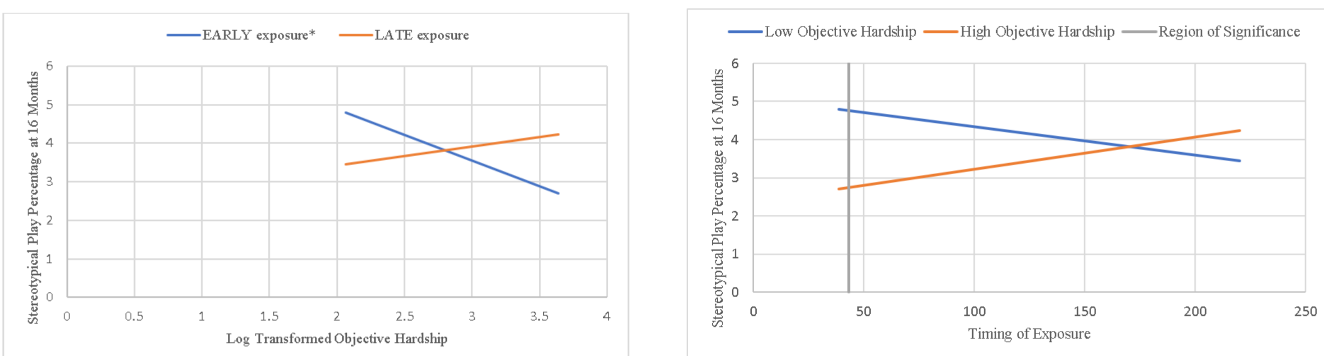
Note. ~ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$

Figure 1

Interaction between Mothers' Objective Hardship and Timing of Exposure in Predicting Stereotypical Plat at 16 Months.

A. The Effect of Mothers' Objective Hardship on Stereotypical Play at 16 Months at Different Levels of Timing of Exposure

B. The Effect of Timing of Exposure on Stereotypical Play at 16 Months for Different Levels of Mothers' Objective Hardship



Panel A represents the effect of objective hardship on stereotypical play at 16 months at different levels of the timing of exposure. The blue line represents the effect of objective hardship at early exposure (38.59 days) while the orange line represents this effect at late exposure (220.12 days). On the other hand, Panel B represents the effect of timing of exposure on stereotypical play at different levels of objective hardship. The vertical grey line delimits the region of significance (below 43.28 days) within which the effect of objective hardship on stereotypical play at 16 months is significant. Significance *: $p < 0.05$.

Stereotypical Play and Subjective Distress. No significant, nor marginal main effects nor timing moderating effects were found between the mothers' subjective distress and the amount of time the child actively engaged in stereotypical play at 16 months, with controlling (Appendix 3) or without controlling for covariates (Table 7).

Stereotypical Play and Cognitive Appraisal. As shown in Table 8, no significant associations were found between the mothers' cognitive appraisal of the event or the timing of exposure on the amount of time the child actively engaged in stereotypical play at 16 months. Timing had a marginally significant moderating effect on the relationship between cognitive appraisal and stereotypical play at 16 months ($p = .065$) where early exposure led to cognitive appraisal having an effect on stereotypical play (Figure 2A). The unadjusted and adjusted models explained 3.5% (Table 8) and 5.5% (Appendix 3) of the variance in stereotypical play at 16 months respectively, of which 2.5% and 2.0% are explained by the interaction, respectively. On examining the interaction in the adjusted model, the interaction was no longer significant ($p = .133$). On applying FILTER, the interaction was marginally significant ($p = .084$) meaning that controlling for covariates makes the interaction non-significant. Additionally, the cross-over point was 2.919 with CI= [2.062; 3.777], which lies within the range of cognitive appraisal values (1.000; 4.000). As such, it can be interpreted as a disordinal interaction with children exposed to the disaster early in gestation being differentially susceptible to the effects of maternal cognitive appraisal.

Table 7

Summary of Hierarchical Regression Analyses of All Subjective Distress Variables for Stereotypical Play at 16 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
				16 Months				
STEP 1				0.92	0.008	0.008	1.194	1.194
QFOSS_lg	-0.092	-0.475	0.435					
STEP 2				0.102	0.010	0.002	0.735	0.282
QFOSS_lg	-0.067	-0.347	0.499					
COSMOSS	-0.051	-0.187	0.352					
STEP 3				0.108	0.012	0.001	0.539	0.158
QFOSS_lg	-0.067	-0.347	0.500					
COSMOSS	-0.052	-0.190	0.353					
TIMING	0.034	0.002	0.004					
STEP 4				0.108	0.012	0.000	0.402	0.001
QFOSS_lg		-0.348	0.502					
COSMOSS		-0.207	0.590					
TIMING		0.002	0.005					
COSMOSS X TIMING		0.000	0.004					

Table 8

Summary of Hierarchical Regression Analyses of All Cognitive Appraisal Variables for Stereotypical Play at 16 Months.

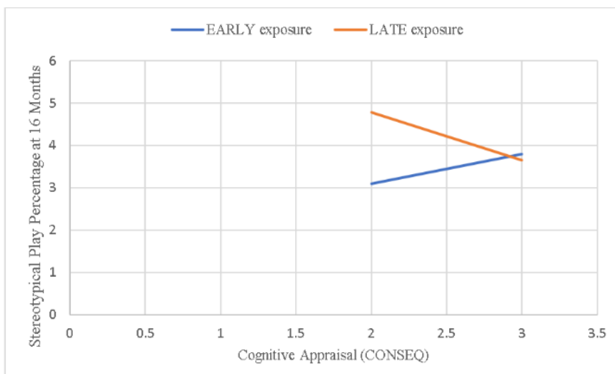
Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
				16 Months				
STEP 1				0.091	0.008	0.008	1.154	1.154
QFOSS_lg	-0.091	-0.472	0.439					
STEP 2				0.095	0.009	0.001	0.629	0.112
QFOSS_lg	-0.101	-0.526	0.470					
CONSEQ	-0.030	-0.156	0.467					
STEP 3				0.100	0.010	0.001	0.459	0.126
QFOSS_lg	-0.101	-0.527	0.472					
CONSEQ	-0.028	-0.145	0.469					
TIMING	0.030	0.002	0.004					
STEP 4				0.186	0.035	0.025	1.218	3.471~
QFOSS_lg		-0.586	0.468					
CONSEQ		1.107	0.817					
TIMING		0.030~	0.016					
CONSEQ x TIMING		-0.010~	0.006					

Note. ~ p <0.1, * p <0.05, ** p < 0.01

Figure 2

Interaction between Mothers' Cognitive Appraisal and Timing of Exposure in Predicting Stereotypical Play at 16 Months.

A. The Effect of Mothers' Cognitive Appraisal on Stereotypical Play at 16 Months at Different Levels of Timing of Exposure



Panel A represents the effect of a cognitive appraisal on stereotypical play at 16 months at different levels of the timing of exposure. The blue line represents the effect of objective hardship at early exposure (39.70 days) while the orange line represents this effect at late exposure (220.28 days).

Relational Play and Objective Hardship at 16 months. As shown in Table 9, exposure to objective hardship during pregnancy had no significant effect on the percentage of time spent in relational play at 16 months. However, the timing of exposure to the flood had a significant effect: the earlier in pregnancy the exposure took place, the more time the child engaged in relational play ($p = .017$). The unadjusted and adjusted models explained 4.9% (Table 9) and 10.3% (Appendix 3) of the variance in relational play at 16 months respectively. In the adjusted model, no significant associations were found between relational play and objective hardship at 16 months although the timing of exposure to the flood again had a significant effect on the amount of time the 16-month old engaged in relational play ($p =.005$). However, no significant timing by objective hardship interaction was found.

Relational Play and Subjective Distress. As shown in Table 10, while controlling for objective hardship, exposure to subjective distress during pregnancy had no significant effect on the percentage of time spent in relational play at 16 months. However, the timing had a significant main effect where the earlier in pregnancy the exposure took place, the more time the child engaged in relational play ($p = .018$). The unadjusted and adjusted models explained 5.9% (Table 10) and 11.3% (Appendix 3) of the variance in relational play at 16 months, respectively. In the adjusted model, no significant associations were found between relational play and subjective distress. The timing of exposure to the flood again had a significant effect on the amount of time the 16-month old engaged in relational play ($p = .005$). However, no significant timing by objective hardship interaction was found.

Table 9

Summary of Hierarchical Regression Analyses of All Objective Hardship Variables for Relational Play at 16 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
16 Months								
STEP 1				0.093	0.009	0.009	1.213	1.213
QFOSS_lg	0.093	0.301	0.274					
STEP 2				0.221	0.049	0.040	3.555*	5.855*
QFOSS_lg	0.096	0.313	0.269					
TIMING	-0.200*	-0.006 *	0.003					
STEP 3				0.235	0.055	0.007	2.696	0.980
QFOSS_lg		0.769	0.533					
TIMING		0.005	0.011					
QFOSS_lg xTIMING		-0.004	0.004					

Note. ~ p <0.1, * p <0.05, ** p < 0.01

Table 10

Summary of Hierarchical Regression Analyses of All Subjective Distress Variables for Relational Play at 16 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
				16 Months				
STEP 1				0.093	0.009	0.009	1.213	1.213
QFOSS_lg	0.093	0.301	0.274					
STEP 2				0.140	0.020	0.011	1.386	1.555
QFOSS_lg	0.151	0.491	0.313					
COSMOSS	-0.120	-0.275	0.220					
STEP 3				0.242	0.059	0.039	2.864*	5.726*
QFOSS_lg	0.152	0.493	0.307					
COSMOSS	-0.114	-0.262	0.217					
TIMING	-0.198*	-0.006	0.003					
STEP 4				0.248	0.062	0.003	2.244	0.421
QFOSS_lg		0.495	0.308					
COSMOSS		-0.074	0.362					
TIMING		-0.006	0.003					
COSMOSS X TIMING		-0.002	0.002					

Note. ~ p <0.1, * p <0.05, ** p < 0.01

Relational Play and Cognitive Appraisal. No significant main effect was found between the mothers' cognitive appraisal of the event and the amount of time the child actively engaged in relational play at 16 months, in the adjusted (Appendix 3) and unadjusted models (Table 11). Timing had a marginally significant moderating effect on the relationship between cognitive appraisal and relational play at 16 months ($p = .057$) but on examining the same interaction in the adjusted model, a significant timing by cognitive appraisal interaction was found ($p = .041$). The unadjusted and adjusted models explained 8.5% (Table 11) and 4.7% (Appendix 3) of the variance in relational play at 16 months respectively, of which 2.5% and 3.4% are explained by the interaction, respectively. On applying FILTER, the timing by cognitive appraisal interaction was still significant ($p= .036$) meaning that the reduced sample size led the interaction to become significant. As illustrated in Figure 3A and 3B, when children were exposed to the flood at an earlier stage in pregnancy (< 72.67 days), mothers' neutral/ positive cognitive appraisal of the flood was associated with higher instances of relational play, while no statistically significant association was found for late exposure. Additionally, only when the cognitive appraisal was high (>2.60), was later exposure associated with lower relational play at 16 months. Furthermore, the cross-over point for this interaction was 1.772 with CI= [0.461; 3.082] which overlaps with the range of cognitive appraisal values (1.000; 4.000). As such, it cannot be interpreted as either an ordinal or disordinal interaction, that is, we cannot conclude that any of the children were either differentially susceptible or vulnerable to the effects of their mothers' cognitive appraisal.

