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Infant temperament: repercussions of Superstorm Sandy-related maternal stress

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Abstract

This study recruited a prospective cohort of 380 pregnant women before, during, or after Superstorm Sandy in 2012 to examine the association between disaster-related prenatal and postnatal maternal stress and offspring temperament at 6 months-old. Mothers prospectively reported stressful experiences during the storm and rated their child's temperament 6 months postpartum. Results indicated that length of time without phone or electricity and financial loss was associated with offspring negative affect, whereas financial loss and threat of death or injury was associated with emotion dysregulation. Furthermore, offspring born before the storm had greater negative affect and lower emotion regulation than those born after the storm. Given the probable increase in the occurrence of natural disasters due to climate change in recent years [1], our results highlight the necessity of education and planning to help ameliorate any potential consequences on the developing infant.

Keywords

prenatal maternal stress; early life stress; temperament; natural disaster; infant development

The intrauterine period is a particularly vulnerable stage during which fetal insults may elicit structural and functional changes that can impact the offspring's neurobehavioral

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Compliance with Ethical Standards

We have no conflicts of interest to disclose. All research had approval from the appropriate Institutional Review Board and is in accordance with the Declaration of Helsinki. Informed consent was obtained from all participants.

development [2, 3]. The fetus is particularly sensitive to prenatal maternal stress (PNMS) [4, 5], including symptoms of anxiety and depression [6, 7]. Increased production of the stress hormone cortisol readily crosses the placenta to the fetus and can contribute to a maladaptive structural and functional organization of the central and autonomic nervous systems [8–10]. Furthermore, exposure to excess cortisol during the early postnatal period as a result of stress-provoking environmental conditions is also thought to contribute to maladaptive development, as the brain grows rapidly during this period [11]. These pre- and postnatal alterations may increase the risk for difficulties in emotion regulation [12] and other psychiatric disorders later in life [13].

In animal studies, which can experimentally control the timing and intensity of PNMS, PNMS is frequently associated with increased risk for mental health deficits in offspring. Animal research has demonstrated that stress exposure during preconception, prenatal, or early postnatal periods is linked with aberrations that can lead to lasting changes in postnatal neurobehavior such as altered stress response, amygdala size, and Hypothalamic-Pituitary-Adrenal (HPA) axis function [14–20]. While animal models offer hypothetical mechanisms through which PNMS influences offspring development, they may not accurately inform human models of development because species-specific differences in length of gestation and stage of development at birth. However, most human studies must rely on measuring pre-existing levels and types of life stress that are rarely discrete and often confounded by other biopsychosocial factors, such as maternal genetics and psychopathology, which can also impact the long-term development of offspring.

It is crucial to detect risk for psychopathology in populations of children exposed to substantial stress in preconception, prenatal, and/or postnatal periods. Researchers have found associations between stress and maladaptive development in human studies. For example, bereavement-related preconception stress in humans was linked to a marginally significant increase in bipolar and schizophrenia development in offspring [21]. Maternal stress such as stressful life events [22, 23], mental health [24, 25], and elevated cortisol levels [26, 27] during the index pregnancy predicted child temperament, which relates to emotionality, personality, and risk for psychopathology. Notably, O'Connor et al. [28] found that prenatal maternal anxiety predicted emotion dysregulation, even while controlling for maternal postnatal anxiety. In the postnatal period poor maternal mental health and early life stressors including maltreatment have been linked with offspring suicide, autism spectrum disorders [21] emotion dysregulation [29, 30], internalizing symptomatology [31], and anxiety [27] later in life. Most of these studies, however, were limited by their correlational nature and many confounding variables.

In order to approximate the experimental clarity of animal studies in a human sample in which a cohort of pregnant women are exposed to the same stressful event, research groups have studied natural disasters. King conducted the first extensive, prospective study of PNMS using the Quebec Ice Storm of 1998 and found that PNMS had a lasting effect on most areas of physical, cognitive and behavioral development, and that these effects are often moderated by timing of exposure [32]. Researchers have also followed mothers exposed to the Iowa Flood of 2008 and found that PNMS predicts stress reactivity in offspring at 2.5 years of age [33]. Most recently, high levels of subjective PNMS related to

the 2011 Queensland Flood predicted lower problem solving scores for girls, and the timing of the flood later in pregnancy predicted lower personal-social scores and delayed motor development for both sexes at six months of age [34].

Of relevance to this current study of early infant temperament, the Ice Storm project reported that higher levels of subjective PNMS was associated with difficult temperament characteristics such as fussiness, dullness, and needing attention among 6-month-old offspring in an ethnically homogenous sample [35]. However, Tees et al. [36] studied Hurricane Katrina in 2005 in a majority Caucasian sample and found that objective measures of disaster stress did not predict infant temperament, although maternal PTSD, depression and hostility significantly correlated with ratings of “difficult temperament” at 2 and 12 months of age.

