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Research paper

A cross-lagged panel analysis of children's sleep, attention, and mood in a prenatally stressed cohort: The QF2011 Queensland flood study

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ABSTRACT

Background: It is well recognized that childhood sleep, attention and mood problems increase risk for multiple adverse outcomes across the life-span; therefore, understanding factors, such as prenatal maternal stress, that underlie these types of childhood problems is critical for developing interventions that may optimize longer-term functioning. Our goal was to determine the association between disaster-related stress in pregnancy and young children's sleep, attention, and anxious/depressed symptoms.
Methods: Soon after a major flood in Australia in 2011, we assessed various aspects of disaster-related prenatal maternal stress (PNMS) in women who had been pregnant at the time. Mothers rated several domains of their children's development with the Child Behavior Checklist (CBCL) at ages 2½ (n = 134) and 4 years (n = 118).
Results: The primary finding was that more severe objective flood-related hardship in pregnancy predicted higher sleep problem scores at 2½ years, and that a negative maternal cognitive appraisal of the flood predicted lower attention problem scores at 2½ years. A cross-lagged panel analysis examined the association between children's sleep, attention, and anxious/depressed symptoms within and across ages. Results showed that these problems were likely to co-occur at each age, and that they were stable from 2½ to 4 years. Additionally, anxious/depressed scores at age 2½ predicted sleep problem scores at 4 years, all else being equal.
Limitations: Limitations of the study include a relatively small sample size and the children's outcome data relied on maternal report using the CBCL, rather than independent observation of the children's functioning, which may have introduced reporter bias.
Conclusions: These findings highlight the importance of early intervention for these childhood problems to optimize long-term mental health, particularly under conditions of prenatal stress.

1. Introduction

It is well recognized that childhood sleep, attention and mood problems increase risk for multiple adverse outcomes across the life-span, including poorer educational success and interpersonal skills (Breslau et al., 2008; Lawrence et al., 2015) and increased physical and mental health problems (Betts et al., 2016). These outcomes present a significant economic cost to society (Cobham, 2018). Therefore, understanding factors that underlie these types of childhood problems is critical for developing interventions that may optimize their longer-term outcomes and reduce the burden to society. One recently identified contributing factor to children's sleep, attention and mood problems is the prenatal environment.

Prenatal maternal stress (PNMS) due to anxiety, depression, negative life events or daily hassles is associated with increased childhood sleep disturbances (Gerardin et al., 2010; Netsi et al., 2015; O'Connor et al., 2007), attentional difficulties (Grizenko et al., 2012; Van den Bergh et al., 2006), and mood problems such as anxiety (Capron et al., 2015) and depression (Slykerman et al., 2015). PNMS-associated behavioral problems in early childhood have been linked to poor mental

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health in adolescence (Nilsen et al., 2013) and early adulthood (Betts et al., 2014) showing that the effects are enduring rather than transient.

It is also well recognized that there is a high correlation among childhood sleep, attention, and mood problems. For example, sleep problems are commonly associated with mood and attentional difficulties (Chorney et al., 2008; Gruber, 2014, 2016). Among youth with clinically significant anxiety presentations, the incidence of sleep problems ranges from 42 to 92% (Forbes et al., 2008; Hansen et al., 2011). This relationship appears to be bidirectional in nature (Chorney et al., 2008; Gregory et al., 2006; Ong et al., 2006). Thus, anxiety symptoms, such as compulsions and worrying, are likely to contribute to sleep problems (Storch et al., 2008), while sleep problems are likely to exacerbate anxiety symptoms (Alfano and Gamble, 2009), potentially via disrupted emotional regulation (Sagaspe et al., 2006). While there is some evidence that depressive presentations predict the onset of sleep disturbances in adolescents (Patten et al., 2000), stronger support exists for the opposite, unidirectional relationship—namely that sleep problems predict the subsequent development of depression (Gregory and O'Connor, 2002). Finally, between 25 and 50% of youth with attentional difficulties also experience significant sleep problems (Owens, 2005) with evidence that children with attention deficit hyperactivity disorder (ADHD) have significant problems falling and staying asleep compared to typically developing children (Wiebe et al., 2013). It has been hypothesized that sleep problems exacerbate attentional problems (Alfano and Gamble, 2009). Importantly, anxiety and ADHD commonly occur comorbidly and, not surprisingly, when this comorbidity exists sleep problems tend to be more prevalent (Hansen et al., 2011).

However, research has not yet examined the role that PNMS may play in the development, maintenance, and correlation among these three childhood problems. One methodological issue isolating the potential role of PNMS in this complex relationship is the difficultly ascertaining PNMS-effects from genetic factors shared between the mother and child that also predict children's sleeping difficulties, attention and mood problems; this is particularly the case with respect to children who were exposed in utero to prenatal maternal depression and/or anxiety (King and Laplante, 2015).

One way to overcome this confound is to make use of disaster-related hardship occurring during pregnancy. This naturally occurring pregnancy stressor is akin to controlled PNMS experiments with non-human animals in that the same independent stressor randomly affects a large number of women to various degrees irrespective of the women's heritable traits (e.g., sleep, attention, or mood). Additionally, researchers can isolate different aspects of the maternal stress experience (their objective hardship versus their cognitive and emotional reactions) (King and Laplante, 2015). There is evidence that PNMS from disasters predicts difficult or negative aspects of temperament in infancy (Laplante et al., 2016; Simcock et al., 2017; Tees et al., 2010; Zhang et al., 2018) and is related to increases in children's externalizing and internalizing symptoms (King et al., 2012) and mood problems (McLean et al., 2018). Whether disaster-related PNMS affects children's sleep or attentional problems has not yet been reported. Thus, this study will be the first to investigate the effects of disaster-related PNMS on these important aspects of child development, and makes a unique contribution by investigating their inter-relationship and maintenance during early childhood using cross-lagged panel analysis.