Table 11

Summary of Hierarchical Regression Analyses of All Cognitive Appraisal Variables for Relational Play at 16 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
				16 Months				
STEP 1				0.096	0.009	0.009	1.283	1.283
QFOSS_lg	0.096	0.313	0.276					
STEP 2				0.145	0.021	0.012	1.477	1.666
QFOSS_lg	0.136	0.445	0.294					
CONSEQ	0.116	0.377	0.292					
STEP 3				0.245	0.060	0.039	2.917*	5.695*
QFOSS_lg	0.137	0.448	0.289					
CONSEQ	0.102	0.331	0.288					
TIMING	-0.198*	-0.006*	0.003					
STEP 4				0.291	0.085	0.025	3.152*	3.688~
QFOSS_lg		0.410	0.287					
CONSEQ		1.121	0.500					
TIMING		0.011	0.010					
Conseq x Timing		-0.006~	0.003					

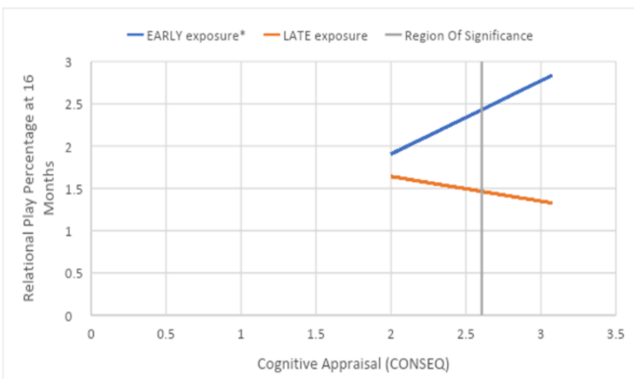
Note. ~ p <0.1, * p <0.05, ** p < 0.01

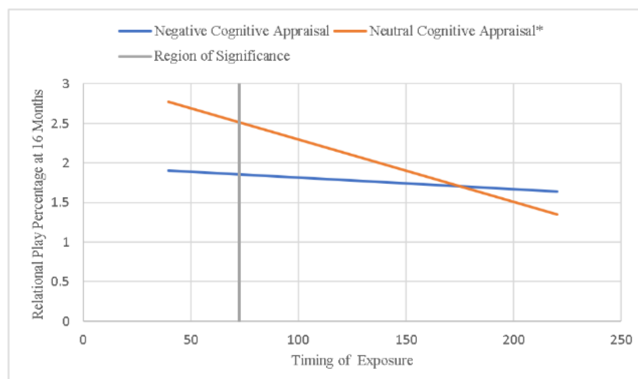
Figure 3

Interaction between Mothers' Cognitive Appraisal and Timing of Exposure in Predicting Relational Play at 16 Months.

A. The Effect of Mothers' Cognitive Appraisal on Relational Play at 16 Months at Different Levels of Timing of Exposure

B. The Effect of Timing of Exposure on Relational Play at 16 Months for Different Levels of Mothers' Cognitive Appraisal





Panel A represents the effect of a cognitive appraisal on relational play at 16 months at different levels of the timing of exposure. The blue line represents the effect of cognitive appraisal at early exposure (39.70 days) while the orange line represents this effect at late exposure (220.28 days). The vertical grey line delimits the region of significance (2.61) within which the effect of timing on relational play at 16 months is significant. On the other hand, Panel B represents the effect of timing of exposure on relational play at different levels of cognitive appraisal. The vertical grey line delimits the region of significance (below 72.67 days) within which the effect of a cognitive appraisal on relational play at 16 months is significant. Significance *: $p < 0.05$.

Functional Play and Objective Hardship. As shown in Table 12, exposure to objective hardship during pregnancy had no significant effect on the percentage of time spent in functional play at 16 months. However, the timing of exposure to the flood had a marginally significant effect on the amount of time the 16-month old engaged in functional play ($p = .087$): the later in pregnancy the exposure to the flood took place, the lower were the instances of functional play at 16 months. The unadjusted and adjusted models explained 2.6% (Table 12) and 5.1% (Appendix 3) of the variance in functional play at 16 months, respectively. On controlling for covariates, no significant associations were found between functional play and objective hardship or between the timing of exposure and the percentage of time spent in functional play at 16 months. Additionally, no significant timing by objective hardship interaction was found.

Table 12

Summary of Hierarchical Regression Analyses of All Objective Hardship Variables for Functional Play at 16 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
16 Months								
STEP 1				0.073	0.005	0.005	0.759	0.759
QFOSS_lg	-0.073	-0.668	0.767					
STEP 2				0.162	0.026	0.021	1.867	2.965~
QFOSS_lg	-0.071	-0.644	0.761					
TIMING	-0.144~	-0.013	0.008					
STEP 3				0.166	0.274	0.001	1.296	0.176
QFOSS_lg		-1.191	1.513					
TIMING		-0.026	0.032					
QFOSS_lg x TIMING		0.005	0.011					

Note. ~ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$

Functional Play and Subjective Distress. As shown in Table 13, while controlling for objective hardship, exposure to subjective distress after the disaster had a marginally significant effect on the percentage of time spent in functional play at 16 months ($p = .061$): higher levels of subjective distress were associated with lower levels of functional play at 16 months of age. Similarly, the timing of exposure to the flood also had a marginally significant effect on instances of functional play ($p = .093$): the earlier in pregnancy the exposure took place, the more time the child spent engaging in functional play at 16 months. The unadjusted and adjusted models explained 5.1% (Table 13) and 10.3% (Appendix 3) of the variance in functional play at 16 months respectively. Upon controlling for covariates, subjective distress had a significant effect on the instances of functional play ($p = .014$). The timing of exposure, however, had no significant effect. On applying FILTER, subjective distress remained significant ($p = .008$) meaning that the reduced sample size led the association between subjective distress and functional play to become significant at 16 months. Additionally, no significant timing by subjective distress interaction was found.

Table 13

Summary of Hierarchical Regression Analyses of All Subjective Distress Variables for Functional Play at 16 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
				16 Months				
STEP 1				0.073	0.005	0.005	0.759	0.759
QFOSS_lg	-0.073	-0.668	0.767					
STEP 2				0.176	0.031	0.026	2.229	3.684~
QFOSS_lg	0.016	0.142	0.869					
COSMOSS	-0.183	-1.176	0.613					
STEP 3				0.225	0.051	0.020	2.458~	2.857~
QFOSS_lg	0.016	0.148	0.863					
COSMOSS	-0.179~	-1.150 ~	0.609					
TIMING	-0.140~	-0.013~	0.007					
STEP 4				0.225	0.051	0.000	1.830	0.000
QFOSS_lg		0.148	0.866					
COSMOSS		-1.156	1.018					
TIMING		-0.013	0.008					
COSMOSS x TIMING		0.000	0.006					

Note. ~ p <0.1, * p <0.05, ** p < 0.01

Functional Play and Cognitive Appraisal. As shown in Table 14, while controlling for objective hardship, no significant associations were found between the mothers' cognitive appraisal of the event and the amount of time the child actively engaged in functional play at 16 months. However, the timing of exposure had a marginally significant effect on the same ($p = .081$): the earlier in pregnancy the exposure took place, the more time the child engaged in functional play at 16 months. The unadjusted and adjusted models explained 2.8% (Table 14) and 5.2% (Appendix 3) of the variance in functional play at 16 months respectively. In the adjusted model, no significant associations were found between functional play and mother's cognitive appraisal of the event. Similarly, the timing of exposure also had no significant effect on functional play at 16 months. Additionally, no significant timing by cognitive appraisal interaction was found.

Table 14

Summary of Hierarchical Regression Analyses of All Cognitive Appraisal Variables for Functional Play at 16 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
				16 Months				
STEP 1				0.068	0.005	0.005	0.641	0.641
QFOSS_lg	-0.068	-0.619	0.773					
STEP 2				0.078	0.006	0.002	0.425	0.213
QFOSS_lg	-0.053	-0.486	0.827					
CONSEQ	0.042	0.379	0.821					
STEP 3				0.167	0.028	0.022	1.315	3.081~
QFOSS_lg	-0.053	-0.481	0.821					
CONSEQ	0.031	0.283	0.817					
TIMING	-0.148~	-0.013~	0.008					
STEP 4				0.206	0.042	0.014	1.499	2.019
QFOSS_lg		-0.402	0.820					
CONSEQ		-1.387	1.430					
TIMING		-0.051	0.028					
CONSEQx TIMING		0.014	0.010					

Note. ~ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$

Displayed Hypotheses and Objective Hardship. As shown in Table 15, exposure to objective hardship during pregnancy had no significant effect on the displayed hypotheses at 16 months without controlling for covariates. The unadjusted and adjusted main effects models explained 3.9% and 7.7% of the variance in displayed hypotheses at 16 months respectively. Timing had a marginally significant moderating effect on the relationship between objective hardship and displayed hypotheses ($p = .051$). However, no interaction effect was found for the adjusted model. The unadjusted and adjusted models explained 6.6% (Table 15) and 9% (Appendix 3) of the variance in displayed hypotheses at 16 months respectively, of which 2.6% and 1.2% are explained by the interaction, respectively. In the unadjusted model, only when exposure took place earlier in pregnancy (< 72.17), higher objective hardship was associated with greater displayed hypotheses at 16 months. Additionally, only when objective hardship was high (>2.89), later exposure was associated with lower displayed hypotheses at 16 months (Figure 4A and 4B). Furthermore, the cross-over point was 2.178 with CI= [1.110; 3.246] which lies within the range of the objective hardship values (1.101; 3.246), although borderline. As such, it can be interpreted as a disordinal interaction with early-exposed children being differentially susceptible to the effects of objective hardship.

Table 15

Summary of Hierarchical Regression Analyses of All Objective Hardship Variables for Displayed Hypotheses at 16 Months.

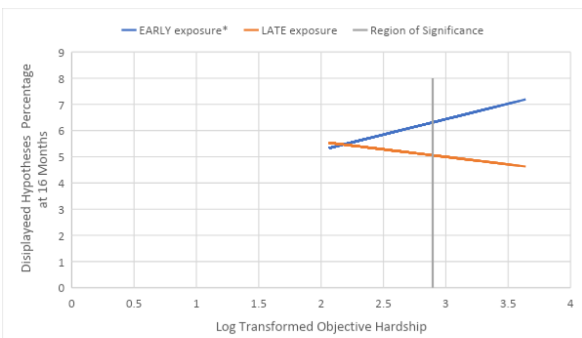
Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
			16 Months					
STEP 1				0.082	0.007	0.007	0.937	0.937
QFOSS_lg	0.082	0.350	0.361					
STEP 2				0.198	0.039	0.033	2.850~	4.738*
QFOSS_lg	0.085	0.364	0.356					
TIMING	-0.181	-0.008	0.004					
STEP 3				0.256	0.066	0.026	3.232*	3.876~
QFOSS_lg		1.551*	0.699					
TIMING		0.021	0.015					
QFOSS_lg x TIMING		-0.010~	0.050					

Note. ~ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$

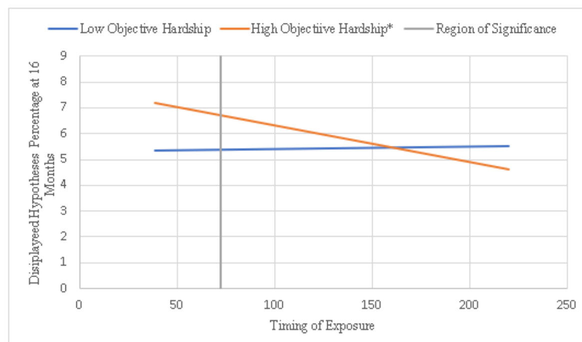
Figure 4

Interaction between Mothers' Objective Hardship and Timing of Exposure in Predicting Displayed Hypotheses at 16 Months.

A. The Effect of Mothers' Objective Hardship on Displayed Hypotheses at 16 Months at Different Levels of Timing of Exposure



B. The Effect of Timing of Exposure on Displayed Hypotheses at 16 Months for Different Levels of Mothers' Objective Hardship



Panel A represents the effect of objective hardship on displayed hypotheses at 16 months at different levels of the timing of exposure. The blue line represents the effect of objective hardship at early exposure (38.58 days) while the orange line represents this effect at late exposure (220.12 days). The vertical grey line delimits the region of significance (2.89) within which the effect of timing on displayed hypotheses at 16 months is significant. On the other hand, Panel B represents the effect of timing of exposure on displayed hypotheses at different levels of objective hardship. The vertical grey line delimits the region of significance (below 72.17 days) within which the effects of objective hardship on displayed hypotheses at 16 months is significant. Significance *: $p < 0.05$.