To further clarify and substantiate the impact of PNMS related to storm exposure on infant temperament, the current study reports findings from a prospective study of a diverse group of pregnant women exposed to Superstorm Sandy, which hit the New York metropolitan area in October 2012. The storm killed 117 people in the United States alone, 53 of whom were in New York [37]. Nearly 8 million residents lost electricity in the northeastern region of the U.S., widespread gasoline shortages occurred, and public transportation systems were shut down with damage that continues to be repaired [38]. 46% of the sample was pregnant before the storm, 44% of the sample was pregnant during the storm, and the remaining 10% became pregnant shortly after the storm occurred. After the disaster, measures of objective and subjective levels of stress resulting from the storm as well as timing of the exposure in relation to the pregnancy were obtained. Child temperament was reported at 6 months postpartum.

The present study seeks to examine associations between maternal stress related to a natural disaster in the preconception, prenatal, and postnatal periods in a diverse population. Prior natural disaster studies have largely excluded children exposed postnatally from analysis. Following Laplante and his colleagues [35], we hypothesized that objective and subjective measures of PNMS due to Superstorm Sandy would be associated with infant temperament characterized by high negative affect and low surgency/extraversion and emotion regulation in offspring. Departing from Laplante et al. we will analyze individual subscales of objective stress rather than a sum score to examine if any particular component correlates more strongly than others with temperament or the impact of all components on temperament were equal. Furthermore, we hypothesized that timing of the storm exposure would be related to temperament, such that *in utero* exposure to the storm would be associated with high negative affect and low surgency/extraversion and regulation than exposure after birth or before conception.

Methods

Participants

The study included 380 mother-child dyads part of an on-going birth cohort study at two New York metropolitan area prenatal obstetrics and gynecological (OB/GYN) clinics. Participating mothers were originally recruited from the prenatal OB/GYN clinic at Mt.

Sinai Hospital, which draws patients from East Harlem and the South Bronx in New York City. In 2012, the study expanded recruitment to women in the OB/GYN Department at New York Presbyterian Queens, which draws patients from Queens and Long Island, New York. Mount Sinai Hospital is located approximately 1 mile from the East River, which surged and flooded major roadways in Manhattan. New York Presbyterian Queens is located approximately 2.5 miles from Flushing Bay, which also surged and resulted in flooding, and 15 miles from the Rockaway Beach area that was severely damaged by the storm. Criteria for exclusion included HIV infection, maternal psychosis, maternal age < 15 years, or life-threatening medical complications of the fetus. The study was approved by the institutional review board at Mt. Sinai Hospital, New York Presbyterian Queens Hospital, and CUNY Queens College. Written informed consent was obtained from all eligible women for all study procedures. Detailed information can be found in the study's cohort profile [39].

Measures

Child temperament (negative affect, emotion regulation, and surgency).

The 91-item Infant Behavior Questionnaire-Revised (IBQ-R; [40, 41]) was the primary outcome measure. It is a widely used, reliable, and validated parent-report measure of infant temperament. At six months postpartum mothers reported the relative frequency of specified infant behaviors in the past week on a seven-point Likert scale from 1 (never) to 7 (always), with an option to indicate that she had not observed her child in the situation in question. The mean age of the infants at the time the IBQ-R was completed was 6.96 months (SD = 2.71, range = 11.9). The IBQ-R consists of 14 subscales which yield three composite scores (negative affect, emotion regulation, and surgency/extraversion), according to the formula prepared by the creators of the instrument [40, 41]. Negative affect consists of distress to limitations, sadness, fear, and reverse coded falling reactivity. Regulation consists of duration of orientation, cuddliness, soothability, and low-pleasure seeking. Surgency consists of high-pleasure seeking, activity level, smiling and laughter, approach, perceptual sensitivity, and vocal reactivity. These composite scales were reported to have high internal reliability, with a reported Cronbach's alpha of .91 for negative affect, .91 for emotion regulation, and .92 for surgency [40].

Superstorm Sandy exposure measures.

Our main predictors included objective and subjective measures of Superstorm Sandy related stressors. Specifically, data assessing objective hardship (Storm32), subjective distress (IES-R), and timing of the pregnancy in relation to Superstorm Sandy (before, during, or after Superstorm Sandy) were collected immediately after the storm or at the time of enrollment. Each of these measures are described in detail below.

Gestational timing in relationship to the storm.—The specific gestational timing during which Superstorm Sandy occurred was calculated based on the date of birth of the child and the day the storm hit the metropolitan New York area (October 29, 2012). They were grouped in three categories: children born before the storm who experienced it early in life (postnatal group, 46% of the sample), children *in utero* during the storm (*in utero* group,

44% of the sample), and children who were not exposed to the storm (preconception group, 10% of the sample).

Hardship.—Objective hardship due to Superstorm Sandy was assessed with the Storm32 measure developed by King and Laplante [42] based on Bromet and Dew's [43] review. The questionnaire produces four dimensions of hardship as objectively and systematically as possible. Those four dimensions include threat, loss, scope, and change. Threat measures the degree to which life or injury to self or others was threatened by the event (Cronbach's $\alpha = .70$). Financial loss refers to loss of income and property damage (Cronbach's $\alpha = .78$). Scope measures amount of time without electricity and telephone (Cronbach's $\alpha = .90$). Change is the degree of disruption to living arrangements (Cronbach's $\alpha = .38$). Each dimension was weighted equally on a scale of 0 to 8, ranging from no to high hardship due to the disaster. Convergent validity is demonstrated in the correlations among these four scales and with the subjective distress scale described below (all $p < .01$).