The QF2011 Queensland Flood Study was established in the wake of severe sudden-onset floods that affected three-quarters of the state of Queensland in Australia in January 2011, inundating over 200,000 residences, resulting in over AU$2 billion in insurance and clean-up costs, and leading to 32 fatalities. Since 2011, QF2011 has been investigating the effects of this flood on women's pregnancies, psychological functioning, birth outcomes, and their children's development (King et al., 2015).

The primary goal of the current study was to investigate whether aspects of flood-related PNMS (objective hardship, cognitive appraisal, subjective distress) predict the development of childhood sleep, attention, or anxious/depressed problems at 2½ and 4 years of age, and to examine the maintenance and inter-relation of these problems during early childhood. Specifically, after accounting for the effects of PNMS on child sleep and anxious/depressed problems, cross-lagged panel analyses were conducted to determine (1) the stability of sleep, attention and mood problems from 2½ to 4 years of age; (2) the cross-sectional relationship between sleep and attention or mood problems at each age; and (3) the cross-lagged influences between sleep and behavior from 2½ years to 4 years of age.

2. Methods

2.1. Participants and procedure

Women at a major tertiary hospital (Mater Mothers' Hospital) in a flood-affected area of Brisbane who were attending antenatal clinics or who were already enrolled in another unrelated study (Midwives @ New Group Practice Options, M@NGO) (Tracy et al., 2011) were invited to participate in QF2011. Additional women also volunteered in response to recruitment ads posted in hospitals or doctors' offices both within and outside of the Greater Brisbane area. Eligibility criteria included English speaking women over 18 years of age who were pregnant with a singleton during the flood. Recruitment commenced once ethical approval was obtained (April 2011) and continued until 12 months post-flood (January 2012). The QF2011 study protocol provides more detailed methods of eligibility criteria and recruitment (King et al., 2015).

From these recruitment methods, 230 women completed a survey regarding their flood-related experiences (objective experiences of the flood, cognitive appraisal, and emotional reactions), demographics and mental health. At 2½ and 4 years postpartum all women were invited to complete questionnaires about their children's development and their own mental health and demographics. Participants who completed the survey were thanked for their participation with a $30 gift voucher at each time point.

From this initial sample, 46 women were no longer participating at the 2½ and 4-year assessments (loss of contact, withdrawal). Of the 184 women who were invited to participate in the 2½ and 4-year surveys, 153 women returned the questionnaires (83% response rate): 134 at 2½ years and 118 at 4 years; 86 women participated at both time points. Analyses revealed that the only differences in the characteristics between the mothers who returned developmental questionnaires at 2½ and 4 years and those who did not were the number of schooling years and household income at recruitment, such that participants who returned the questionnaires are more educated and had higher household incomes. Table 1 presents the maternal demographic data and characteristics.

The study had approval from ethical review boards at Mater Research (1709M) and The University of Queensland (#2013001236); informed consent was obtained from all participants at all assessment points.

2.2. Maternal stress variables

The level of *objective hardship* that women experienced during the flood was assessed using the Queensland Flood Objective Stress Scale (QFOSS), a questionnaire developed specifically for QF2011 based on prior disaster PNMS research (Laplante et al., 2008; Ping et al., 2015). Items were based on the events that occurred during the disaster, and generated scores on four key dimensions of stress: Threat (e.g., "Were you physically hurt because of the flood?"), Loss (e.g., "Did you experience a loss of property because of the flooding?"), Scope (e.g., "How many days were you out of your home because of the flooding?"), and Change (e.g., "How many times were you required to change home

Table 1
Descriptive statistics for children's sleep problem, attention, and anxious/depressed total scores on the Child Behavior Checklist (CBCL), the maternal stress predictor variables, and covariates.

	2½ years (N = 134)	4 years (N = 118)
CBCL syndrome scales	M (SD)	M (SD)
Sleep problems	54.41 (7.04)	53.15 (4.79)
Attention problems	52.13 (3.88)	51.89 (4.19)
Anxious/depressed	51.43 (2.66)	52.16 (4.98)
Prenatal maternal stress variables	M (SD)	M (SD)
Objective hardship	20.00 (15.93)	20.51 (17.42)
Composite subjective stress	−0.007 (0.93)	−0.0001 (0.88)
	N (%)	*N*
Cognitive appraisal: negative	45 (33.6)	39 (33.1)
Cognitive appraisal: neutral/positive	89 (66.4)	79 (66.9)
Covariates	M (SD)	M (SD)
Pregnancy depression (EPDS)	5.01 (3.59)	5.08 (3.65)
School level (years)	14.46 (1.82)	14.36 (1.75)
Partners' school level (years)	14.98 (2.48)	14.89 (2.36)
Socioeconomic status (SEIFA)	1056.00 (53.98)	1052.75 (54.86)
Maternal mood (DASS)	19.24 (17.07)	19.68 (19.64)
Gest age at birth (weeks)	39.19 (1.98)	39.24 (1.86)
Birth weight (grams)	3528.15 (562.50)	3536.77 (536.00)
Child age at assessment (months)	30.25 (1.44)	48.80 (1.29)
	N (%)	*N* (%)
Income: <$[a]51,999	22/121 (18)	17/105 (16)
Income: $52,000–$103,999	56/121 (46)	53/105 (51)
Income: >$104,000	43/121 (36)	35/105 (33)
Ethnicity: Caucasian	125/129 (96.9)	113/115 (98.3)
Ethnicity: other	4/129 (3.1)	2/115 (1.7)
Marital status: married/de facto	104/120 (86.7)	96/107 (89.8)
Marital status: single/separated	16/120 (13.3)	11/107 (10.2)
Infant sex: boys	72 (53.7)	61 (51.7)
Infant sex: girls	62 (46.3)	57 (48.3)

Note: EPDS = Edinburgh Postnatal Depression Scale; DASS = Depression, Anxiety, and Stress Scale (total score); SEIFA = Socio Economic Indexes For Areas.
[a] Australian dollars.

because of the flood?"). Scores on each dimension ranged from 0 (no impact) to 50 (extreme impact) and were summed to provide a total QFOSS score (range = 0 – 200), with higher scores indicating higher levels of objective hardship.