Displayed Hypotheses and Subjective Distress. As shown in Table 16, while controlling for objective hardship, the severity of subjective distress during pregnancy had a significant effect on the displayed hypotheses at 16 months ($p = .012$): the higher the levels of subjective distress, the lower were the instances of children's displayed hypotheses at 16 months. Additionally, the timing of exposure to the flood also had a significant effect on the displayed hypotheses at 16 months ($p = .033$): the later in pregnancy the exposure took place, the lower were the instances of displayed hypotheses. The unadjusted and adjusted models explained 8.3% (Table 16) and 14% (Appendix 3) of the variance in displayed hypotheses at 16 months, respectively. Furthermore, on assessing which stress measure of COMOSS had a significant effect on the displayed hypotheses at 16 months, the Peritraumatic Distress Inventory scale (PDI) was found to have a significant effect ($p = .027$): the greater the levels of subjective distress 'at the time of the flood', the lower were the instances of displayed hypotheses at 16 months. Additionally, on controlling for covariates, subjective distress ($p = .006$) and timing of exposure ($p = .007$) again had significant effects on the displayed hypotheses of the 16-month-old children. However, no significant timing by subjective distress interaction was found.

Table 16

Summary of Hierarchical Regression Analyses of All Subjective Distress Variables for Displayed Hypotheses at 16 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
				16 Months				
STEP 1				0.082	0.007	0.007	0.937	0.937
QFOSS_lg	0.082	0.350	0.361					
STEP 2				0.227	0.052	0.045	3.788*	6.601*
QFOSS_lg	0.199	0.855	0.405					
COSMOSS	-0.243	-0.734	0.286					
STEP 3				0.287	0.083	0.031	4.140**	4.645*
QFOSS_lg	0.200	0.858	0.400					
COSMOSS	-0.238*	-0.719*	0.282					
TIMING	-0.176*	-0.007*	0.003					
STEP 4				0.296	0.088	0.005	3.292	0.769
QFOSS_lg		0.862	0.400					
COSMOSS		-0.389	0.470					
TIMING		-0.007	0.004					
COSMOSS x TIMING		-0.003	0.003					

Note. ~ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$

Displayed Hypotheses and Cognitive Appraisal. As shown in Table 17, while controlling for objective hardship, no significant associations were found between the mothers' cognitive appraisal and the displayed hypotheses at 16 months. Upon controlling for objective hardship and cognitive appraisal, the timing of exposure had a significant effect on the displayed hypotheses at 16 months ($p = .032$): the later in pregnancy the exposure took place, the lower were the instances of displayed hypotheses at 16 months of age. The unadjusted and adjusted models explained for 5.4% (Table 17) and 8.6% (Appendix 3) of the variance in displayed hypotheses at 16 months, respectively. In the adjusted model, no significant associations were found between the mother's cognitive appraisal and the child's displayed hypotheses, but timing again had a significant effect on the displayed hypotheses at 16 months ($p =.012$). However, no significant timing by cognitive appraisal interaction effect was found.

Table 17

Summary of Hierarchical Regression Analyses of All Cognitive Appraisal Variables for Displayed Hypotheses at 16 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
16 Months								
STEP 1				0.087	0.008	0.008	1.053	1.053
QFOSS_lg	0.087	0.374	0.364					
STEP 2				0.149	0.022	0.015	1.556	2.051
QFOSS_lg	0.132	0.567	0.387					
CONSEQ	0.129	0.550	0.384					
STEP 3				0.233	0.054	0.032	2.623~	4.673*
QFOSS_lg	0.132	0.570	0.382					
CONSEQ	0.116	0.495	0.380					
TIMING	-0.180*	-0.008*	0.004					
STEP 4				0.248	0.062	0.007	2.230	1.050
QFOSS_lg		0.596	0.383					
CONSEQ		-0.067	0.667					
TIMING		-0.020	0.013					
CONSEQ x TIMING		0.005	0.005					

Note. ~ p <0.1, * p <0.05, ** p < 0.01

Children at 30-Months of Age

Stereotypical Play and Objective Hardship. As shown in Table 18, exposure to objective hardship during pregnancy had a marginally significant effect on the amount of time the child spent in stereotypical play at 30 months (p = .099): the higher the levels of objective hardship, the lower were the instances of stereotypical play. The timing of exposure to the flood had no significant effect on the amount of time the 30-month old engaged in stereotypical play, with or without controlling for covariates. The unadjusted and adjusted models explained 2.1% (Table 18) and 8.3% (Appendix 3) of the variance in stereotypical play at 30 months, respectively. In the adjusted model, objective hardship again had a marginally significant effect on the child's stereotypical play (p =.053). Moreover, no significant timing by objective hardship interaction was found.

Table 18

Summary of Hierarchical Regression Analyses of All Objective Hardship Variables for Stereotypical Play at 30 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
30 Months								
STEP 1				0.143	0.020	0.020	2.769~	2.769~
QFOSS_lg	-0.143	-0.289~	0.174					
STEP 2				0.144	0.021	0.000	1.396	0.043
QFOSS_lg	-0.143	-0.290	0.174					
TIMING	-0.018	0.000	0.002					
STEP 3				0.172	0.030	0.009	1.330	1.194
QFOSS_lg		0.044	0.352					
TIMING		0.007	0.007					
QFOSS x Timing		-0.003	0.002					

Note. ~ p <0.1, * p <0.05, ** p < 0.01

Stereotypical Play and Subjective Distress. No significant, nor marginal associations were found between mothers' subjective distress and stereotypical play at 30 months, with controlling (Appendix 3) or without controlling for covariates (Table 19). Moreover, neither the timing of exposure, nor the timing by subjective distress interaction effect was significant.

Table 19

Summary of Hierarchical Regression Analyses of All Subjective Distress Variables for Stereotypical Play at 30 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
30 Months								
STEP 1				0.143	0.020	0.020	2.769	2.769
QFOSS_lg	-0.143	-0.289	0.174					
STEP 2				0.199	0.039	0.019	2.714	2.625
QFOSS_lg	-0.218	-0.442	0.197					
COSMOSS	0.157	0.240	0.148					
STEP 3				0.199	0.040	0.000	1.797	0.006
QFOSS_lg	-0.218	-0.442	0.197					
COSMOSS	0.157	0.239	0.149					
TIMING	-0.006	0.000	0.002					
STEP 4				0.199	0.040	0.000	1.342	0.016
QFOSS_lg		-0.444	0.199					
COSMOSS		0.217	0.232					
TIMING		-0.000	0.002					
COSMOSS X TIMING		0.000	0.002					

Stereotypical Play and Cognitive Appraisal. No significant, nor marginal associations were found between mothers' cognitive appraisal and stereotypical play at 30 months, with controlling (Appendix 3) or without controlling for covariates (Table 20). Moreover, neither the timing of exposure, nor the timing by cognitive appraisal interaction effect was significant.

Relational Play and Objective Hardship. As shown in Table 21, exposure to objective hardship during pregnancy had no significant effect on the percentage of time spent in relational play at 30 months. However, the timing of exposure to the flood had a marginally significant effect on the amount of time the 30-month-old engaged in relational play ($p = .084$): the earlier in pregnancy the exposure took place, the higher were the instances of relational play. The unadjusted and adjusted models explained 2.7% (Table 21) and 8.8% (Appendix 3) of the variance in relational play at 30 months, respectively. In the adjusted model, no significant associations were found between relational play and objective hardship at 30 months, but the effect of timing of exposure on the relational play was still significant ($p =.037$). However, no significant timing by objective hardship interaction was found.

Table 20

Summary of Hierarchical Regression Analyses of All Cognitive Appraisal Variables for Stereotypical Play at 30 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
				30 Months				
STEP 1				0.137	0.019	0.019	2.530	2.530
QFOSS_lg	-0.137	-0.279	0.175					
STEP 2				0.137	0.019	0.000	1.261	0.013
QFOSS_lg	-0.133	-0.271	0.189					
CONSEQ	0.010	0.022	0.192					
STEP 3				0.139	0.019	0.000	0.856	0.066
QFOSS_lg	-0.134	-0.272	0.190					
CONSEQ	0.010	0.020	0.193					
TIMING	-0.022	0.000	0.002					
STEP 4				0.140	0.020	0.000	0.644	0.025
QFOSS_lg		-0.271	0.191					
CONSEQ		-0.025	0.341					
TIMING		-0.002	0.007					
CONSEQ x TIMING		0.000	0.002					

Table 21

Summary of Hierarchical Regression Analyses of All Objective Hardship Variables for Relational Play at 30 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
				30 Months				
STEP 1				0.070	0.005	0.005	0.646	0.646
QFOSS_lg	0.070	0.335	0.416					
STEP 2				0.165	0.027	0.022	1.839	3.022~
QFOSS_lg	0.065	0.312	0.414					
TIMING	-0.149~	-0.007~	0.004					
STEP 3				0.210	0.044	0.017	2.020	2.344
QFOSS_lg		1.418	0.832					
TIMING		0.019	0.0173					
QFOSS_lg xTIMING		-0.009	0.006					

Note. ~ p <0.1, * p <0.05, ** p < 0.01

Relational Play and Subjective Distress. As shown in Table 22, while controlling for objective hardship, exposure to subjective distress during pregnancy had no significant effect on the percentage of time spent in relational play at 30 months. However, when controlling for objective hardship and composite subjective distress, the timing of exposure to the flood had a marginally significant effect on the amount of time the 30-month old engaged in relational play ($p = .082$): the earlier in pregnancy the exposure took the place, the higher were the instances of relational play. The unadjusted and adjusted models explained 2.8% (Table 22) and 9.4% (Appendix 3) of the variance in relational play at 30 months, respectively. In the adjusted model, no significant associations were again found between relational play and subjective distress, but the effect of timing of exposure on the relational play was still significant ($p = .037$). However, no significant timing by objective hardship interaction was found.

Table 22

Summary of Hierarchical Regression Analyses of All Subjective Distress Variables for Relational Play at 30 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
				30 Months				
STEP 1				0.070	0.005	0.005	0.646	0.646
QFOSS_lg	0.070	0.335	0.416					
STEP 2				0.072	0.005	0.000	0.340	0.038
QFOSS_lg	0.079	0.379	0.476					
COSMOSS	-0.019	-0.069	0.358					
STEP 3				0.167	0.028	0.023	1.257	3.080~
QFOSS_lg	0.081	0.389	0.473					
COSMOSS	-0.034	-0.121	0.356					
TIMING	-0.152~	-0.007~	0.004					
STEP 4				0.184	0.034	0.006	1.141	0.800
QFOSS_lg		0.434	0.476					
COSMOSS		0.256	0.552					
TIMING		-0.007	0.004					
COSMOSS X TIMING		-0.004	0.004					

Note. ~ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$

Relational Play and Cognitive Appraisal. As shown in Table 23, while controlling for objective hardship, the mothers' cognitive appraisal of the event had a marginally significant effect on the amount of time the child actively engaged in relational play at 30 months ($p = .073$): the more negative the mothers' cognitive appraisal of the event was, the higher were the instances of relational play at 30 months. Additionally, when controlling for objective hardship and cognitive appraisal, the timing of exposure to the flood also had a marginally significant effect on the amount of time the 30-month old engaged in relational play ($p = .064$): the earlier in pregnancy the exposure took place, the greater were the instances of relational play. The unadjusted and adjusted models explained 5.3% (Table 23) and 11.3% (Appendix 3) of the variance in relational play at 30 months, respectively. In the adjusted model, no significant associations were found between relational play and cognitive appraisal at 30 months. The timing of exposure to the flood again had a significant effect on the amount of time the child engaged in relational play at 30 months ($p = .033$). On applying FILTER, the effect of cognitive appraisal on relational play was no longer significant, meaning that the reduced sample size led the association between cognitive appraisal and relational play at 30 months to become non-significant. Additionally, no significant timing by cognitive appraisal interaction effect was found.

Table 23

Summary of Hierarchical Regression Analyses of All Cognitive Appraisal Variables for Relational Play at 30 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
				30 Months				
STEP 1				0.075	0.006	0.006	0.737	0.737
QFOSS_lg	0.075	0.36	0.420					
STEP 2				0.167	0.028	0.022	1.877	3.006~
QFOSS_lg	0.016	0.076	0.448					
CONSEQ	-0.161~	-0.790 ~	0.456					
STEP 3				0.231	0.053	0.025	2.440~	3.495~
QFOSS_lg	0.010	0.049	0.444					
CONSEQ	-0.166 ~	-0.817 ~	0.452					
TIMING	-0.160~	-0.008~	0.004					
STEP 4				0.232	0.054	0.000	1.827	0.042
QFOSS_lg		0.047	0.446					
CONSEQ		-0.682	0.798					
TIMING		-0.005	0.016					
CONSEQ x TIMING		-0.001	0.006					

Note. ~ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$

Functional Play and Objective Hardship. No significant, nor marginal associations were found between mothers' objective hardship and functional play at 30 months, with controlling (Appendix 3) or without controlling for covariates (Table 24). Moreover, neither the timing of exposure, nor the timing by objective hardship interaction effect was significant.