Subjective distress.—The Impact of Event Scale-Revised (IES-R) was used to measure maternal subjective distress related to Superstorm Sandy [44]. Questions asked how respondents felt about the disaster in the seven days after the event. The 22-item IES-R, which has a high internal consistency (Cronbach's $\alpha = .92$), assesses three dimensions of post-traumatic stress disorder (intrusion, hyperarousal, and avoidance). Items are responded to on a five-point Likert scale (0 – 4), producing a theoretical range of 0 to 88. Convergent validity is demonstrated in the correlations between this scale and all four subscales of objective hardship described above and the state anxiety measure described below (all $p < .01$).

Potential confounders.

A host of variables potentially related to child temperament or experience during Superstorm Sandy were collected, including demographic characteristics, pregnancy and birth outcomes, and maternal physical and mental health.

Maternal demographic characteristics.—Self-reported maternal age, education, parity (i.e., number of lifetime pregnancy including miscarriages and abortions), and marital status were collected at the time of enrollment in the study.

Obstetric and birth outcomes.—Traditional indicators of pregnancy outcomes (e.g., birth weight and gestational age), history of birth complications (e.g., C-section, forceps delivery, and premature rupture of membrane), and neonatal problems (jaundice, admission to the neonatal intensive care unit, and shoulder dystocia) were collected at birth via electronic medical records. The number of birth complications formed a birth complication index used for analysis.

Maternal health problems during pregnancy.—Information on two of the most common forms of maternal medical illness during pregnancy, i.e., endocrine disorders and infection, was collected both via medical chart reviews and maternal self-report. Endocrine disorders included gestational diabetes mellitus, preeclampsia, and gestation-induced

hypertension. Infection includes vaginal infection and sexually transmitted infection such as chlamydia, herpes simplex, group B streptococcus, and human papillomavirus (HPV).

Maternal depression.—The Edinburgh Postnatal Depression Scale (EPDS) [45], a widely utilized self-report inventory of pre- and postnatal depression, measured depression symptomatology during pregnancy. Mothers reported how they felt in the past seven days on a four-point Likert scale. Response options included "*yes, all the time*," "*yes, most of the time*," "*no, not very often*," and "*no, not at all*." The total score on all items, after certain items were reverse scored, yielded the "maternal depression" scale. The inventory has acceptable reliability (Cronbach's α = .74 during pregnancy, Cronbach's α = .79 after pregnancy), satisfactory sensitivity (79%) and specificity (85%). Depression symptomatology was assessed during the second trimester and repeated at postpartum when infants were assessed at 6 months of age. These two scores are highly correlated with each other and the maternal state anxiety and negative life events measures described below (all p < 01.)

Maternal anxiety.—The State-Trait Anxiety Inventory (STAI) [48] measures the temporary condition of "state anxiety" and long-standing quality of "trait anxiety." Each type is assessed by 20 statements that may or may not describe the participants, responded to on a 4-point Likert scale ranging from 1 "*not at all*" to 4 "*very much so*." The current study used state anxiety as a measure of prenatal anxiety during the second trimester (Cronbach's α = .92). Convergent validity is demonstrated in the significant correlations between this measure and stressful life events (described below), maternal depression, and subjective storm distress measures described above (all p < .01).

Stressful life events.—The Psychiatric Epidemiology Research Interview Life Events Scale (PERI) [50] assessed the occurrence of stressful events in five major areas of life: relationships, health, legal matters, work and financials, and friendships. Mothers reported their experiences with stressful life events in those five areas of life during the second trimester. They endorsed for specific events and reported the valence (i.e., positive or negative) associated with each. This measure is widely used, has been shown to have good validity with narrative reports of life events, and has low intra-category variability [51]. We used the total number of negative life events reported by the mothers as our measure of stressful life events. Convergent validity is demonstrated in the significant correlations between this measure and maternal depression and state anxiety measures (all p < .01).

Data analysis

All analyses were conducted using SPSS version 23 (IBM, Inc.). First, descriptive statistics were calculated to evaluate the correlation, mean, and standard deviation (SD) among the three composite temperament scores (i.e., negative affect, emotion regulation, and surgency), nine measures of maternal characteristics, (i.e., state anxiety, stressful life events, prenatal depression, postnatal depression, the number of birth complications, maternal age, parity, education attainment, endocrine disorders and infections), three child characteristics, (i.e., birthweight gestational age at birth, and sex), and objective and subjective Sandy-related stress, and gestational timing of exposure (before, during, or after gestation).