A *composite subjective stress* score summarizes the emotional distress that women experienced during the flood and was assessed using three validated scales. The 22-item Impact of Event Scale-Revised (IES-R;Weiss and Marmar, 1997) self-report assessed the current severity of post-traumatic stress-type symptoms (avoidance, hyperarousal, and intrusive thoughts and images). The women rated each item (e.g., "Any reminder brought back feelings about the flood") with respect to the past seven days using a 5-point Likert scale: 0 (not at all true) to 4 (extremely true). The IES-R has high internal consistency (alpha coefficients range: 0.79–0.94) and good test–retest reliability (correlation coefficients range: 0.51–0.94) (Weiss and Marmar, 1997). The *peritraumatic responses* women experienced, that is, their retrospective reporting of how they had felt at the time of the flood, were assessed with two self-report questionnaires. The 13-item Peritraumatic Distress Inventory (PDI-Q; Brunet et al., 2001) retrospectively assessed emotional distress and panic-like physical reactions that were experienced at the time of the flood (e.g., "I thought I might die"). The 10-item Peritraumatic Dissociative Experiences Questionnaire (PDEQ; Marmar et al., 1997) retrospectively assessed dissociative-like experiences at the time of the flood (e.g., "My sense of time changed. Things seemed to be happening in slow motion"). Mothers rated the statements on the PDI and PDEQ using a 5-point scale from "not at all true" to "extremely true".

A *COmposite Score for MOthers' Subjective Stress* (COSMOSS) was computed using Principal Component Analysis (PCA) on the standardized total scores of the three subjective stress questionnaires (N = 230). The PCA-derived algorithm was: COSMOSS = 0.359 × IESR + 0.396 × PDI + 0.389 × PDEQ, resulting in one factor explaining 76.27% of the overall subjective stress variance, with mean of 0 and standard deviation of 1. Thus, a positive score indicates levels of subjective stress higher than the mean, and a negative score indicates levels of subjective stress lower than the mean.

Women's *cognitive appraisal* of the overall impact of the flood was assessed using the following question: "If you think about all of the consequences of the 2011 Queensland flood on you and your household, would you say the flood has been…?" Mothers rated their appraisal on a 5-point Likert scale, from Very Negative (−2) to Neutral (0) to Very Positive (+2). Due to the narrow range of scores, and to isolate a negative cognitive appraisal as one aspect of PNMS, scores were dichotomized into Negative (coded 0) versus Neutral/Positive (coded 1).

2.3. Child outcome variables

At 2½ and 4 years of age mothers completed the 100-item Child Behavior Checklist 1½–5 years (CBCL;Achenbach and Rescorla, 2000). Mothers rated each item on the CBCL describing their children's behavior over the past two months on a 3-point scale as: 0 = Not True, 1 = Somewhat or Sometimes True, to 2 = Very True or Often True. Three of the CBCL empirically based syndrome scales were used in the current study: Sleep Problems, Attention Problems, and Anxious/Depressed. For each scale, a raw score was calculated as the sum of the responses to the statements, which converts to a standardized Total (T) score (M = 50, SD = 10); T-scores were used in the current analyses. Standardized cut-offs on the T-scores classify children as within Normal ($T \leq 59$), Borderline ($T \geq 60$ but ≤ 63) and Clinical ranges ($T = \geq 64$). The CBCL sleep problems, attention problems, and anxious/depressed syndrome scales have very good retest reliability (r's = 0.92, 0.78, 0.68) and stability (r's = 0.60, 0.58, 0.64), respectively (Achenbach and Rescorla, 2000). The validity of the CBCL scales used here have been established with objective measures of sleep (Becker et al., 2015), attention (Chen et al., 1994), and anxious/depressed symptoms (Ebesutani et al., 2009).

2.4. Control variables

We controlled for several variables other than flood-related PNMS that can be related to PNMS and might affect maternal ratings of children's sleep, attention, and mood. Depression during pregnancy, using the Edinburgh Postnatal Depression Scale (EPDS; Cox et al., 1996), was obtained from hospital databases as it is associated with these aspects of child functioning. Current maternal mood (depression, anxiety and stress) was assessed using total scores of the 21-item Depression, Anxiety and Stress Scale (DASS-21; Lovibond and Lovibond, 1995) at 2½ and 4 years as it may introduce reporter bias when mother's complete the CBCL. We also controlled for maternal demographic factors known to influence relevant aspects of childhood behavior, including maternal marital status (Buckhalt et al., 2006), socioeconomic status (SES) using the Socio-Economic Indexes For Areas (SEIFA) scale based on post-code status (M = 1000, SD = 100), and education level using number of years schooling (in the Australian system there are 13 years of school), all assessed at recruitment into the study.