Table 24

Summary of Hierarchical Regression Analyses of All Objective Hardship Variables for Functional Play at 30 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
				30 Months				
STEP 1				0.036	0.001	0.001	0.177	0.177
QFOSS_lg	0.036	0.422	1					
STEP 2				0.12	0.014	0.013	0.962	1.745
QFOSS_lg	0.04	0.464	1					
TIMING	0.114	0.013	0.01					
STEP 3				0.129	0.017	0.002	0.734	0.288
QFOSS_lg		-0.481	2.027					
TIMING		-0.009	0.042					
QFOSS_lg x TIMING		0.007	0.014					

Functional Play and Subjective Distress. No significant, nor marginal associations were found between mothers' subjective distress and functional play at 30 months, with controlling (Appendix 3) or without controlling for covariates (Table 25). Moreover, neither the timing of exposure, nor the timing by subjective distress interaction effect was significant.

Functional Play and Cognitive Appraisal. No significant, nor marginal associations were found between mothers' cognitive appraisal and functional play at 30 months, with controlling (Appendix 3) or without controlling for covariates (Table 26). Moreover, neither the timing of exposure, nor the timing by subjective distress interaction effect was significant.

Displayed Hypotheses and Objective Hardship. No significant, nor marginal associations were found between mothers' objective hardship and child's displayed hypotheses at 30 months, with controlling (Appendix 3) or without controlling for covariates (Table 27). Moreover, neither the timing of exposure, nor the timing by objective hardship interaction effect was significant.

Table 25

Summary of Hierarchical Regression Analyses of All Subjective Distress Variables for Functional Play at 30 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
				30 Months				
STEP 1				0.036	0.001	0.001	0.177	0.177
QFOSS_lg	0.036	0.422	1.002					
STEP 2				0.045	0.002	0.001	0.133	0.089
QFOSS_lg	0.051	0.586	1.146					
CONSEQ	-0.03	-0.258	0.862					
STEP 3				0.121	0.015	0.013	0.649	1.679
QFOSS_lg	0.049	0.568	1.143					
CONSEQ	-0.019	-0.165	0.862					
TIMING	0.113	0.013	0.01					
STEP 4				0.146	0.021	0.007	0.711	0.901
QFOSS_lg		0.453	1.15					
CONSEQ		-1.132	1.335					
TIMING		0.011	0.01					
CONSEQ x TIMING		0.01	0.01					

Table 26

Summary of Hierarchical Regression Analyses of All Cognitive Appraisal Variables for Functional Play at 30 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
			30 Months					
STEP 1				0.052	0.003	0.003	0.355	0.355
QFOSS_lg	0.052	0.597	1.002					
STEP 2				0.060	0.004	0.001	0.238	0.123
QFOSS_lg	0.064	0.736	1.081					
CONSEQ	0.033	0.386	1.100					
STEP 3				0.120	0.014	0.011	0.628	1.408
QFOSS_lg	0.067	0.777	1.080					
CONSEQ	0.036	0.427	1.099					
TIMING	0.103	0.012	0.010					
STEP 4				0.141	0.020	0.006	0.658	0.750
QFOSS_lg		0.749	1.081					
CONSEQ		1.807	1.936					
TIMING		0.044	0.038					
CONSEQ x TIMING		-0.012	0.013					

Table 27

Summary of Hierarchical Regression Analyses of All Objective Hardship Variables for Displayed Hypotheses at 30 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
			30 MONTHS					
STEP 1				0.002	0.000	0.000	0.000	0.000
QFOSS_lg	0.002	0.009	0.408					
STEP 2				0.137	0.019	0.019	1.261	2.521
QFOSS_lg	-0.003	-0.012	0.406					
TIMING	-0.137	-0.006	0.004					
STEP 3				0.161	0.026	0.007	1.161	0.961
QFOSS_lg		-0.711	0.820					
TIMING		-0.023	0.017					
QFOSS_lg x TIMING		0.006	0.006					

Displayed Hypotheses and Subjective Distress. No significant, nor marginal associations were found between mothers' subjective distress and child's displayed hypotheses at 30 months, with controlling (Appendix 3) or without controlling for covariates (Table 28). Moreover, neither the timing of exposure, nor the timing by subjective distress interaction effect was significant.

Table 28

Summary of Hierarchical Regression Analyses of All Subjective Distress Variables for Displayed Hypotheses at 30 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
				30 MONTHS				
STEP 1				0.002	0.000	0.000	0.000	0.000
QFOSS_lg	0.002	0.009	0.408					
STEP 2				0.002	0.000	0.000	0.000	0.000
QFOSS_lg	0.002	0.009	0.466					
COSMOSS	0.000	0.000	0.351					
STEP 3				0.137	0.019	0.019	0.840	0.252`
QFOSS_lg	0.004	0.017	0.464					
COSMOSS	-0.013	-0.046	0.350					
TIMING	-0.138	-0.006	0.004					
STEP 4				0.142	0.020	0.001	0.688	0.168
QFOSS_lg		-0.003	0.468					
COSMOSS		-0.216	0.543					
TIMING		-0.007	0.004					
COSMOSS x TIMING		0.002	0.004					

Displayed Hypotheses and Cognitive Appraisal. No significant associations were found for mothers' cognitive appraisal of the event and timing of exposure with the child's displayed hypotheses at 30 months, in both the unadjusted (Table 29) and adjusted models (Appendix 3). Timing however had a significant moderating effect on the relationship between cognitive appraisal and displayed hypotheses at 30 months in both the unadjusted and adjusted models ($p = .050$, $p = .020$). When children were exposed to the flood at an earlier stage in pregnancy (< 69.76 days), a more positive mothers' cognitive appraisal was associated with higher displayed hypotheses at 30 months, while no statistically significant effect of cognitive appraisal was found for late exposure (Figure 5A and 5B). Additionally, the cross-over point was 2.182 with CI= [1.202; 3.162], which lies within the range of cognitive appraisal values (1.000; 4.000). As such, it can be interpreted as a disordinal interaction with early-exposed children being differentially susceptible to the effects of their mothers' cognitive appraisal of the Queensland floods.

Table 29

Summary of Hierarchical Regression Analyses of All Cognitive Appraisal Variables for Displayed Hypotheses at 30 Months.

Predictor Variables	β	B	Std. Error	R	R^2	ΔR^2	F	ΔF
				30 MONTHS				
STEP 1				0.005	0.000	0.000	0.003	0.003
QFOSS_lg	0.005	0.022	0.412					
STEP 2				0.100	0.010	0.010	0.661	1.318
QFOSS_lg	0.044	0.209	0.442					
CONSEQ	0.107	0.516	0.450					
STEP 3				0.170	0.029	0.019	1.284	2.515
QFOSS_lg	0.039	0.187	0.440					
CONSEQ	0.103	0.494	0.447					
TIMING	-0.137	-0.006	0.004					
STEP 4				0.239	0.057	0.028	1.956	3.887~
QFOSS_lg		0.161	0.435					
CONSEQ		1.758	0.779					
TIMING		0.023	0.015					
CONSEQ x TIMING		-0.011~	0.005					

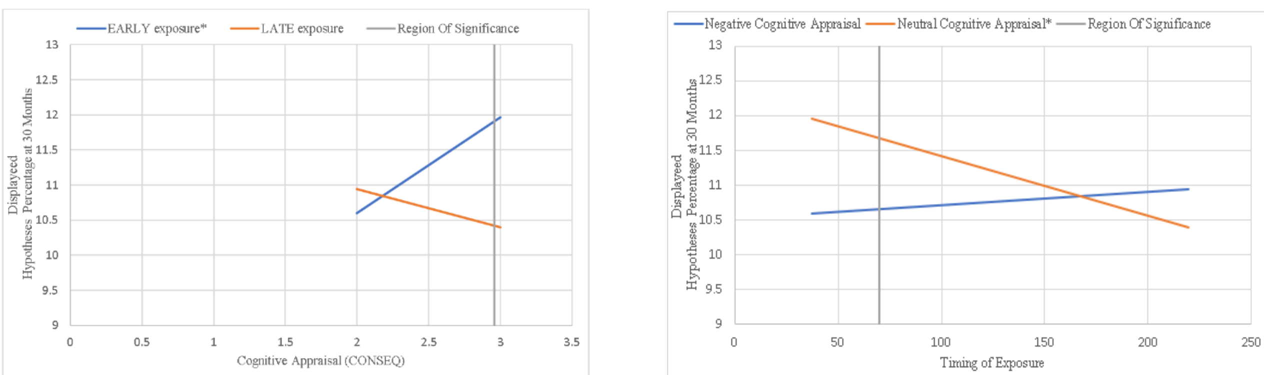
Note. ~ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$

Figure 5

Interaction between Mothers' Cognitive Appraisal and Timing of Exposure on Displayed Hypotheses at 30 Months.

A. The Effect of Mothers' Cognitive Appraisal on Displayed Hypotheses at 30 Months at Different Levels of Timing of Exposure

B. The Effect of Timing of Exposure on Displayed Hypotheses at 30 Months for Different Levels of Mothers' Cognitive Appraisal



Panel A represents the effect of the cognitive appraisal on displayed hypotheses at 30 months at different levels of the timing of exposure. The blue line represents the effect of cognitive appraisal at early exposure (37.35 days) while the orange line represents this effect at late exposure (219.4 days). The vertical grey line delimits the region of significance (2.95) within which the effect of timing on displayed hypotheses at 30 months is significant. On the other hand, Panel B represents the effect of timing of exposure on displayed hypotheses at different levels of cognitive appraisal. The vertical grey line delimits the region of significance (below 69.76 days) within which the effects of the cognitive appraisal on displayed hypotheses at 16 months is significant. Significance *: $p < 0.05$.

Discussion

The idea behind this study was to determine the effects of prenatal maternal stress caused by a natural disaster on the play behavior of children. In other words, the goal was to determine the extent to which PNMS influences the cognitive development of prenatally stressed children at the ages of 16 and 30 months. PNMS was assessed using objective hardship, subjective distress, and cognitive appraisal, as well as the effect of the timing of the disaster in pregnancy. It was predicted that exposure to higher levels of PNMS would cause higher levels of immature stereotypical play and lower levels of more mature functional play and play diversity at both 16 and 30-months. It was also predicted that the effects of PNMS on play behavior would be greatest for children at both ages who were exposed to the flood during the 1st and 2nd trimester.

Previous research suggests that by 16 months, higher instances of displayed hypotheses, relational play, and functional play indicate normal development of the child whereas instances of stereotypical play imply immaturity. However, at 30 months if a child still exhibits both relational and stereotypical play, it implies a delay in cognitive maturity (Largo and Howard, 1979). Functional play and displayed hypotheses can be interpreted as 'mature' play behavior at both ages in the current study.

At 16 months, two interesting patterns were found: First, in the absence of a timing-by-PNMS interaction, the later the exposure, the less time the child engaged in more mature forms of play (relational and functional) and the fewer displayed hypotheses they performed. The second pattern was that exposure to the flood in early pregnancy seemed to render children more sensitive to the effects of PNMS. This was seen in interactions between timing and objective

PNMS predicting stereotypical play. This pattern of early exposure being sensitive to PNMS, and late exposure being relatively resilient to PNMS but still having relatively immature play behavior, was also seen in the association between cognitive appraisal and stereotypical and relational play, and between objective PNMS and displayed hypotheses. In addition to these two patterns, a main effect for greater subjective PNMS ‘at the time of the flood’ was found predicting fewer displayed hypotheses at 16 months.

At 30 months, our models did not explain significant variance in stereotypical, relational, or functional play. The results did, however, uncover a timing-by-PNMS interaction predicting the number of displayed hypotheses: once again, late pregnancy exposure was associated with lower displayed hypotheses no matter the mothers’ cognitive appraisal of the flood. However, children exposed early in pregnancy to their mothers’ negative appraisal had low levels of displayed hypotheses (on par with the late-exposed children) while more positive appraisals led to more displayed hypotheses.