Prior to the analysis, the three temperament subscales were evaluated for normality by examining univariate indices of skewness. These subscales were normally distributed and consequently no transformation was applied. The frequency of missing data in this sample was negligible (less than 0.6%) for all variables except temperament variables (5.2%). No substitutions or imputations were used. Subjects with missing data did not significantly differ from the rest of the sample. Followed by the initial descriptive statistics, multivariable analysis was conducted using a general linear model (GLM) to examine the main effects of Sandy-related stress variables (i.e., threat, loss, scope, change, subjective distress, and exposure timing) simultaneously on each of the three temperament outcomes separately. All analyses were performed first without potential confounders (Model 1), then with potential confounders, including *a priori* determined maternal and child demographic confounders and prenatal problems (i.e., maternal age, parity, obstetric complication, maternal education, birthweight, gestational age, endocrine illness, and infection during pregnancy; Model 2), and finally with additional normative, non-Sandy related stress (i.e., stressful life events, state-anxiety, prenatal and postnatal depression symptomatology; Model 3). In order to control for Type I errors due to multiple testing (3 models), we made an adjustment using the Benjamini–Hochberg procedure [52, 53].

Results

Demographic Characteristics of Participants

The mean age of mothers was 27. Mothers had, on average, approximately three pregnancies prior to the index pregnancy in the present study. The majority of participants were Hispanic (50%) or Black (24%), then White (15%) or Asian (10%). Slightly more than half of the mothers were single (55%), and 44% were either married or in a common law marriage. Approximately 50% were girls and 50% were boys. Approximately 46% of the total sample was pregnant prior to Superstorm Sandy and their offspring experienced the storm in the postnatal period. Of the postnatal group, a majority were Hispanic (45%) or black (38%), 66% had single mothers, 53.7% were male, and the mean age of the mother was 27.7 (SD = 6.2). Forty-four percent of participants were pregnant at the time of Superstorm Sandy with offspring experiencing the storm *in utero*. Of the *in utero* group, more than half were Hispanic (56%), 44.4% had single mothers, 52% were male, and the mean age of the mother was 27.49 (SD = 5.67). The remaining 10% were conceived after the storm. Of the pre-conception group, nearly half were Hispanic (47%), nearly half had single mothers (47.2%), 25% were male, and the mean age of the mother was 26.29 (SD = 6.3). The mean age of the infants at the time the IBQ-R was completed was 6.96 months (SD = 2.71, range = 11.9). Additional demographic characteristics can be found in Table 1.

Correlations and Mean (SD) among Predictors and Child Temperament Scales

Means and standard deviations (SDs) of the outcome variables are as follows: negative affect M = 3.42, SD = 0.86; regulation M = 5.32, SD = 0.69; and surgency M = 5.26, SD = 0.86. Means and standard deviations of the main predictors, Superstorm Sandy related stress, are as follows: threat M = 0.44, SD = 1.00; loss M = 0.68, SD = 1.29; scope M = 0.43, SD = 1.25; change M =1.08, SD = 1.05; and subjective distress M = 7.85, SD = 12.88. Means, SDs, and ranges of all variables used in the study can be found in Table 2. Table 3 shows the

correlations among predictors and the outcomes: the three composite temperament scores of negative affect, emotion regulation, and surgency/extraversion.

General Linear Model Predicting Temperament

Results of the conducted multivariable general linear models predicting infant temperament dimensions of negative affect, emotion regulation, and surgency/extraversion are found in Table 4.

Timing of storm exposure.

As hypothesized, the timing of the occurrence of Superstorm Sandy in relation to the timing of the pregnancy (i.e., before, during, or after the pregnancy) predicted negative affect after controlling for confounders in Model 2 ($p = .03$) and Model 3 ($p = .02$, partial $\eta^2 = .01$), such that children exposed to these factors postnatally had the greatest negative affect scores. Exposure timing was also marginally associated with emotion dysregulation in Model 1 ($p = .06$) and significantly associated in Model 2 ($p = .05$) and in Model 3 ($p = .03$, partial $\eta^2 = .02$). Similar to negative affect, this suggested a decline in emotion regulation among offspring if they were exposed to the storm during pregnancy or shortly after the birth of the infants. Exposure timing was not significantly associated with surgency.

Disaster related hardship.

As hypothesized, objective measures of hardship related to the storm correlated with negative affect and emotion regulation. Scope of time without phone or electricity was associated with an increase in negative affect ($p = .05$). This association remained significant when other demographics, obstetric, and maternal illness risks were controlled for in Model 2 ($p = .04$), and with further adjustment of prenatal stress unrelated to the storm in Model 3 ($p = .02$, partial $\eta^2 = .03$). Financial loss was also ($p < .01$) associated with increased negative affect. The association remained significant in both Model 2 ($p = .02$) and Model 3 ($p = .05$, partial $\eta^2 = .01$).

Financial loss was associated with decreased emotion regulation in Model 1 ($p = .05$). The association remained significant in both Model 2 ($p = .01$) and Model 3 ($p < .01$, partial $\eta^2 = .01$). Threat of injury was only marginally ($p = .06$) associated with decreased emotion regulation in Model 1, until confounders were adjusted and the associations became significant in Model 2 ($p = .01$) and Model 3 ($p < .01$, partial $\eta^2 = .01$). There was no notable association with surgency and disaster related hardship.