As PNMS is related to shorter gestation and lowered birthweight (Dancause et al., 2011), which are associated with increases in developmental problems (Sucksdorff et al., 2015), we controlled for infant birth size (gestational age and birth weight) using data obtained from hospital records.

2.5. Statistical analyses

First, we ran descriptive analyses on all outcomes, predictors, and

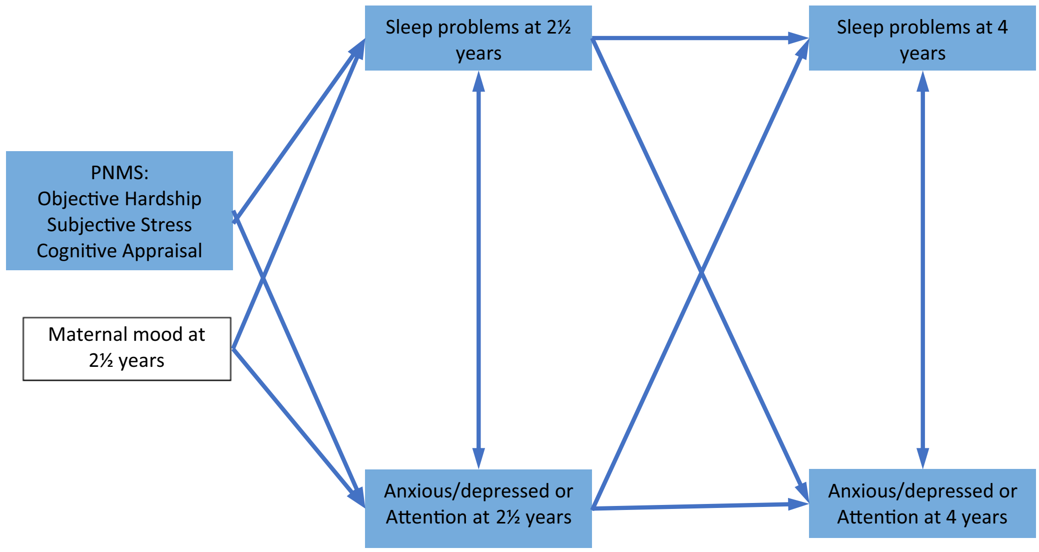

Fig. 1. Theoretical cross-lagged panel analysis showing the pathways between the prenatal maternal stress (PNMS) measures and children's sleep, attention and anxious/depressed syndrome scores at 2½ and 4 years.

covariates. Next we ran Pearson's correlation analyses between all PNMS measures, outcomes, and possible confounding variables. To determine the causality of the relationship between *T*-scores for sleep problems and attention problems or anxious/depressed, we conducted two cross-lagged panel analyses using Structural Equation Modeling, as presented in Fig. 1. We analyzed the effects of objective hardship, composite subjective stress, and cognitive appraisal on sleep problems and attention problems at 2½ years, adjusting for any covariate that was significantly related to the outcome variables. The only significant covariate was concurrent maternal mood and as none of the other covariates were significant they were not included in the final trimmed models. The cross-lagged effects from sleep problems at 2½ years to attention problem at 4 years and from attention problems at 2½ years to sleep problems at 4 years were included in the model, controlling for the stability effects of sleep and attention problems, as well as for the synchronous effects at 2½ years and 4 years. We then analyzed a second, similar model testing anxious/depressed symptoms instead of attention problems. Model fit was determined using Confirmatory Fit Index (CFI). All cross- lagged analyses were run using MPlus version 6.1, which handles missing data using Full Information Maximum Likelihood (FIML), proven to give very similar results to other popular methods likes Multiple Imputation or Expectation–Maximization (Dong and Peng, 2013).

3. Results

As objective hardship (QFOSS) had a non-normal distribution it was log-transformed; subjective stress (COSMOSS) was not transformed.

3.1. Descriptive statistics

Descriptive statistics for the CBCL syndrome scales, PNMS variables, and covariates are shown in Table 1. The majority of the children fell within the normal range on the three CBCL syndrome scales: at 2½ years for the sleep problem scale three children (3%) were in the borderline clinical range and six children (6%) were in the clinical range; for the anxious/depressed scale three children (3%) were in the borderline clinical range and five children (5%) were in the clinical range; and for the attention problems scale three children (3%) were in the borderline clinical range and five children (5%) were in the clinical range. At 4 years three children (3%) were in the borderline clinical range for the sleep problem scale and six children (5%) were in the clinical range; for the anxious/depressed scale four (3%) children were in the borderline clinical range and five (4%) children were in the clinical range; and for the attention problems scale four (3%) children were in the borderline clinical range and five children (4%) were in the clinical range.

4. Correlations

Correlations among the key variables are presented in Table 2. There were moderate significant correlations among the three PNMS measures, showing that although they were related they were measuring separate aspects of the PNMS experience. Correlations between the three PNMS measures and sociodemographic indicators (education, socioeconomic status, marital status) were mostly non-significant but all ≤ 0.22, suggesting that these highly heritable maternal characteristics explain less than 5% of the variance in the severity of their PNMS. At each age children's sleep problem scores were significantly correlated with their attention problem and anxious/depressed scores. At 2½ there was a marginally significant correlation between children's anxious/depressed and attention problem scores, and this correlation was significant at 4 years of age. Further, objective hardship was significantly, positively correlated with children's sleep problem scores at 2½ years. Depression (EPDS scores) in pregnancy was positively correlated with attention problems and anxious/depressed scores at 2 ½ years and at 4 years with sleep problems and anxious/depressed scores. Other correlations of interest were the significant, positive associations between current maternal mood at 2½ years and the three CBCL outcomes, and at 4 years maternal mood was significantly, positively correlated with sleep problem scores and marginally correlated with anxious/depressed scores. As such, concurrent maternal mood was entered in the cross-lagged panel analysis models as a covariate.