The results suggest that early pregnancy is a critical period for PNMS to have any significant associations with play behavior at 16 months. When the exposure to the disaster was as early as the first 6 weeks (<=43 days), objective hardship had a significant effect on stereotypical play at 16 months: with high levels of objective hardship leading to lower instances of stereotypical play. Similarly, when the exposure to the disaster was as early as 63 days (2 months), the level of objective hardship had a significant effect on the displayed hypotheses at 16 months: with higher objective hardship leading to greater displayed hypotheses. This finding however contradicts the hypothesis that high levels of objective hardship would be associated with lower levels of displayed hypotheses and challenges the previous findings that found the same hypothesized association at 24 months (Laplante et al., 2007). A possible explanation for the discrepancies between the present and previous findings can be attributed to the Yerkes Dodson Law of Optimal Arousal (Yerkes and Dodson 1908). The law states that an individual's performance in certain tasks would show an increment if he/she is mentally or physiologically aroused only up to a certain point, after which performance declines as arousal increases. To begin with, the Ice Storm was very high in its level of objective hardship (Laplante et al., 2005) as compared to the Queensland Flood. However, since the 1998 Quebec Ice Storm and the 2011 Queensland Flood are two very different types of disaster, with differing measures of objective hardship, it would not be appropriate to compare the two to assess the effects of objective hardship on child development. Although not a perfect analogy, it may be that the levels of objective hardship in QF2011 pushed the mother and her unborn child up the ascending slope of the Yerkes-Dodson curve rather than pushing them down the descending slope of the curve. In other words, it may be that relatively mild levels of PNMS, as seen in QF2011, are beneficial for fetal development while greater degrees of stress (as seen in Project Ice Storm) are detrimental. This idea is supported by Project Ice Storm results showing that, at age 5, the association between objective hardship and IQ is curvilinear, mimicking the Yerkes-Dodson law (Laplante et al., 2008).

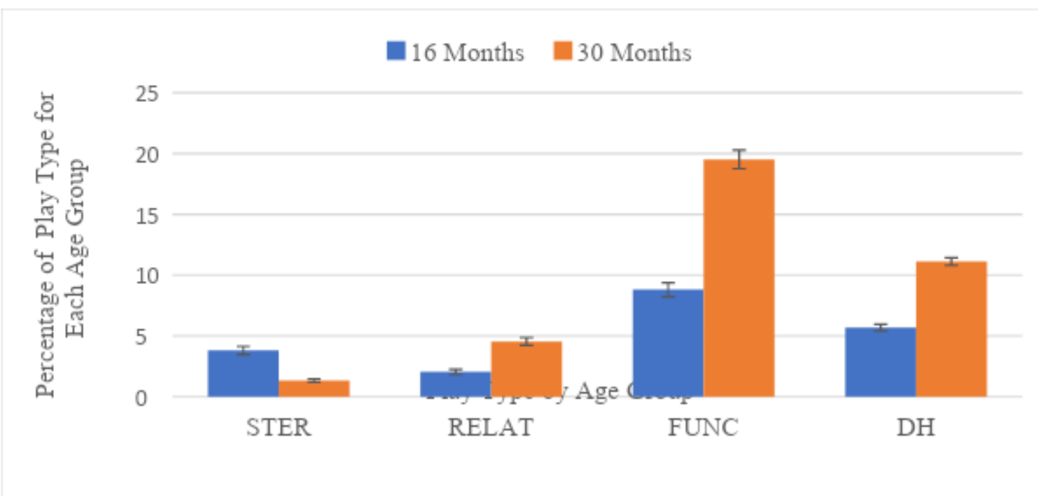
In addition to these interactions with PNMS, timing also had significant main effects. Early exposure was subject to levels of PNMS, whereas late exposure to the disaster was associated with worse outcomes, as seen in both main effects and interactions. Later exposure was associated with lower levels of relational play, functional play, and lower levels of displayed hypotheses. These trends can be attributed to the development of different brain regions at different periods. Aiding with motor functioning, the cerebellum develops later in pregnancy (Charil et al., 2010). Thus, it is possible that the exposure to PNMS later in pregnancy impacts the child's neuromotor maturity and consequently limits the extent to which the infant can manipulate toys more functionally. This motor disadvantage further restricts the child from exploring and learning which then impedes the child's sensorimotor stage of cognitive development (Huitt and Hummel, 2003).

Upon assessing the actions of 16-month-old children in our study, the trends for relational and stereotypical play appear consistent with previous play studies (Largo and Howard, 1979). On the other hand, however, the present study demonstrated a different trend from the normal developmental progression of play behavior for the 30-month-old children exposed to a natural disaster in utero, as described below.

Stereotypical play, recognized as a dominant play pattern only up until 13 months and known to completely disappear by 21 months, was however still frequently visible in our sample at both 16 and 30 months of age. On average, 16-month-old participants spent 3.8% of their entire play session on stereotypical play, while 30-month-old participants spent 1.34% of their entire play session on stereotypical play. Additionally, although the main goal of this study was to see the effects of PNMS on the immature stereotypical play and mature functional play, unanticipated results were found for the play type bridging the gap between these two. Relational play, known to completely disappear by 24 months was still frequently exhibited by the children at 30 months of age, suggesting a possible cognitive delay in maturity in this group of prenatally stressed children (Figure 6). In fact, the amount of time spent in relational play doubled between 16 and 30 months. This was surprising because by 30 months a child is expected to form appropriate associations and have functional play as their dominant play pattern with no instances of relational or stereotypical play whatsoever (Largo and Howard, 1979). Thus, the appearance of stereotypical and relational play at 30 months suggests that the children are still engaging in more immature play and not enough mature play.

Figure 6

Percentage of Play Type of Prenatally Stressed Children at 16 and 30 months in QF2011



Note: STER = Stereotypical Play, RELAT = Relational Play, FUNC = Functional Play, DH = Displayed Hypotheses

Another goal was to determine which aspect(s) of PNMS (objective, subjective or cognitive appraisal) had significant effects on child play behavior and whether the findings are coherent with the previous literature. Consistent with the Laplante (2007) study, the present study found subjective distress to have a marginally significant main effect on the percentage of time the child spent in functional play at 16 months. Furthermore, subjective distress again had a significant main effect on displayed hypotheses at 16 and 30 months of age: where high levels of subjective distress led to lower levels of displayed hypotheses. However, contrary to the previous findings where objective hardship had a significant main effect on stereotypical play, functional play, and displayed hypotheses at 24 months, the present study only reported objective hardship to have a marginally significant main effect on the stereotypical play of the 30-month-old children. Additionally, while the previous study reported a significant objective by timing interaction on displayed hypotheses at 24 months, no such interactions were reported for the present study at both 16 and 30 months. However, surprisingly, a marginally significant objective by timing interaction was found for stereotypical play only for the 16-month-old children.

Furthermore, this study improves upon previous research by measuring the association between the mothers' cognitive appraisal of the flood and the child's cognitive maturity, a feature of the maternal stress experience that was not included in the Laplante et al. (2007) paper. Our findings suggest that cognitive appraisal is usually associated with the child's play behavior but only in an interaction with the timing of the flood in pregnancy. At 16 months, when the exposure to the disaster was as early as the first 10 weeks (<= 2 1/3 months or 72 days) the more positive the mothers' cognitive appraisal was, the higher were the instances of relational play which, at 16 months, seems to be a positive outcome. Alternately, the more negative the cognitive appraisal was, the lower were the instances of the relational play. Additionally, the covariates were found to increase the variance in this association from 6% to 11.3%. There was however no association between the maternal cognitive appraisal and the child's relational play for children exposed to the flood later in pregnancy who tended to have less relational play than their early-exposed peers at 16 months.

At 30 months, a similar timing by cognitive appraisal interaction was reported for displayed hypotheses, where when exposure to the disaster was as early as 69 days, the more positive the mothers' cognitive appraisal was, the greater were the child's displayed hypotheses, which, at 30 months, is a positive outcome. Alternately, the more negative the cognitive appraisal was, the lower were the instances of the displayed hypotheses. The significant interaction between timing and cognitive appraisal in predicting displayed hypotheses once again shows that children exposed in early pregnancy are sensitive to the level of PNMS. The positive effects of maternal cognitive appraisal were greatest for children exposed to the flood in the 1st trimester of pregnancy: when exposure to the disaster was within the first 69 days of pregnancy, the more positive the mothers' cognitive appraisal, the greater the child's displayed hypotheses at 30 months; but if children were exposed early and the mothers had a negative appraisal, the children displayed lower levels of displayed hypotheses than did later-exposed children. This pattern points to the fact that the early exposure makes the children more sensitive to the effects of PNMS in a differential-susceptibility manner: for better AND for worse. "Individuals are differentially susceptible to environmental influences, with some people being not just more vulnerable than others to the negative effects of adversity, as the prevailing diathesis-stress view of psychopathology maintains, but also disproportionately susceptible to the beneficial effects of supportive and enriching experiences" (Belsky and Pluess, 2009, p. 886). For this study, it is the early exposed children that are differentially susceptible because they are the ones with the significant trend lines while the later-exposed children typically did not have significant trend lines. It is however not clear what exactly the early exposure to PNMS is associated with in terms of the brain or cardiovascular or other physiological aspects, but one can assume that whichever parts of the fetus are developing in early pregnancy, these changes are rendering the children more sensitive to their environment, including the mothers' objective hardship and cognitive appraisal. On the other hand, late exposure being associated with worse outcomes can possibly mean that the late exposure disrupted the development of the fetus' cerebellum (Charil et al., 2010) which is important for the child's play behavior.

Last but not the least, the study also incorporated covariates to the model which helped in understanding whether PNMS in itself is a strong predictor for the child's cognitive outcomes. At 16 months, the covariates transformed the marginally significant association between functional play and subjective distress to a significant association. This implies that the covariates significantly adjusted the dependent variable, functional play at 16 months. On the other hand, at 30 months, the addition of the covariates did not lead to any changes in significant associations between PNMS predictors and play type. Some covariates, however, were significantly associated with the play outcomes as described below.

In the adjusted models estimating the effects of all three PNMS variables on functional play at 30 months, temperament had a significant association with the outcome, such that worse child temperament was associated with less functional play at 30 months. Additionally, for the adjusted model estimating the effect of subjective distress on stereotypical play at 30 months, daycare enrollment had a marginally significant effect, with those attending daycare having a less stereotypical play at 30 months than those who did not.

Strengths and Limitations

The findings demonstrate a clear trimester effect where early pregnancy can be seen as a critical time for the development of a heightened sensitivity to the maternal prenatal environment most often in a differential-susceptibility fashion, while exposure later in pregnancy predicts poorer cognitive outcomes irrespective of the level of PNMS. Nevertheless, the results should be interpreted in light of some limitations.

First, the sample was relatively homogenous, with the majority of the mothers being highly educated and belonging to high SES families. Consequently, the results with this highly resourced sample suggests that the effect sizes might have been even greater in a less advantaged samples. Second, the collection of data using questionnaires as much as a year after the stressful event may also introduce potential recall bias. Third, the covariates were assessed at a later time point than the PNMS and timing variables, and as such, due to attrition, the sample size was smaller when including the covariates. Fourth, all the models in the present study (including covariates) explained less than 15% of the variance in play behavior. Thus implying, that even in a prenatally stressed sample, PNMS is far from being a major predictor of the child's cognitive outcomes. Future research should consider other covariates such as parent-child interactions, social support, maternal substance use, and other variables for an integrated understanding of the predictors of child cognitive development. Additionally, this study did not take into account the sex of the child as a potential moderator in the association between PNMS and play outcomes due to the modest sample size. Lastly, the lack of a control sample is a major limitation. Future research should compare the findings of this study with that of a comparable non-stressed population to arrive at definitive conclusions about the moderating effect of timing of exposure on cognitive maturity.

Despite the limitations of the study, it also has several strengths. Firstly, using natural disasters to study PNMS helps to randomize the distribution of stress exposure in the population; as reported elsewhere (King et al., 2015) there is no correlation between our QFOSS objective hardship measure and any socioeconomic indicator. Because disasters are independent stressors that are unrelated to personal characteristics such as personality, it becomes possible to tease apart the effects of objective hardship, subjective distress, and cognitive appraisal. Secondly, the use of a free play setting helps to curb the confounding effects of the child's temperament. Additionally, the repeated evaluation of children at 16 and 30 months allows for a better understanding of the continuity of the long-term effects of PNMS. This study also used the same approach from a published paper in 2007 (Laplante et al., 2007) using two of the same three PNMS measures i.e., IES-R and the cognitive appraisal item. Lastly, the relatively larger sample size, compared to Laplante et al (2007) makes ours a more reliable study for generalizability to the general population. Finally, the inclusion of various covariates helps to understand whether the associations found are linear or confounded.