Subjective distress.

Subjective distress related to Superstorm Sandy was not significantly associated with any of the three temperament dimensions.

Discussion

The present study examined the effects of maternal experience with Superstorm Sandy (hardship and distress) as well as the timing of the exposure to the storm on infant temperament at 6 months of age. This study had four main findings. First, in line with our

hypotheses, subscales reflecting objective financial loss and scope of time without electricity or telephone were associated with greater negative affect. Decreased emotion regulation was associated with financial loss and threat of injury to self or others. Second, the timing of the exposure to the Storm (before, during, and shortly after) was associated with increased negative affect and decreased emotion regulation, such that infants who experienced the storm early in the postnatal period had the highest negative affect and lowest emotion regulation. Third, these associations remained significant after controlling for other risk factors, including demographics, obstetrics, maternal stress unrelated to the storm, maternal health problems during pregnancy, and maternal prenatal and postnatal depression. Fourth, contrary to expectations, we found no notable associations with the temperament dimension of surgency and storm variables.

Our findings are largely consistent with the results of Laplante et al. [35] who studied a cohort of mothers and infants exposed to the 1998 Quebec Ice Storm and unlike the results of Tees et al. [36], who found that maternal mental health, but not exposure to a disaster (i.e., Hurricane Katrina) predicted infant temperament. Interestingly, we found that subjective maternal distress related to Superstorm Sandy did not predict any temperament dimensions (negative affect, emotion regulation and surgency), whereas Laplante et al. found it predicted three temperament dimensions they measured: fussy/difficult, dullness, and need for attention. This is similar to another study that found the timing rather than the subjective distress of the Queensland Flood predicted interpersonal skills in offspring [34]. Laplante et al. used the Infant Characteristics Questionnaire (ICQ) [54]. We used the Infant Behavior Questionnaire-Revised (IBQ-R) [40, 41], which covers a wider range of temperament characteristics than the ICQ and is more strongly correlated with the Revised Infant Temperament Questionnaire (RITQ), which closely follows the nine temperament dimensions identified by The New York Longitudinal Study (NYLS) [55]. Furthermore, it is worth noting that Laplante et al. assessed temperament in children exposed *in utero*, Tees et al. assessed children who were exposed *in utero* or shortly before conception with unexposed children, and we assessed children *in utero* before, during, or after the storm.

Results from this study, along with the similar findings from the 1998 Quebec Ice Storm [35], strengthen the idea that PNMS related to a natural disaster has negative consequences on developing infants. Our findings that financial adversity and the occurrence of the disaster during the early postnatal period correlated with poor temperament outcomes underscore the importance of psychosocial stability for mother and child. Importantly, these findings held in a diverse sample following one stressful event while accounting for a host of potentially confounding variables, including prior stress. Although the stress caused by natural disasters might not be preventable, mental health services and other support for expectant mothers and mothers with young children who experience disasters and other stressful events may mitigate their impact. Increased awareness that stress brought by natural disasters to mothers may have a negative impact on infant temperament, which has been repeatedly linked to risk for development of future behavior problems is warranted [56, 57]. Notably, none of the variables related to the storm were associated with surgency, which may indicate that characteristics related to surgency, such as activity level and approach, are more resilient to early life and prenatal stressors. Taken together, our findings add to the

growing body of literature suggesting that periods of early development are especially vulnerable to stressors.

The limitations of the current study highlight several avenues for future research. Although mothers, our sole informants, are generally considered the best informant of her child's behavior, especially at young ages, multiple informants or independent observation of child temperament could have strengthened our findings. We controlled for mother's depressive symptomology at the time she reported temperament, yet readers should be mindful that maternal perception could have influenced her report of temperament in an unforeseeably systematic way. Future studies may consider collecting biological samples of cortisol or measures of autonomic functioning in mothers and children, which could provide an objective measure of stress response to strengthen interpretation of temperament scores. Maternal cortisol during pregnancy would have also substantiated our measures of stress. Additionally, only 10% of the sample became pregnant after the storm occurred. There may have been insufficient power to detect alterations in temperament in this group, and future research should aim to increase the proportion of the sample falling in this group. It is also possible that being pregnant or having a young child during a natural disaster makes the event more stressful. Moreover, identification of trimester-specific vulnerability to PNMS was not the focus of this study, but would greatly improve understanding of neurobehavioral development during gestation. Lack of data about the father of the child constitutes a further limitation. Roughly half of the mothers in the sample were single and unable to provide information about paternal stress or mental health, which would have helped form a more comprehensive picture of factors contributing to the child's development. We must cautiously interpret our findings in relation to other forms of stressors expecting mothers face. Press coverage, environmental cues, and other lasting consequences of natural disasters may make associated stressors substantially different. Relatedly, we also would like to acknowledge that reliability of one of the disaster specific stress scales (i.e., change) was poor. We considered dropping this subscale from the analysis, however, as it is one of the four scales the instrument we used extract, we thought the benefit of keeping it in the analysis outweigh than the limitation due to poor reliability of this particular scale. Nevertheless, it requires caution when interpreting the results. Lastly, we must take into account the small effect sizes of the associations found in this study and proceed with caution when drawing conclusions.