4.1. Cross-lagged panel analyses

The results of the two cross-lagged panel analyses are summarized in Table 3.

Composite subjective stress and pregnancy EPDS scores were removed from the final models as they were not significantly correlated with the sleep, attention or anxious/depressed CBCL syndrome scales.

Sleep and Attention Problem Scales. The cross-lagged panel model for attention problems had an excellent fit (CFI = 1.00). The resulting model is depicted in Fig. 2 (Panel A). Results showed that maternal

Table 2
Correlations among children's scores for sleep problems, attention problems, and the anxious/depressed syndrome scale on the Child Behavior Checklist (CBCL), the prenatal maternal stress variables, and the covariates.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Sleep problems 2½ yrs	–													
2. Attention 2½ years	0.204*	–												
3. Anxious/Dep 2½ years	0.253**	0.162$^{\#}$		–										
4. Sleep problems 4 years	0.377**	0.097	0.368**	–										
5. Attention 4 years	0.023	0.379**	0.034	0.221*	–									
6. Anxious/Dep 4 years	0.059	0.051	0.507**	0.517**	0.297**	–								
7. Objective hardship	0.185*	0.023	0.014	0.140	0.091	0.037	–							
8.Composite subjective stress	0.062	−0.008	−0.006	0.017	−0.069	−0.049	0.528**							
9.Cognitive appraisal	−0.080	0.117	−0.077	−0.064	−0.010	0.067	−0.487**	−0.356**						
10. Pregnancy depression	0.161	0.233*	0.253*	0.244*	0.091	0.201$^{\#}$	0.138$^{\#}$	0.220**	−0.141$^{\#}$	–				
11. Years schooling	−0.011	−0.171*	−0.072	−0.055	0.061	−0.100	0.092	−0.018	−0.088	−0.041	–			
12. Socioeconomic status	−0.079	0.044	−0.022	0.098	−0.015	−0.020	0.208**	0.040	−0.186**	−0.043	0.161*	–		
13. Maternal mood 2½ yr	0.242**	0.209*	0.298**	0.213*	0.099	0.166$^{\#}$	0.117	0.241**	−0.277**	0.571**	0.058	0.007	–	
14. Maternal mood 4 yr	0.248*	−0.121	0.240*	0.209*	0.020	0.299**	0.022	0.137	0.071	0.199$^{\#}$	0.137	−0.035	0.273**	–
15. Marital status	0.067	−0.133	0.147	0.031	−0.022	0.010	0.034	−0.029	0.036	−0.025	0.091	0.243**	0.015	−0.025
16. Gestational age	0.120	−0.143$^{\#}$	0.033	0.044	−0.086	−0.020	0.013	−0.059	−0.028	−0.108	0.125$^{\#}$	0.227**	0.042	0.087
17. Infant birth weight	0.103	−0.234**	−0.084	0.057	−0.066	−0.014	0.018	0.031	−0.104	−0.065	0.138*	0.083	−0.031	0.120
18. Infant sex (0 = *M*, 1 = *F*)	−0.131	−0.092	−0.070	0.083	−0.133	−0.052	−0.013	−0.056	−0.016	−0.055	−0.160*	−0.029	0.012	0.015

Cognitive appraisal (0 = negative; 1 = neutral/positive).
$^{\#}$ <0.1.
* <0.05.
** <0.05.

objective hardship had a significant effect on children's sleep problem scores at 2½ years ($p = 0.028$), such that higher objective hardship was associated with higher sleep problem scores. Also, maternal cognitive appraisal was significantly associated with child attention ($p = 0.010$), such that negative cognitive appraisal was associated with lower attention problem scores. Current maternal mood at 2½ years was associated with both children's sleep and attention problem scores ($p = 0.003$ and 0.001, respectively), such that higher maternal mood scores were associated with higher child CBCL scores. Sleep and attention scores were stable over time ($p < 0.001$ and $p < 0.001$, respectively). Also, there was a marginally significant association for the synchronous effect at 2½ years ($p = 0.066$), and a significant synchronous effect at 4 years ($p = 0.042$). Controlling for the stability and synchronous effects, neither of the cross-lagged effects were significant, that is, sleep problems at 2½ years did not significantly affect attention problems at 4 years, and attention problems at 2½ years did not significantly affect sleep problems at 4 years.

Sleep Problems and Anxious/Depressed Scales. The cross-lagged panel model for the CBCL anxious/depressed scale had a modest fit (CFI = 0.88). The resulting model is depicted in Fig. 2 (Panel B). Results showed that maternal objective hardship had a significant effect on child's sleep problem scores at 2½ years ($p = 0.033$), such that higher objective hardship was associated with higher sleep problem scores. There was no association between maternal cognitive appraisal of the flood and children's anxious/depressed syndrome scores. Current maternal mood at 2½ years was associated with both child's sleep and anxious/depressed problem scales ($p = 0.003$ and <0.001, respectively), such that higher maternal mood scores were associated with higher child problem scores. Sleep problem and anxious/depressed scores were stable over time ($p = 0.001$ and $p < 0.001$, respectively), and the synchronous effects at 2½ years and 4 years were significant ($p = 0.010$ and $p < 0.001$, respectively). Controlling for the stability and synchronous effects, anxious/depressed scores at 2½ years were significantly associated with sleep problems at 4 years ($p = 0.001$), but sleep problem scores at 2½ years did not significantly predict attention at 4 years.

Table 3
Cross-lagged panel analysis results for children's sleep, attention and anxious/depressed syndrome scales.