Conclusion

The enduring effects of natural disaster exposure in utero and the resulting developmental patterns in children are of major public health concern. The current results show that it is the early exposure to a stressor that is associated with greater sensitivity to PNMS while later exposure generally predicts poorer cognitive outcomes in the unborn child. Given these results, more attention must be drawn towards the physical and mental well-being of the mothers during periods of population upheaval. Interventions such as mindfulness programs that can positively affect the psychological and physical well-being of the mother and her unborn child should be effectively administered during pregnancy to control for the long-term negative effects of stress on the child (Henrichs et al., 2011).

Clinical Implications

Given these results, it is important that more attention is drawn towards the physical and mental well-being of the mothers during periods of population upheaval. A strong social support along with substantial prenatal care can have positive long-term consequences, which impacts not only health outcomes but also possibly school success and, in the long-term, human capital.

To deal with objective hardship during such adversities, provision of basic needs, which implies having a strong and established disaster-rescue structure in place along with disaster relief programs, is an effective way to reduce damage and promote recovery. Additionally, to help with mental well-being, psychosocial interventions such as cognitive behavioral therapies, promoting cognitive reframing, should be administered to help transform pregnant women's distressing cognitions to more adaptive ones. Interventions such as mindfulness programs, that have the ability to positively affect the psychological and physical well-being of the mother and her unborn child, should also be effectively administered during pregnancy to control for the long-term negative effects of stress on the child (Hencrichs et al., 2011).

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Discussion

With previous research showing that the prenatal period is a vulnerable time for the developing fetus, this present study contributes to the field of PNMS and its consequences on the child's developmental progression. Observational studies of play behavior of young children have long attracted the attention of many researchers who are concerned with early cognitive development. The idea behind this study was to determine the effects of prenatal maternal stress caused by a natural disaster on the play behavior of children at the ages of 16 and 30 months. Although prior research has found that using a structured play setting with an examiner can reflect prominent developmental changes with the advancing age of the child (Largo and Howard, 1979), previous research has also found the child's temperament to be a potential confounding factor (Zelazo and Kearsley, 1980). Temperament could influence the child's ability to perform to their full potential in the presence of an unfamiliar experimenter (Zelazo and Kearsley, 1980). Thus, our goal was to examine children's play behavior in a non-structured free play session, where the children could explore the toys without being directed by an adult. In this way, by controlling for their temperament, the study had good internal validity.

The main goal of this study was to determine the extent to which PNMS influences the cognitive development of a sample of prenatally stressed children at the ages of 16 and 30 months. PNMS was assessed as three separate categories (i.e., objective hardship and subjective distress and cognitive appraisal), as well as the effect of the timing of the disaster in pregnancy. It was predicted that exposure to higher levels of PNMS would predict higher levels of immature stereotypical play and lower levels of more mature functional play and play diversity at both ages 16 and 30-months. It was also expected that the effects of PNMS on play behavior would be greatest for children at both ages who were exposed to the onset of the flood during the 1st or 2nd trimester.

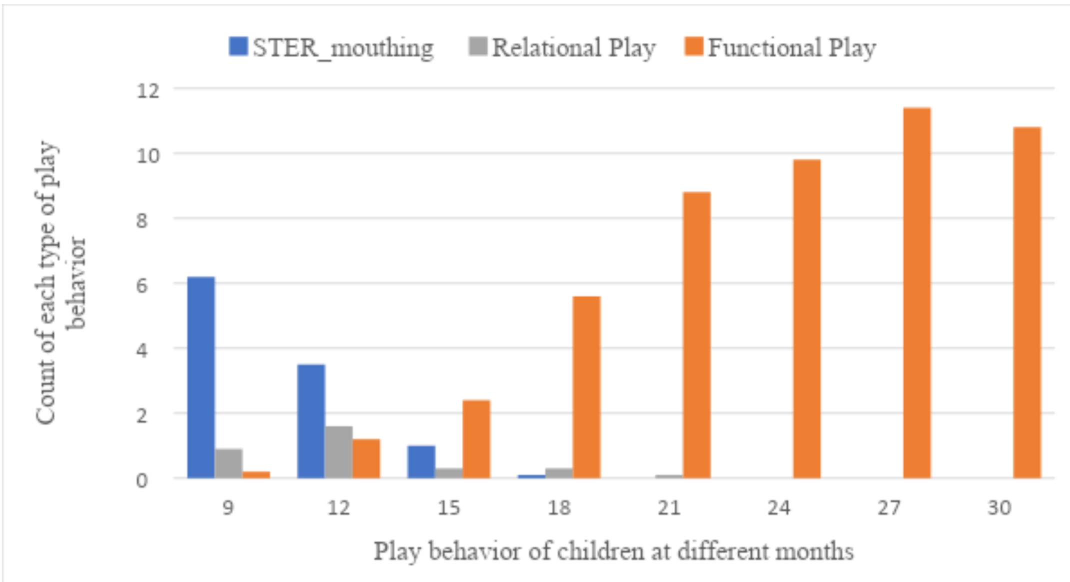
At 16 months, we found two interesting patterns: First, in the absence of a timing-by-PNMS interaction, the later the exposure in pregnancy to the floods the less time the child engaged in the more mature forms of play (relational and functional) and the fewer displayed hypotheses they performed. The second pattern seen at 16 months was that exposure to the flood in early pregnancy seemed to render children more sensitive to the effects of PNMS. This was seen in interactions between timing and objective PNMS predicting stereotypical play: although children exposed later in pregnancy had average levels of stereotypical play irrespective of the level of PNMS, those exposed in early pregnancy had a strong negative association between objective PNMS and stereotypical play; that is, when they had been exposed to low objective PNMS they had high stereotypical play (higher than that of late-exposed children), but when exposed to high objective PNMS they had lower stereotypical play than late-exposed children. This pattern of early exposure being sensitive to PNMS, and late exposure being associated with poorer performance but also being relatively resilient to PNMS, was also seen in the association between cognitive appraisal and stereotypical and relational play, and between objective PNMS and displayed hypotheses. In addition to these two patterns, we found a main effect for greater subjective PNMS 'at the time of the flood' predicting fewer displayed hypotheses at 16 months.

At 30 months, our models did not explain significant variance in stereotypical, relational, or functional play. The results did, however, uncover a timing-by-PNMS interaction predicting the number of displayed hypotheses: once again, late pregnancy exposure was associated with lower displayed hypotheses no matter their mothers' cognitive appraisal of the flood; however, children exposed in early pregnancy to a mother with negative appraisal had low levels of displayed hypotheses (on a par with the late-exposed children), but the more positive their mothers judged the consequences of the flood to be, the higher their displayed hypotheses.

As suggested by previous research, the normal developmental pattern of play behavior in children progresses from stereotypical to relational and then functional play (using free play or structured play) (Zelazo & Kearsley, 1979). In another study by Largo and Howard, where play behavior was assessed in children at the ages of 9, 11, 12, 15, 18, 21, 24 and 30 months, findings similar to those from the 1980 Zelazo & Kearsley study were obtained. Exploratory behavior such as mouthing, considered “stereotypical” play by Zelazo and Kearsely, was the most dominant play type from 9 to 12 months (Largo & Howard, 1979; Zelazo & Kearsley, 1980) but these instances of stereotypical play, however, started deteriorating around 15 months, and by 21 months it was no longer evident. Relational play, however, was another common play pattern that was frequently demonstrated around the ages of 9 to 15 months but was shown to completely disappear by 24 months. The reason for this decline is because, at around 15 months of age, children develop the ability to form appropriate associations. This ascending pattern being followed by a decline renders relational play as a transitional behavior bridging the developmental shift between stereotypical and functional play with toys (Figure 6). Thus, by 18 months of age functional play was the most dominant play type, and this ability to form appropriate associations doubled progressively over time (Largo & Howard, 1979).

Figure 7

Normal Play Progression of Children by Age (adapted from Largo & Howard, 1979)



With this timeline of progression, we know that by 16 months, higher instances of relational play, functional play and displayed hypotheses, indicates normal development of the child whereas instances of stereotypical play imply immaturity. At 30 months however, if a child exhibits both relational and stereotypical play, it will be interpreted as a delay in cognitive maturity. As such, functional play and displayed hypotheses can be interpreted as ‘mature’ play behavior at both ages in the current study.

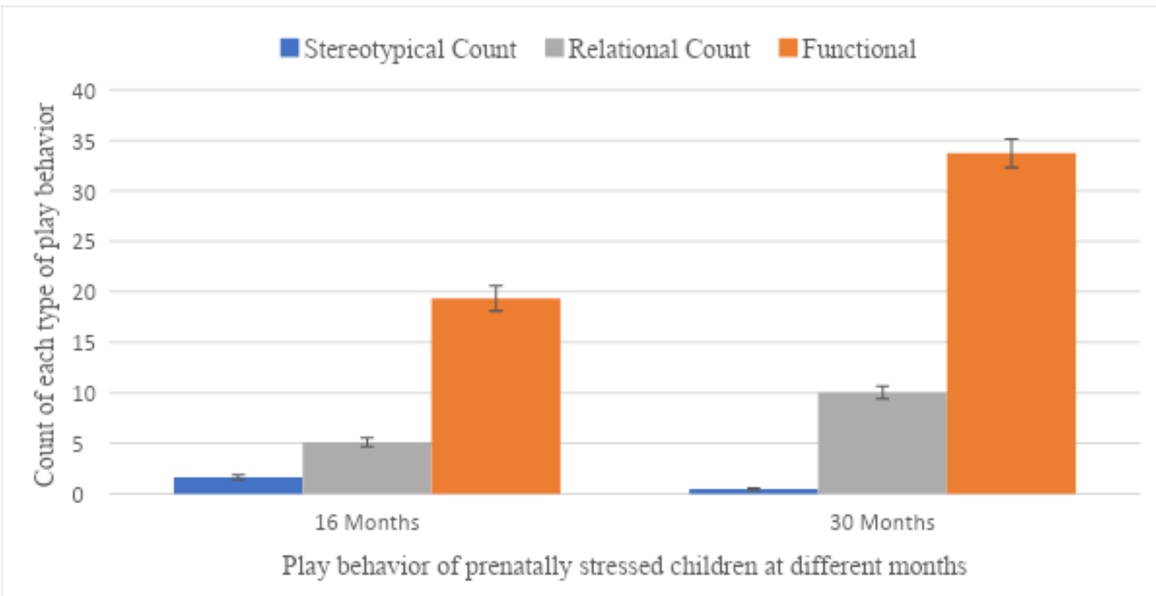
Upon assessing the actions of 16-month-old children in our study, the trends for relational and stereotypical play appear consistent with previous play studies (Largo and Howard, 1979). On the other hand, however, the present study demonstrated a different trend from the normal developmental progression of play behavior for the 30-month-old children exposed to a natural disaster in utero, as described below.

Stereotypical play, recognized as a dominant play pattern only up till 13 months and known to completely disappear by 21 months, was however still frequently visible in our sample at both 16 and 30 months of age. On average, 16-month-old participants spent 3.8% of their entire play session on stereotypical play, while 30-month-old participants spent 1.34% of their entire play session on the same.

Additionally, although the main goal of this study was to see the effects of PNMS on immature stereotypical play and mature functional play, unanticipated results were found for the play type bridging the gap between these two. Relational play, known for its spatial characteristics and non-functional associations (Largo and Howard, 1979) was still frequently exhibited by the children at 30 months of age, suggesting a possible cognitive delay in maturity in this group of prenatally stressed children (Figure 8). In fact, the amount of time spent in relational play actually doubled between 16 and 30 months – although it is normal for the amount of time spent on relational play to increase with age in younger children, in normative samples this kind of play should be decreasing in favor of functional play at these ages (Figure 7). Thus, the continued presence of stereotypical and relational play at 30 months is not consistent with the trends found in previous studies of normative samples (Largo and Howard, 1979). Normally by 30 months a child is capable of making appropriate associations and having functional play as their dominant play pattern with no instances of relational or stereotypical play whatsoever. However, because the previous study (Largo) was administered in a structured setting lasting up to 25 minutes in contrast to this study's free play session lasting only 10 minutes, it was decided not to compare the two directly given these differences in play time and the type of play assessment method used.