Despite limited generalizability to pre- and postnatal stressors other than a natural disaster due to factors discussed above, this evidence is a part of a growing body of literature of human and animal models pointing to the existence of critical periods for neurobehavioral development. It is notable that we included postnatally exposed children in this study. Laplante et al. [35] and Tees et al. [36] did not, yet this was the group with negative temperament characteristics most strongly correlated with Superstorm Sandy. Future investigation of potential mediators and moderators of the relationship between early life and gestational stress and poor infant temperament profile will aid the development of strategies to prevent this outcome in the face of events such as natural disasters. These factors may include epigenetic functioning, mother-child bond, or presence of social support structures including therapeutic intervention.

The compounded importance of the present study comes from recent calls to increase replication of research from the National Institutes of Health [58]. Psychological science has suffered from a lack of reproducibility, calling the validity of the results of many studies into question. This has been particularly difficult in natural disaster research, which presents the unique challenge of collecting data in a timely manner and accurately quantifying participants' storm experience. Additionally, we are able to infer that natural disasters with different characteristics, e.g., ice versus rain, have similar effects on offspring. Replication extending these findings to other extraordinary events such as earthquakes and wild fires will further our understanding of the ways in which these occurrences can be passed on from one generation to the next.

Urgency for understanding the impact of natural disasters on child development is increased by the recent devastation in the United States brought by Hurricanes Harvey, Irma, and Maria as well as reports that the frequency of disasters of this magnitude will increase as climate continues to change [59, 60]. Methods for preventing or modifying poor temperament and other potentially long-lasting outcomes following exposure to these events are imperative. The most effective of these will likely stem from research identifying both the biological underpinnings of this relationship and psychosocial factors that mitigate the impact.

Summary

This quasi-experimental study examined the effects of prenatal and postnatal maternal stress as a result of disaster-related stress on offspring temperament at 6 months-old in a prospective cohort of 380 pregnant women before, during, or after Superstorm Sandy in 2012. Forty-six percent of the sample were pregnant before, 44% during, and the remaining 10% after the storm. Mothers reported on stress experiences during the storm, demographic information, medical history, and mental health at the time of enrollment. At 6 months postpartum mothers reported infant temperament using the Infant Behavior Questionnaire. Results of multivariable general linear models indicated that negative affect was associated with the scope of the storm (i.e., time without phone/electricity) and with loss of income or property damage and that emotion regulation was associated with threat (i.e., threat to life and danger) and loss. These associations remained significant after controlling for demographic confounders, obstetric complication, and maternal illness during pregnancy, as well as mother's stress other than the storm. Furthermore, the timing of exposure to the storm was associated with negative affect and emotion regulation such that offspring born prior to the storm (i.e., exposed postnatally) had greater negative affect and lower emotion regulation than those born after the storm. There was no notable influence of storm related stress with surgency/extraversion. Our findings are consistent with a similar study of a cohort exposed to the Quebec Ice Storm of 1998 (Laplante, Brunet, & King, 2016) and provide further evidence supporting the impact of storm-related stress and the timing of the exposure on child temperament. Given that experts predict an increase in the occurrence of natural disasters related to climate change (McCarthy, Canziani, Leary, Dokken, & White, 2001), our results highlight the necessity of education and planning for early detection and intervention to help ameliorate any potential consequences on the developing infant.

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Table 1.

Demographic Characteristics of the Sample Population

	Total sample (*N* = 380)		**Postnatal (*N* = 175)**		***In utero* (*N* = 169)**		**Preconception (*N* = 36)**	
Parents' age	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Mother's age	27.45	5.97	27.67	6.24	27.49	5.67	26.09	6.3
Father's age	29.84	7.20	30.03	8.05	29.94	6.39	6.34	1.05
Parity	2.78	2.01	3.23	2.25	2.43	1.62	2.31	2.07
Race	*N*	%	*N*	%	*N*	%	*N*	%
Hispanic	189	49.7	78	44.6	94	55.6	17	47.2
Black	92	24.2	59	33.7	25	14.8	8	22.2
White	55	14.5	19	10.9	29	17.2	7	19.4
Asian	37	9.7	17	9.7	18	10.7	2	5.6
Other	7	1.8	2	1.1	3	1.8	2	5.6
Marital status	*N*	%	*N*	%	*N*	%	*N*	%
Single	207	54.5	115	65.7	75	44.4	17	47.2
Married	147	38.7	50	28.6	79	46.7	18	50.0
Common Law Marriage	21	5.5	8	4.6	12	7.1	1	2.8
Divorced/separated	3	0.8	1	0.6	2	1.2	0	0.0
Widowed	2	0.5	1	0.6	1	0.6	0	0.0
Education level	*N*	%	*N*	%	*N*	%	*N*	%
Primary school	13	3.4	4	2.3	7	4.1	2	5.6
Some high school	48	12.6	31	17.7	13	7.7	4	11.1
High school GED	84	22.1	47	26.9	30	17.8	7	19.4
Some college	100	26.3	39	22.3	47	27.8	14	38.9
Associate degree	39	10.3	15	8.6	22	13.0	2	5.6
Bachelor degree	54	14.2	22	12.6	27	16.0	5	13.9
Graduate/professional	42	11.1	17	9.7	23	13.6	2	5.6
Child Sex	*N*	%	*N*	%	*N*	%	*N*	%
Boys	190	50.0	94	53.7	87	51.5	9	25
Girls	190	50.0	81	46.3	82	48.5	27	75