Attention problems					Anxious/depressed			
	β	*b*	(se)	Sig	β	*b*	(se)	Sig
Predictor effects on 2½ years outcomes								
Objective hardship to sleep problems	0.203	1.882	0.870	0.028	0.197	1.809	0.861	0.033
Cognitive appraisal to sleep problems	0.083	1.227	1.430	0.390	0.075	1.109	1.419	0.432
Maternal mood to sleep problems	0.249	0.103	0.035	0.003	0.239	0.099	0.035	0.003
Objective hardship to child behavior*	0.115	0.589	0.480	0.218	−0.038	−0.131	0.324	0.686
Cognitive appraisal to child behavior	0.244	1.987	0.788	0.010	−0.010	−0.058	0.535	0.914
Maternal mood to child behavior	0.274	0.062	0.019	0.001	0.305	0.048	0.013	<0.001
Cross-lagged effects (2½ years to 4 years)								
Sleep problems to child behavior	−0.062	0.011	0.112	0.536	−0.132	−0.094	0.068	0.161
Child behavior to sleep problems	0.008	−0.036	0.058	0.924	0.289	0.167	0.168	0.001
Stability effects (2½ years to 4 years)								
Sleep problems to sleep problems	0.402	0.280	0.070	<0.001	0.312	0.215	0.066	0.001
Child behavior to child behavior	0.371	0.388	0.093	<0.001	0.521	0.982	0.169	<0.001
Synchroneous effects (cross-sectional)								
2½ years	0.154	3.798	2.147	0.066	0.210	3.535	1.473	0.010
4 years	0.191	3.210	1.665	0.042	0.496	9.040	1.933	<0.001

* Behavior = Attention Problems or Anxious/Depressed Syndrome Scale.

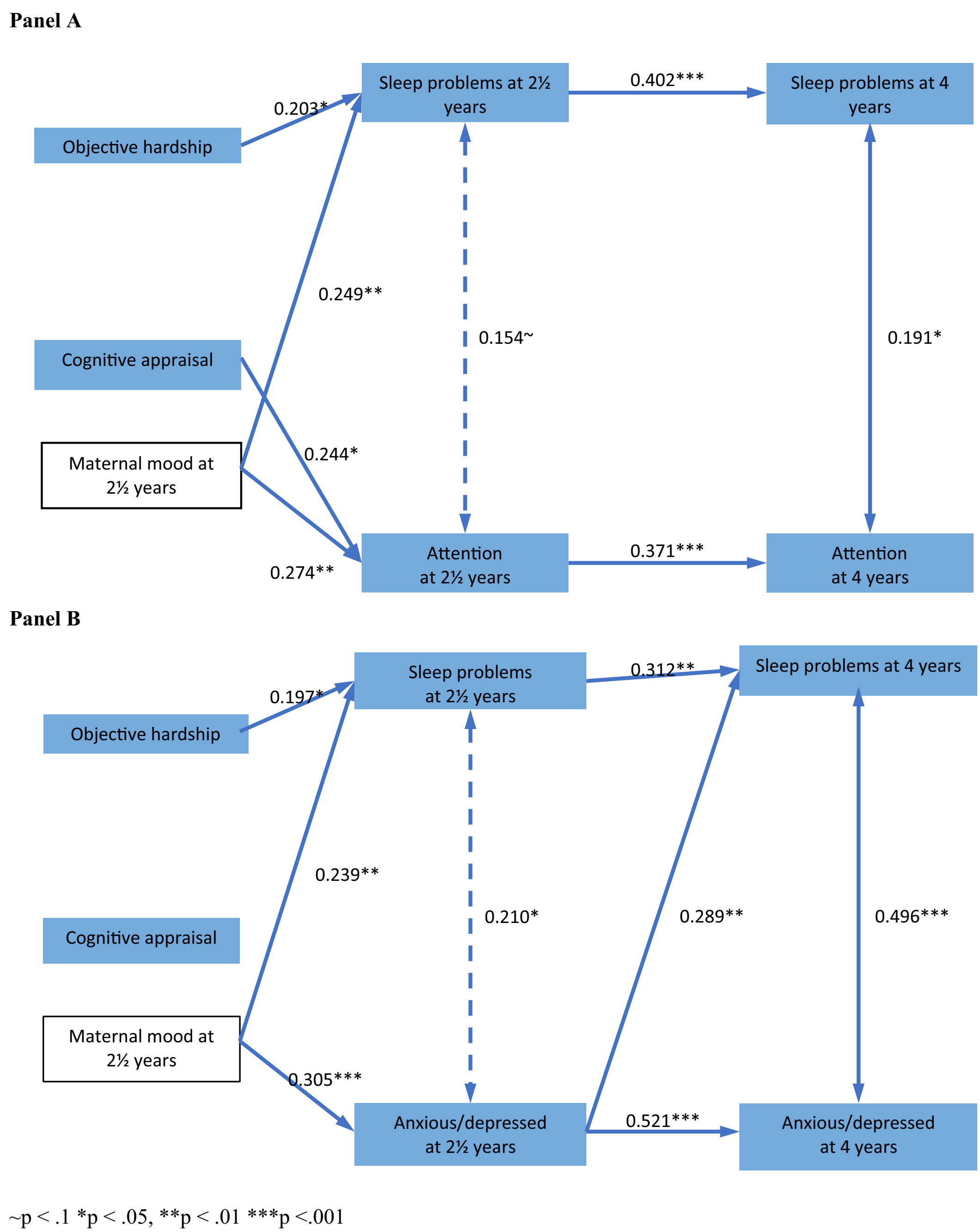

Fig. 2. Cross-lagged panel analysis showing the pathways between the prenatal maternal stress measures and children's sleep and attention scores at 2½ and 4 years (Panel A) and children's anxious/depressed syndrome scores at 2½ and 4 years (Panel B). Cognitive appraisal is coded 0 (negative and 1 (neutral/positive). All coefficients are standardized.