Figure 8

Play Progression of Prenatally Stressed Children from QF2011 at 16 and 30 Months



The results of the present study suggest that early pregnancy is a critical period for PNMS to have any significant associations with play behavior exhibited by 16 months. This study finds such results when looking at the interaction between timing and stereotypical play, relational play, and the displayed hypotheses at 16 months. When the exposure to the disaster was as early as the first 6 weeks (<=43 days), objective hardship had a significant effect on stereotypical play at 16 months: the higher the level of objective hardship the lower the instances of stereotypical play. When the exposure to the disaster was as early as the first 10 weeks (<= 2 1/3 months or 72 days), mothers' cognitive appraisal had a significant effect on relational play at

16 months: the more positive the appraisal the higher the instances of relational play, and the more negative the appraisal the less relational play. Similarly, when the exposure to the disaster was as early as 63 days (2 months), the level of objective hardship had a significant effect on the displayed hypotheses at 16 months: with higher objective hardship leading to greater displayed hypotheses. Many of these results, however, contradict the hypothesis that high levels of objective hardship would be associated with more stereotypical play and lower levels of displayed hypotheses, and challenges the previous findings that found the same hypothesized association (Laplante et al., 2007). A possible explanation for the discrepancies between the present and previous findings can be attributed to the Yerkes Dodson Law of Optimal Arousal (Yerkes and Dodson 1908). The law states that an individual's performance in certain tasks would show an increment if he/she is mentally or physiologically aroused only up to a certain point, after which performance declines as arousal increases. To begin with, the Ice Storm was very high in its level of objective hardship as compared to the Queensland Flood. Unlike the STORM32 scale that had a normal distribution of scores, the QFOSS objective scale was positively skewed (King & Laplante, 2015). Previous Ice Storm studies found the effect of mothers' objective hardship on the child's cognitive development to have a curvilinear relationship where high levels of objective hardship were associated with lower language skills, compared to those with low stress, and moderate levels of objective hardship were associated with a small increase in IQ and vocabulary skills at 5.5 years of age (Laplante et al., 2005). But, since the 1998 Quebec Ice Storm and the 2011 Queensland Flood are two very different types of disaster, with differing measures of objective hardship, it would not be appropriate to compare the two to assess the effects of objective hardship on child development. It is possible that the levels of objective hardship in QF2011 pushed the mother and her unborn child up the ascending

slope of the Yerkes-Dodson curve rather than pushing them down the descending slope of the curve. In other words, it may be that relatively mild levels of PNMS, as seen in QF2011, are beneficial for fetal development while greater degrees of stress (as seen in Project Ice Storm) are detrimental. This idea is supported by Project Ice Storm results showing that, at age 5, association between objective hardship and IQ is curvilinear, mimicking the Yerkes-Dodson Law (Laplante et al., 2008). Research suggests that the association between PNMS and child development is curvilinear, such that the best performance is observed in offspring exposed to moderate levels of maternal anxiety, with poorer outcomes associated with lower and higher maternal anxiety levels (DiPietro et al.,2006).

In addition to these interactions with PNMS, timing also had significant main effects. Early exposure was associated with more relational play, functional play and displayed hypotheses at 16 months; conversely, later exposure to the disaster was associated with worse outcomes, as seen in both main effects and interactions. Later exposure was associated with lower levels of relational play, functional play and even lower levels of displayed hypotheses. This beneficial and non-beneficial effect of early and late exposure respectively, can be attributed to the development of different brain regions at different time periods. For example, the cerebellum is associated with motor functioning and develops later in pregnancy (Charil et al., 2010). Thus, it is possible that the exposure to PNMS later in pregnancy impacts the child's neuromotor maturity and consequently limits the extent to which the infant can manipulate toys in a more functional manner. This motor disadvantage further restricts the child from exploring and learning which then impedes on the child's sensorimotor stage of cognitive development (Huitt and Hummel, 2003).

Following the same pattern, at 30 months of age, early exposure was once again found to be a sensitive period for the effects of PNMS. Recall that, according to the work of Largo (1979), by 30 months of age the child is playing almost exclusively in functional play, with an absence of stereotypical and relational play. In the current study, we found both main effects of timing and interactions with PNMS when the children were 30 months old. If we consider that relational play is immature for a 30-month old child, then the same trend towards negative associations between timing and relational play that was seen at 16 months, with earlier timing predicting more relational play, would be considered a poor outcome at 30 months; at 30 months we found that both later exposure and negative cognitive appraisal tended to predict more relational play. However, the significant interaction between timing and cognitive appraisal in predicting displayed hypotheses once again shows that children exposed in early pregnancy are sensitive to the level of PNMS. The positive effects of maternal cognitive appraisal were greatest for children exposed to the flood in the 1st trimester of pregnancy: when exposure to the disaster was within the first 69 days of pregnancy, the more positive the mothers' cognitive appraisal, the greater the child's displayed hypotheses at 30 months; but if children were exposed early and the mothers had a negative appraisal, the children displayed lower levels of displayed hypotheses than did later-exposed children. This pattern points to the fact that the early exposure makes the children more sensitive to the effects of PNMS in a differential-susceptibility manner: for better AND for worse. "Individuals are differentially susceptible to environmental influences, with some people being not just more vulnerable than others to the negative effects of adversity, as the prevailing diathesis-stress view of psychopathology maintains, but also disproportionately susceptible to the beneficial effects of supportive and enriching experiences" (Belsky and Pluess, 2009, p. 886). For this study, it is the early exposed children that are differentially susceptible because they are the ones with the significant trend lines while the later-exposed children typically did not have significant trend lines. It is however not clear what exactly the early exposure to PNMS is associated with in terms of brain or cardiovascular or other physiological aspects, but one can assume that whichever parts of the fetus are developing in early pregnancy, these changes are rendering the children more sensitive to their environment, including the mothers' objective hardship and cognitive appraisal. On the other hand, late exposure being associated with worse outcomes can possibly mean that the late exposure disrupted the development of the fetus' cerebellum (Charil et al., 2010) which is important for the child's play behavior.

A similar timing by cognitive appraisal interaction was reported for relational play at 16 months. Findings indicate that the mothers' cognitive appraisal was positively correlated with the child's relational play at 16 months only when they were exposed earlier in gestation. This implies that the more positive the mothers' cognitive appraisal was, the higher were the instances of relational play, which, at 16 months, seems to be a positive outcome. Alternately, the more negative the cognitive appraisal was, the lower were the instances of the relational play. There was, however, no association between maternal cognitive appraisal and the child's relational play for children exposed to the flood later in pregnancy who tended to have less relational play than their early-exposed peers. The only difference, however, is that these children were neither inherently differentially susceptible nor vulnerable to the effects of cognitive appraisal.

Another goal of this study was to determine which aspect(s) of PNMS (objective, subjective, or cognitive) had significant effects on child play behavior. Consistent with the

Laplante (2007) study, the present study found subjective distress to have a marginally significant negative effect on the percentage of time the child spent in functional play at 16 months. Moreover, similar to the previous findings, the present study also found subjective distress to have a significant negative main effect on displayed hypotheses at 16 but not 30 months of age: where at 16 months high levels of subjective distress predicted lower levels of displayed hypotheses. However, the results for objective hardship differ from those of the Laplante (2007) study. The 2007 study found significant main effects of objective hardship on stereotypical play, functional play and displayed hypotheses at 24 months. It also reported a significant objective by timing interaction on displayed hypotheses at the same age. However, for the present study, objective hardship only had a marginally significant main effect on the stereotypical play of the 30-month-old children in QF2011. Objective hardship did not have any significant effects on functional play at either age. On the other hand, a marginally significant objective by timing interaction was found for stereotypical play only for the 16 month-old-children.

To recapitulate, for this study, the effects of subjective distress were negative main effects on the child's functional play and displayed hypotheses at 16 months. However, objective hardship and cognitive appraisal had important effects at both ages, 16 and 30 months, but always as a function of timing. This interaction with timing was mostly visible in differential susceptibility patterns. Thus, timing was seen as an important factor for both main effects and interactions with PNMS throughout the results.

In addition to finding direct associations between certain PNMS predictors and certain play types, the introduction of covariates to the model helped in understanding whether PNMS in itself is a strong predictor for the child's cognitive outcomes. For certain associations, the covariates increased the variance explained, whereas for others it did not lead to any significant changes. In general, at 16 months, the unadjusted models explained between 1% to 8.3% of the variance in play behaviors, whereas the adjusted model explained additional unique variance ranging from 3.3% to 14% in the prediction of play type. Furthermore, when the covariates were entered into the models, the variance in relational play explained by cognitive appraisal increased from 6% to 11.3%. It also transformed the marginally significant association between functional play and subjective distress to a significant association (full model explained 10.3% variance). This implies that these covariates significantly adjusted the dependent variable i.e., functional play at 16 months.

At 30 months, the unadjusted models explained between 1.4% to 5.3% of the variance in play behavior, whereas the adjusted models explained between 1.9% to 11.3%. Although, for this age group, the covariates did not lead to any changes in significant associations between PNMS predictors and play type. Some covariates, however, were significantly associated with the play outcomes as described below.

In the adjusted models estimating the effects of all three PNMS variables on functional play at 30 months, temperament had a significant association with the outcome, such that worse child temperament was associated with less functional play at 30 months. Additionally, for the adjusted model estimating the effect of subjective distress on stereotypical play at 30 months, daycare enrollment had a marginally significant effect, with those attending daycare having less stereotypical play at 30 months than those who did not.

Strengths and Limitations

The findings described here demonstrate a clear trimester effect where early pregnancy can be seen as a critical time for the development of a heightened sensitivity to the maternal prenatal environment most often in a differential-susceptibility fashion, while exposure later in pregnancy predicts poorer cognitive outcomes irrespective of the level of PNMS. However, the results of the present study should be interpreted in light of some limitations.

First, the sample was relatively homogenous, with the majority of the mothers being highly educated and belonging to high SES families. Consequently, the results with this highly resourced sample suggests that the effect sizes might have been greater in less advantaged samples. Second, the collection of data using questionnaires as much as a year after the stressful event in some participants may also introduce potential recall bias, although significant associations have not been reported between the time since the flood and rating of PNMS in QF2011. Third, the covariates were assessed at a later time point than the PNMS and timing variables, and as such, due to attrition, the sample size was smaller when including the covariates. Fourth, all the models in the present study (including covariates) explained less than 15% of variance in play behavior, implying that even in a prenatally stressed sample, PNMS is far from being a major predictor of the child's cognitive outcomes. Future research should also consider other covariates such as parent-child interactions, social support, maternal substance use and other variables for an integrated understanding of the predictors of child cognitive development. Additionally, this study did not take into account the sex of the child as a potential moderator in the association between PNMS and play outcomes due to the modest sample size. Future studies should therefore investigate the interaction effects of sex and PNMS on play abilities to arrive at definitive conclusions regarding differences in PNMS effects of boys and girls.

Despite the limitations in the study, it also has several strengths. Firstly, using natural disasters to study PNMS helps to circumvent the many problems associated with human PNMS studies. The sudden onset of a natural disaster means that the timing in pregnancy is comparatively accurate, as compared to other life events that have vague beginnings and end points such as interpersonal breakups or maternal psychopathology. The quasi-random nature of the distribution of PNMS in the sample is seen in the lack of correlation between PNMS and SES. Furthermore, because it is an “independent” stressor, the parents themselves had no role to play in causing the disaster to happen, which might be the case when studying women going through other life events, such as separation or divorce, during pregnancy. This therefore allows the researcher to study the effects independently of the mother’s own personality traits and makes disentangling the mother’s objective, subjective and cognitive evaluation of the event easier.

The other major advantage of this study is the use of a free play setting. This feature helps to curb any effects of the child’s temperament which could be an issue if children who are shy by nature are asked by unfamiliar examiners to complete tasks in standardized test settings. Another major strength is the assessment of child development at two different time points rather than focusing on just one. The evaluation of children at 16 and 30 months using well validated coding scheme for rating the play behavior allows for better understanding of the continuity of long-term effects of PNMS. This study also used the same approach from a published paper in 2007 (Laplante et al., 2007) using two of the same three PNMS measures i.e., IES-R and the cognitive appraisal item. But compared to the 2007 study, which had a sample size of only 52 children, this study had a relatively bigger sample size (142 sixteen-month-old children and 135 thirty-month-old children). The relatively larger sample size, compared to Laplante et al., (2007) also makes this study more reliable for generalizability to the general population. And lastly, the inclusion of various covariates helps to evaluate whether the associations found between PNMS predictors and child outcomes are linear or confounded.