Table 2.

Means and Standard Deviations for Outcomes and Predictors

	Total sample (*N* = 380)			**Postnatal (*N* = 175)**		***In utero* (*N* = 169)**		**Preconception (*N* = 36)**	
Child characteristics	Mean	SD	Range	Mean	SD	Mean	SD	Mean	SD
Surgency	5.26	0.86	4.33	5.17	0.89	5.29	0.80	5.21	0.83
Regulation	5.32	0.69	3.30	5.32	0.68	5.15	0.67	5.11	0.57
Negative affect	3.42	0.86	4.86	3.44	0.92	3.60	0.77	3.67	0.72
Birth complications	0.17	0.37	1.00	0.20	0.40	0.15	0.36	0.10	0.30
Birthweight (kg)	3.19	0.61	4.56	3.15	0.57	3.30	0.56	3.09	0.66
Gestational age	38.93	2.02	18.34	38.92	1.98	39.06	1.98	38.55	2.42
Maternal characteristics	Mean	SD	Range	Mean	SD	Mean	SD	Mean	SD
Postpartum depression	5.7	5.2	24	5.6	5.2	6.1	5.1	6.3	4.8
State anxiety	38.3	11.7	54	37.8	11.9	37.9	11.7	42.3	10.5
Negative life events	1.5	2.0	10	1.6	2.0	1.4	2.0	2.1	2.9
Endocrine illness, N (%)	48	13%	--	30	17%	16	10%	2	6%
Infection, N (%)	77	20%	--	39	22%	31	18%	7	19%
Disaster related factors	Mean	SD	Range	Mean	SD	Mean	SD	Mean	SD
Threat	0.46	1.02	8	0.43	0.08	0.53	0.08	0.31	0.13
Loss	0.73	1.31	8	0.61	0.09	0.85	0.11	0.80	0.22
Scope	0.45	1.28	8	0.44	0.09	0.48	0.12	0.38	0.12
Change	1.20	1.01	8	1.01	0.08	1.18	0.08	1.20	0.23
Subjective distress	7.85	12.89	88	7.04	0.91	8.52	0.98	8.62	3.26

Table 3.

Correlation Coefficients, Means and Standard Deviations (SD) for Outcomes and Predictor Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Temperament Dimension																					
1. Surgency	--	.52**	.16**	−.07	.06	−.06	−.16**	−.04	−.15**	−.02	−.11*	.02	−.02	−.11	−.02	−.01	−.08	−.06	−.05	−.06	.04
2. Regulation [a]		--	−.26**	−.15**	−.01	−.15**	−.22**	.02	.02	.06	−.05	.04	−.02	−.04	−.01	.01	−.05	.01	−.03	−.06	−.13*
3. Negative affect			--	−.18**	.14*	.18**	.24**	−.06	−.05	−.05	−.01	.03	.01	−.04	−.01	.09	.07	−.08	.04	.11*	.11*
Maternal Characteristics																					
4. State anxiety				--	.29**	.66**	.37**	−.01	−.07	.05	−.05	.03	.13*	−.09	−.07	.14**	.11*	.02	.06	.20**	.08
5. Stressful life events					--	.39**	.19**	.01	−.19**	.14*	−.15**	.05	.16**	−.04	.05	.13*	.03	−.04	−.06	.09	−.01
6. Prenatal depression						--	.49**	.05	.01	.01	−.04	.09	.13*	−.05	.02	.15**	.10	−.04	.18**	.24	.04
7. Postnatal depression							--	.07	.05	.17**	−.01	.03	.07	−.01	.02	.02	−.06	−.03	.23**	.05	
8. Birth complications								--	.14**	.04	.02	.84**	.01	−.10	−.08	.01	.04	.04	.02	.06	−.09
9. Mother's age									--	.19**	.39**	.13*	−.12*	.08	−.06	.01	.11*	.12*	.07	.06	−.06
10. Parity										--	−.18**	.04	.02	−.06	−.17**	−.01	−.01	−.07	−.12*	−.05	−.19**
11. Education											--	.03	−.16**	.13*	−.02	−.09	.11*	.14**	.06	.03	.07
12. Endocrine illness												--	.01	−.09	−.09	.03	.03	.03	.03	.04	−.12*
13. Infection													--	−.08	.06	.06	−.05	−.09	−.07	.08	−.04
Child Characteristics at Birth																					
14. Birthweight (kg)														--	.58**	−.05	.07	−.02	.07	.03	.06
15. Gestational age															--	−.01	.05	−.05	.08	−.03	−.01
Disaster-related Factors																					
16. Threat																--	.34**	.29**	.19**	.28**	−.01
17. Loss																	--	.40**	.40**	.24**	.07
18. Scope																		--	.33**	.18**	.01
19. Change																			--	.07	.07
20. Subjective distress																				--	.05
21. Exposure timing																					--

Note: See Table 2 for means and standard deviations for each variable.