5. Discussion

This study utilized a sudden onset flood to determine the extent to which various aspects of disaster-related PNMS predicted the development of sleep disturbances, attention problems, and anxious/depressed scores at 2½ years of age. The longitudinal study design also enabled a unique cross-lagged panel analysis to further examine the inter-related nature of sleep, attention, and anxious/depressed problems at 2½ and 4 years of age. This is the first disaster-related PNMS study to examine these specific developmental outcomes in childhood, and to explore how they influence each other within and across ages.

5.1. Prenatal maternal stress effects and mechanisms

With respect to the primary goal of the study, the key finding was that the greater the flood-related objective hardship the women experienced, the higher the children's CBCL sleep problem scores. Further, contrary to the study expectations, a negative maternal cognitive appraisal of the flood predicted lower attention problem scores at 2½. There was no effect of objective hardship or cognitive appraisal on children's attention problem or anxious/depressed scores, and subjective stress did not predict any of the three target child outcomes.

The finding that objective hardship from the flood predicted more severe sleep problems is a novel addition to the PNMS and sleep literature and indicates that stress from an independently-occurring natural disaster can adversely influence this area of child functioning. We also found that maternal depression scores in pregnancy were correlated with many of the children's syndrome scale scores; yet they did not retain their significance when entered into the cross lagged panel analysis. This contrasts with prior research showing symptoms of maternal depression and anxiety in pregnancy predict higher rates of childhood sleep problems, assessed by maternal report of sleep duration and awakenings (O'Connor et al., 2007; Netsi et al., 2015). Between-study methodological differences in the way prenatal stress and mood were conceptualized and how children's sleep was assessed may account for this disparity. The current findings suggest that the effects of PNMS on sleep problems are not solely due to the confound of maternal depression in pregnancy genetically influencing child outcomes; but rather that objective disaster-related PNMS may have programming influences on fetal development.

According to the fetal programming hypothesis, stress causes increases in maternal glucocorticoid levels which cross the placenta and subsequently affect fetal neurodevelopment and hypothalamic-pituitary-adrenal (HPA) axis functioning (Davis et al., 2011). In particular, animal studies show that prenatal stress leads to hyperresponsivity of HPA axis functioning, with higher basal activity and prolonged responses to stressors (Weinstock, 1997). Importantly, hyperresponsivity of the HPA axis is a feature of chronic insomnia, which is characterized by elevated stress-sleep reactivity (Bonnet and Arand, 2010). It is hypothesized that fetal changes in response to PNMS are thought to prepare it for a potentially threating postnatal environment with behavioral changes, such as hyperarousal, that allow adaptation to this environment. However, if the prenatal stressor has abated by the time the baby is born, these behavioral changes may be maladaptive (Gluckman and Hansono, 2004), and present as sleep, anxiety, or attention problems.

Interestingly, the fetal programming effects of PNMS are not always negative. As seen here, when concurrent maternal mood was included in the model, a negative evaluation of the overall impact of the flood was associated with lower attention problem scores at 2½ years. This finding is contrary to the above-mentioned effects of PNMS on fetal programming on maladaptive behavior, and the literature that includes other types of PNMS (e.g., maternal anxiety Van den Bergh et al., 2006 or stressful life events Grizenko et al., 2012) predict increases in children's attention or hyperactivity symptoms. However, within the QF2011 cohort there is some evidence that higher levels of PNMS have a facilitative effect on some child outcomes, with boys having better problem solving skills than girls with higher levels of subjective stress (Simcock et al., 2016). Similarly, in a cohort of women affected by a severe ice storm when pregnant (Project Ice Storm) moderate levels of PNMS were associated with higher IQ (Laplante et al., 2008). This developmental 'advantage' from PNMS exposure for cognition is also reported in studies in which the pregnancy stressor is psychological distress (DiPietro et al., 2006) or high cortisol levels in late gestation (Davis and Sandman, 2010). The influence of concurrent maternal mood on the relation between cognitive appraisal and attention found here indicate that further research, or replication, in this area is warranted.

The lack of significant effects of PNMS predicting children's anxious/depressed syndrome scores is also unexpected and contrary to the stress in pregnancy literature showing that PNMS negatively impacts children's functioning in these domains (McLean et al., 2018; Slykerman et al., 2015). One potential explanation for this is that the ages studied here are very rarely diagnosed with depression or anxiety and the items on CBCL anxious/depressed syndrome scale are akin to behavioral tendencies rather than the psychiatric disorders that the scale indicates.

The advantage of the design of the current study, which enables the determination of whether different aspects of the maternal stress experience influence child outcomes, shows that they exert distinct effects even on the same developmental domain. For example, high levels of objective hardship predicted sleep problems at 2½ years yet there were no effects of subjective stress or cognitive appraisal. Although maternal cognitive appraisal of the flood was associated with attention problems, neither objective hardship nor subjective stress predicted attention problems. These findings complement our prior research (McLean et al., 2018; Moss et al., 2017) and others' (Buitelaar et al., 2003; DiPietro et al., 2006; Nolvi et al., 2016) in relation to how different aspects of PNMS are associated with different child outcomes. The findings further demonstrate the necessity of a comprehensive post-disaster assessment of maternal hardship and stress reactions to ensure that these pregnant women can receive support that may mitigate any adverse effects of the disaster on their wellbeing and their children's development. For example, we have found that flood-affected women who received midwifery group practice (MGP) maternity care had lower levels of postnatal depression and anxiety at 6 weeks postpartum compared to those who received standard maternity care (Kildea et al., 2017); the benefits of MGP care to the mothers were also evident for their infants' developmental milestones at 6 months (Simcock et al., 2018).