Conclusion

With the rise in global temperatures, it is likely that natural disasters will soon be a more frequently occurring phenomenon. The enduring effects of natural disaster exposure in utero and the resulting developmental patterns in children makes this study of extreme relevance to public health and policy making. The current results show that it is the early exposure to a stressor that is associated with greater sensitivity to PNMS while later exposure generally predicts poorer cognitive outcomes in the unborn child. As such, women at all stages of pregnancy need to be protected from the objective, subjective and cognitive aspects of stress during disasters or, indeed, after any kind of major life stressor.

Clinical Implications

Given these results, it is important that more attention is drawn towards the physical and mental well-being of the mothers during periods of population upheaval. The study in general raises critical questions about the importance of the prenatal environment and how much the support to expecting women, especially when facing extreme forms of adversity like disasters, is essential to guarantee better developmental outcomes in the offspring. A strong social support along with substantial prenatal care can have positive long-term consequences, which impacts not only health outcomes but also possibly school success and, in the long-term, human capital.

To deal with objective hardship during such adversities, provision of basic needs, which implies having a strong and established disaster-rescue structure in place along with disaster relief programs, is an effective way to reduce damage and promote recovery. Additionally, to help with mental well-being, psychosocial interventions such as cognitive behavioral therapies, promoting cognitive reframing, should be administered to help transform pregnant women's distressing cognitions to more adaptive ones. Interventions such as mindfulness programs, that have the ability to positively affect the psychological and physical well-being of the mother and her unborn child, should also be effectively administered during pregnancy to control for the long-term negative effects of stress on the child (Hencrichs et al., 2011).

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Appendix 1

Questions used to Assess the Four Dimensions (Threat, Loss, Scope, and Change) of our Objective Stress Questionnaire that the Mothers completed shortly after the Ice Storm.

	Threat		Loss		Scope		Change
1	Were you injured? No = 0 Yes = 1	1	Did your residence suffer damage as a result of the ice storm? No = 0 Yes = 2	1	How many days were you without electricity? 0 = 0 – 5 days 1 = 6 – 13 days 2 = 14 – 19 days 3 = 20 – 21 days 4 = >22 days	1	Did your family stay together for the duration of the ice storm? Yes = 0 No = 1
2	Was anyone close to you injured? No = 0 Yes = 1	2	Did you experience a loss of personal income? No = 0 Yes = 2	2	How many days were you without the use of your telephone? 0 = 0 days 1 = .01 – 1 day 2 = 2 – 4.5 days 3 = 5 – 7 days 4 = 8+ days	2	Did you spend any time in a temporary shelter? No = 0 Yes = 1
3	Were you ever in danger due to:	3	How much was the total financial loss including income, food, damage to home? 0 = < $100 1 = $100 - $1000 2 = $1000 - $10000 3 = $10000 – 100000 4 = > $100000			3	How often were you required to change residence during the ice storm? 0 = 0 1 = 1 time 2 = 2+ times
3.1	…the cold No = 0 Yes = 1					4	Did you take in guests during the ice storm? No = 0 Yes = 1
3.2	…exposure to downed electrical power lines No = 0 Yes = 1					5	Did you experience an increase in physical work during the ice storm? 0 = less or same 1 = little or lot more
3.3	...exposure to carbon monoxide					6	Number of nights away from home:

No = 0 Yes = 1			0 = none 1 = 1 – 7.5 nights 2 = 8+ nights
3.4 ...lack of potable water No = 0 Yes = 1			
3.5 ...lack of food No = 0 Yes = 1			
3.6 …falling branches and ice No = 0 Yes = 1			
8 points	8 points	8 points	8 points

Note. Reprinted from "Functional Play at 2 Years of Age: Effects of Prenatal Maternal Stress", by Laplante et al., 2007, Infancy, 12(1),p. 75-76.

Appendix 2

Toys with the 36 Adult Classified Appropriate Uses, and Order of their Placement (from the Infant's left in a Semi-Circle) in the Testing Room.

Toys	Appropriate Uses
Baseball bat, ball, glove, and hat	Throw ball Roll ball Glove in hand Place ball in glove Place hat on head Hit ball with bat
Large baby doll with dress, hair brush and bottle	Undress Dress Brush hair Feed with spoon Feed with bottle Feed with cup Cradle in arms Kiss doll
Telephone	Receiver to ear Dial Converse (babble) Present phone to other Replace receiver properly
Plastic dump truck, blocks and garage	Push truck Make truck noises Push/place truck in garage Place block in truck Dump block from truck
Small unisex doll with chair, table, and bed	Set doll in chair/bed Lay doll in bed Arrange furniture Stand and walk doll Child sit on toy chair
Teapot, two cups, two saucers, and one spoon	Cover on pot Stir spoon in cut/pot Pour from pot to cup Drink from cup Drinking sounds Offer drink from cup to mother/doll Set cup in saucer

Note. Reprinted from “Functional Play at 2 Years of Age: Effects of Prenatal Maternal Stress”, by Laplante et al., 2007, Infancy, 12(1),p. 78.

Appendix 3

Hierarchical Regression Analyses of All PNMS Variables including Covariates in the Model.

Outcomes	Predictors of Interest Unstandardized Coefficients			Covariates					Interaction			Full Adjusted Model R2
Type of play	QFOSS	COSMOSS	Conseq	Timing	Sex	Daycare	STST	Parity	Interaction term	Coefficient	R2-ch	
Stereotypical 16 Months	0.009			0.005	-0.104	0.321	0.198	-0.523				0.033
Stereotypical 16 Months	-0.871			-0.015	-0.136	0.339	0.216	-0.507	QFOSS x Timing	0.007	0.009	0.042
Stereotypical 16 Months	0.028	-0.030		0.005	-0.110	0.329	0.196	-0.521				0.033
Stereotypical 16 Months	0.034	0.156		0.005	-0.090	0.301	0.228	-0.538	Cosmoss x Timing	-0.002	0.000	0.034
Stereotypical 16 Months	-0.074		-0.270	0.005	-0.133	0.317	0.227	-0.510				0.035

Stereotypical 16 Months	-0.168		0.899	0.031~	-0.050	0.169	0.223	-0.461	Conseq x Timing	-0.010	0.020	0.055
Relational 16 Months	0.425			-0.009**	-0.063	0.073	-0.496	-0.229				0.103
Relational 16 Months	1.050			0.005	-0.040	-0.061	-0.509	-0.240	QFOSS x Timing	-0.005	0.010	0.112
Relational 16 Months	0.641~	-0.334		-0.009**	-0.132	0.159	-0.513	-0.206				0.113
Relational 16 Months	0.647~	-0.139		-0.008**	-0.110	0.129	-0.479	-0.223	Cosmoss x Timing	-0.002	0.002	0.116
Relational 16 Months	0.545		0.394	-.008**	-0.021	0.080	-0.539	-0.247				0.113
Relational 16 Months	0.462		1.422*	0.015	0.052	-0.050	-0.543	-0.203	Conseq x Timing	-0.008*	0.034	0.147
Functional 16 Months	-0.672			-0.011	1.449	-0.565	-1.057	-0.686				0.051
Functional 16 Months	-1.565			-0.031	1.417	-0.547	-1.039	-0.670	QFOSS x Timing	0.070	0.003	0.054

Functional 16 Months	0.580	-1.941*		-0.011	1.050	-0.069	-1.158	-0.554				0.103
Functional 16 Months	0.572	-2.155~		-0.011	1.026	-0.037	-1.195	-0.535	Cosmoss x Timing	0.002	0.000	0.103
Functional 16 Months	-0.577		0.313	-0.010	1.483	-0.560	-1.092	-0.701				0.052
Functional 16 Months	-0.470		-1.010	-0.040	1.389	-0.393	-1.087	-0.757	Conseq x Timing	0.011	0.008	0.060
Displayed Hyp. 16Months	0.239			-0.010**	0.017	-0.153	-0.560	0.034				0.077
Displayed Hyp.16 Months	1.100			0.009	0.048	-0.170	-0.579	0.018	QFOSS x TIMING	-0.007	0.012	0.090
Displayed Hyp. 16 Months	0.884~	-1.000**		-0.010**	-0.189	0.103	-0.612	0.102				0.140

Displayed Hyp. 16 Months	0.887~	-0.923		-0.010**	-0.181	0.091	-0.599	0.095	Cosmoss x Timing	-0.001	0.000	0.141
Displayed Hyp. 16 Months	0.370		0.427	-0.010*	0.062	-0.145	-0.608	0.014				0.086
Displayed Hyp. 16 Months	0.384		0.251	-0.014	0.050	-0.123	-0.607	0.006	Conseq x Timing	0.001	0.000	0.086
Stereotypical 30 Months	-0.433~			-0.002	0.166	-0.546	-0.219	-0.145				0.083
Stereotypical 30 Months	-0.037			0.007	0.165	-0.561~	-0.213	-0.147	QFOSS x Timing	-0.003	0.012	0.095
Stereotypical 30 Months	-0.591*	0.284		-0.002	0.185	-0.589~	-0.176	-0.143				0.105
Stereotypical 30 Months	-0.590*	0.310		-0.002	0.186	-0.590~	-0.176	-0.143	Cosmoss x Timing	0.000	0.000	0.106

Stereotypical 30 Months	-0.452~		-0.061	-0.002	0.158	-0.539	-0.208	-0.144				0.084
Stereotypical 30 Months	-0.453~		-0.045	-0.002	0.160	-0.541	-0.207	-0.143	Conseq x Timing	0.000	0.000	0.084
Relational 30 Months	0.308			-0.009*	-0.310	0.862	0.508	-0.361				0.088
Relational 30 Months	0.453			-0.006	-0.311	0.857	0.510	-0.361	QFOSS x Timing	-0.001	0.000	0.089
Relational 30 Months	0.127	0.325		-0.009*	-0.289	0.814	0.556	-0.358				0.094
Relational 30 Months	0.136	0.608		-0.009~	-0.277	0.797	0.559	-0.368	Cosmoss x Timing	-0.002	0.003	0.097
Relational 30 Months	0.057		-0.792	-0.009*	-0.417	0.960	0.649	-0.346				0.113
Relational 30 Months	0.061		-0.859	-0.011	-0.425	0.969	0.646	-0.348	Conseq x Timing	0.000	0.000	0.113
Functional 30 Months	1.738			0.013	-2.899	1.349	-4.040*	1.327				0.100

Functional 30 Months	0.190			-0.022	-2.895	1.406	-4.063*	1.333	QFOSS x Timing	0.012	0.005	0.106
Functional 30 Months	1.547	0.342		0.013	-2.876	1.298	-3.99*	1.329				0.101
Functional 30 Months	1.499	-1.166		0.010	-2.937	1.387	-4.006	1.382	Cosmoss x Timing	0.123	0.010	0.111
Functional 30 Months	2.137		1.256	0.014	-2.729	1.195	-4.264*	1.303				0.109
Functional 30 Months	2.103		1.825	0.026	-2.669	1.115	-4.238*	1.321	Conseq x Timing	-0.004	0.000	0.109
Displayed Hyp. 30 Months	0.068			-0.004	-0.014	0.293	0.407	0.433				0.019
Displayed Hyp. 30 Months	-0.896			-0.026	-0.011	0.328	0.393	0.438	QFOSS x Timing	0.007	0.013	0.032

Displayed Hyp. 30 Months	0.219	-0.272		-0.003	-0.032	0.333	0.367	0.431				0.023
Displayed Hyp. 30 Months	0.201	-0.846		-0.005	-0.055	0.367	0.360	0.451	Cosmoss x Timing	0.005	0.009	0.032
Displayed Hyp. 30 Months	0.295		0.715	-0.003	0.083	0.205	0.280	0.420				0.036
Displayed Hyp. 30 Months	0.179		2.662	0.038*	0.291	-0.070	0.366	0.481	Conseq x Timing	-0.015*	0.055	0.092

Note. ~p <0.1, * p <0.05, ** p < 0.01