[a]Regulation = Emotion Regulation

* $p < .05$

** $p < .01$

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Table 4.

Summary of Multivariable General Linear Model

	A) Negative Affect						B) Emotion Regulation						C) Surgency/Extraversion					
	Model 1[a]		Model 2[b]		Model 3[c]		Model 1[a]	Model 2[b]		Model 3[c]			Model 1[a]		Model 2[b]		Model 3[c]	
	B	*SE*	*B*	*SE*	*B*	*SE*	*B*	*SE*	*B*	*SE*	*B*	*SE*	*B*	*SE*	*B*	*SE*	*B*	*SE*
Threat	0.06	.05	0.09^{+}	.05	0.07	.06	−0.05	.05	0.11**	.04	−0.12**	.04	0.05	0.05	0.08	.06	0.10^{+}	.06
Loss	0.04	.04	0.11*	.05	0.10*	.05	−0.06^{+}	.04	−0.06**	.04	−0.09**	.04	−0.05	0.04	−0.22	−.04	−0.02	.05
Scope	−0.06^{+}	.04	−0.11*	.05	−0.13**	.05	0.15	.03	−0.02	.04	0.02	.04	−0.02	0.04	0.01	.05	−0.03	.06
Change	0.01	.05	0.06	.06	0.06	.06	−0.08	.04	−0.02	.05	−0.01	.05	−0.01	0.05	−0.03	.06	−0.04	.07
Distress	0.02^{+}	.01	−0.01	.08	−0.01	.02	0.01	.01	0.01	.01	0.01	.01	−0.01	0.01	−0.01	.01	−0.01	.02
Exposure timing	0.09	.07	0.12**	.03	0.15^{+}	.08	−0.16*	.05	−0.13**	.06	−0.16**	.07	0.04	0.07	0.07	.08	0.02	.09
Maternal age	--	--	−0.01	.01	0.01	.01	--	--	−0.01	.01	−0.01	.01	--	--	−0.01	.01	−0.01	.01
Parity	--	--	0.01	.03	−0.01	.03	--	--	−0.01	.02	0.02	.02	--	--	0.02	.03	0.01	.03
Complication	--	--	0.31	.27	0.38	.29	--	--	0.13	.21	−0.01	.22	--	--	−0.58*	.26	−0.65*	.29
Education	--	--	−0.01	.04	−0.04	.04	--	--	0.02	.03	0.40	.03	--	--	−0.04	.03	−0.06	.04
Birthweight	--	--	−0.01	.11	−0.15	.11	--	--	0.04	.08	0.01	.09	--	--	−0.16	.10	−0.14	.12
Gestational age	--	--	−0.01	.03	0.01	.03	--	--	−0.01	.08	−0.04	.03	--	--	0.01	.03	−0.14	.11
End illness[d]	--	--	−0.27	.29	0.32	.03	--	--	−0.26	.23	−0.40^{+}	.24	--	--	0.63*	.28	0.77*	.32
Infection	--	--	0.04	.13	0.14	.02	--	--	−0.03	.09	−0.10	.10	--	--	0.01	.12	−0.02	.14
Life events[e]	--	--	--	--	0.04	.03	--	--	--	--	−0.04	.02	--	--	--	--	−0.04	.03
State anxiety	--	--	--	--	0.01	.02	--	--	--	--	0.01^{+}	.01	--	--	--	--	−0.01	.02
Pre depression[f]	--	--	--	--	0.01	.01	--	--	--	--	−0.01^{+}	.01	--	--	--	--	−0.01	.01
Post depression[g]	--	--	--	--	0.03*	.01	--	--	--	--	0.02^{+}	.01	--	--	--	--	−0.01	.02

Note:

$^{+}p < .1$

$^{*}p < .05$

$^{**}p < .01$

[a]Model 1 includes only Superstorm Sandy related trauma, including threat, loss, scope, change, distress, and the time the participant was exposed to the disaster (prenatal, during, and postnatal)

[b]Model 2 includes all predictors in Model 1 after adjusting for maternal age, parity, pregnancy complication, maternal education, birth weight, gestational age, endocrine illness and infection (in pregnancy)

[c]Model 3 additionally include stressful life events, state anxiety, and depression during pregnancy and postnatal depression.

[d]End illness denotes endocrine illness

[e]Life events denote stressful life events

[f]Pre depression denotes prenatal depression

[g]post depression denotes postnatal depression