5.2. Maternal mood effects

The current results showed that mothers with higher concurrent levels of depression, stress and anxiety report their children as having more severe sleep, attention, and anxious/depressed problems at 2½ years of age. This link could be due to reporter bias. Another possibility is that children's sleep problems influence maternal depression and stress (Hiscock and Wake, 2001). The association between current maternal mood and risk for poor child outcomes is a well-documented phenomenon (Goodman et al., 2011). This link may also be explained by some combination of the following hypotheses: current maternal mood is related to their children's propensity to develop mental health problems via genetically inherited vulnerability (Kovacs et al., 1997; Williamson et al., 1995), or via sub-optimal parenting behaviors such as inconsistent parenting (Patterson et al., 1992) or reduced maternal sensitivity (Goodman and Gotlib, 1999).

5.3. Associations among the CBCL scales

The current results showed that children's scores for sleep, attention, and anxious/depressed problems at 2½ years were correlated with their scores on these scales at 4 years of age (stability effects). Prior research has demonstrated that early problems such as these often continue and predict poor mental health outcomes in the longer-term (Kovacs, 1996); the evidence for the three child outcomes assessed in this study support this literature, at least during early childhood. Further, at each age, children who exhibit problems in one domain usually have accompanying problems in another domain (cross-sectional effects). At 2½ years, for example, children with more severe sleep problems also exhibited more severe anxious/depressed symptoms, and there was a marginal trend ($p = 0.07$) for them to also have more severe attention problems. Similarly, at age 4 years more severe sleep problems were significantly associated with more severe attention problems and with anxious/depressed symptoms. These findings highlight the need for clinicians to understand the adverse impact of PNMS on child outcomes so that at-risk children can be monitored; if problems are identified early interventions can be implemented to ensure optimal long-term functioning.

The cross-lagged findings support a large body of research demonstrating the comorbidity among childhood sleep, attention, and mood problems. However, as described in the introduction, research elucidating the direction of the influence these three childhood problems have with each other over development is mixed. The current results, with a prenatally-stressed cohort of children, showed that anxious/depressed symptoms at 2½ years of age predicted sleep problems at 4 years of age—supporting one body of research (Patten et al., 2000), but not the other (Ong et al., 2006). Contrary to our expectations and to prior research with clinical samples, we did not find any cross-lagged effects between children's sleep problems and their attentional difficulties, or vice versa (Alfano and Gamble, 2009). However, this association may be seen only in children with a clinical diagnosis of ADHD, whereas QF2011 is a community-based sample of typically developing children whose mothers experienced various levels of disaster-related stress while pregnant.

5.4. Study limitations

There are some limitations to the current study. For example, the sample size is relatively small and the sample is comprised of participants of mid to high SES; this fact may have made detecting significant effects more difficult and may reduce the generalizability of the results to the broader population. Generalization may also be reduced due to attrition from the original sample (20%) to the follow-up developmental assessments; a common problem in longitudinal research. We utilized PNMS from a natural disaster which may limit generalizability to other kinds of prenatal stressors such as maternal mood or daily hassles; however, the advantage of the current design with an objective stressor is that it disentangles the propensity for genetic transmission of traits from mother to child (King and Laplante, 2015). The mothers reported on their children's behavior which may have introduced recall or reporter biases of their children's characteristics. However, the CBCL has sound psychometric properties (Achenbach and Rescorla, 2000) showing that mothers can accurately rate their child's behavior, and we controlled for maternal mood at the time of completing the questionnaire to account for this possibility. Nonetheless, objective observer-rated assessments of these child outcomes would have strengthened the design and results of the current study.

6. Conclusions

This paper makes a unique contribution to the literature by investigating the effects of disaster-related PNMS on important aspects of child functioning and examining their inter-relationship and maintenance during early childhood. In summary, these results show that objective disaster-related PNMS negatively influences children's sleep at 2½ years which then predicts sleep problems at 4 years. As well, we show that anxious/depressed symptoms at age 2½ predict sleep problems at age 4 even when controlling for PNMS and for sleep problems at 2½. There was no effect of subjective stress on any of the child outcomes, and PNMS did not predict anxious/depressed symptoms in the children. Moreover, sleep, attention and mood at 2½ years predicted the severity of these same problems at age 4. As the children's CBCL scores were consistent with community norms, these results suggest that PNMS may have reduced the likelihood that the children reached their full potential on the studied domains. It is possible that higher levels of PNMS may have produced clinically significant effects. However, as even sub-clinical symptoms are predictors of poor psychological functioning in later life, it is important to target interventions during the early years to optimize children's long-term wellbeing, particularly in prenatally stressed children. However, a negative maternal appraisal of the impact of the event lead to higher attention scores at 2½ years of age; suggesting that some stress in utero may have facilitative effects on child outcomes.

Author statement contributors

S. King, G. Simcock, R. Gruber, and S. Kildea contributed to conceptualization of the study. G. Elgbeili conducted the formal analysis and drafted the results. G. Simcock and V. E. Cobham wrote the origianl draft. D. P. Laplante and other co-authors provided critical review and editing. All authors have approved the final version of the manuscript.

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Declaration of Competing Interest

The authors declare that they have no conflicts of interest.

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Supplementary materials

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