

Chapman University

Chapman University Digital Commons

Psychology Faculty Articles and Research

Psychology

7-27-2021

Maternal Caregiving Ameliorates the Consequences of Prenatal Maternal Psychological Distress on Child Development

Leah A. Grande

Danielle A. Swales

Curt A. Sandman

Laura M. Glynn

Elyssia Poggi Davis

Follow this and additional works at: https://digitalcommons.chapman.edu/psychology_articles

Maternal Caregiving Ameliorates the Consequences of Prenatal Maternal Psychological Distress on Child Development

Comments

This article was originally published in *Development and Psychopathology* in 2021. <https://doi.org/10.1017/S0954579421000286>

Creative Commons License



This work is licensed under a [Creative Commons Attribution 4.0 License](https://creativecommons.org/licenses/by/4.0/).

Copyright

The authors

Regular Article

Maternal caregiving ameliorates the consequences of prenatal maternal psychological distress on child development

Leah A. Grande¹, Danielle A. Swales¹ , Curt A. Sandman², Laura M. Glynn³ and Elysia Poggi Davis^{1,2} 

¹Department of Psychology, University of Denver, Denver, CO, USA; ²Department of Psychiatry and Human Behavior, University of California-Irvine, Irvine, CA, USA and ³Department of Psychology, Chapman University, Orange, CA, USA

Abstract

Children exposed to prenatal maternal psychological distress are at elevated risk for a range of adverse outcomes; however, it remains poorly understood whether postnatal influences can ameliorate impairments related to prenatal distress. The current study evaluated if sensitivematernal care during the first postnatal year could mitigate child cognitive and emotional impairments associated with prenatal psychological distress. Prenatal maternal psychological distress was assessed via self-reports of anxiety, depression, and perceived stress for 136 mothers at five prenatal and four postpartum time points. Quality of maternal care (sensitivity to nondistress, positive regard, and intrusiveness reverse-scored) were assessed during a mother–child play interaction at 6 and 12 months. Child cognitive function and negative emotionality were assessed at 2 years, using The Bayley Scales and the Early Childhood Behavior Questionnaire. Elevated prenatal distress was associated with poorer child cognitive function and elevated negative emotionality. Children exposed to elevated prenatal maternal distress did not, however, display these outcomes if they received high-quality caregiving. Specifically, maternal care moderated the relation between prenatal psychological distress and child cognitive function and negative emotionality. This association remained after consideration of postnatal maternal psychological distress and relevant covariates. Sensitive maternal care was associated with altered offspring developmental trajectories, supporting child resilience following prenatal distress exposure.

Keywords: cognitive function, depression, fetal programming, maternal care, parenting, prenatal stress, resilience

(Received 2 August 2020; revised 5 February 2021; accepted 9 March 2021)

Maternal Caregiving Ameliorates the Consequences of Prenatal Maternal Psychological Distress on Child Development

Fetal life is an exceptionally rapid period of neurological development, and is a time when the fetus is highly susceptible to both beneficial and harmful environmental influences (Barker, 1998). Prenatal maternal psychological distress is linked to profound and lasting consequences for developmental trajectories and increases risk for subsequent mental health problems (Davis et al., 2007; Davis & Sandman, 2010, 2012; Demers, Aran, Glynn, & Davis, 2021; Glynn et al., 2018; Van den Bergh et al., 2017). The evidence that prenatal maternal stress and mental health has long-reaching implications for offspring psychopathology raises the need to investigate factors that can reduce or eliminate the consequences of prenatal adversity. High-quality parental caregiving is a likely factor that may increase resiliency in the face of prenatal adversity (Davis et al., 2019; Kok et al., 2015; NICHD Early Childcare Research Network, 1999). The current study addresses an important knowledge gap by investigating

whether high-quality maternal caregiving during infancy ameliorates the consequences of prenatal maternal distress on child cognitive and emotional development, thereby shifting trajectories of risk towards more optimal mental health.

Fetal programming research illustrates that children exposed to maternal psychological distress (e.g., anxiety, depression, and stress) during pregnancy have poorer cognitive function and elevated negative emotionality during infancy, childhood, and adolescence (Blair, Glynn, Sandman, & Davis, 2011; Glynn et al., 2018; Korja, Nolvi, Grant, & McMahon, 2017; Madigan et al., 2018; Mahrer et al., 2019; Sandman & Davis, 2010; Van den Bergh, Mulder, Mennes, & Glover, 2005, 2017). Importantly, these prospective and longitudinal studies document the predictive importance of prenatal distress on child outcomes, even after covarying potential confounders, including postnatal maternal psychological distress. Further, an independent line of research focusing on postnatal experiences reports that sensitive and responsive maternal care is associated with benefits for child cognitive and emotional development, as well as adult psychological health (Davis et al., 2017; Deans, 2018; Fan et al., 2014; Farrell et al., 2019; Malmberg et al., 2016; Spinrad & Stifter, 2002). Maternal caregiving during the first year postpartum may be especially important, because this is a sensitive window for mother–infant relationship development (Ainsworth, 1979; Feldman, 2007).

Although the opportunity to assess the joint contributions of prenatal and postnatal experiences are rare in human research,

Author for Correspondence: Elysia Davis, 2155 South Race Street, Denver, CO 80210, E-mail: elysia.davis@du.edu.

Cite this article: Grande LA, Swales DA, Sandman CA, Glynn LM, Davis EP (2021). Maternal caregiving ameliorates the consequences of prenatal maternal psychological distress on child development. *Development and Psychopathology* 1–10. <https://doi.org/10.1017/S0954579421000286>

and often are limited by a lack of objective assessment of maternal behavior (Sharp et al., 2012, 2015), experimental research with animals shows that high-quality maternal care can compensate for exposure to prenatal maternal stress. Specifically, the adverse effects of prenatal maternal stress on offspring cognition, emotion stress regulation, and brain development can be prevented with experimental manipulations of maternal quality of care (Bogoch, Biala, Linial, & Weinstock, 2007; Lemaire, Lamarque, Le Moal, Piazza, & Abrous, 2006; Rainekei, Lucion, & Weinberg, 2014; Wakshlak & Weinstock, 1990).

Several studies with clinical populations have tested the benefit of sensitive, responsive care on human infant development. Among mothers with an anxiety or a depression diagnosis during pregnancy, high-quality maternal care is associated with a reduction in the correlation between prenatal maternal mental health and offspring cortisol regulation at 4 months (Kaplan, Evans, & Monk, 2008), on negative affect responses to still-face at 7 months (Grant, McMahon, Reilly, & Austin, 2010a), and on Bayley cognitive development scores at 7 months (Grant, McMahon, Reilly, & Austin, 2010b). In addition to the relatively small sample sizes of these studies (ranging from 47 to 84), limitations include reliance on assessment of a single diagnostic category (i.e., diagnoses of anxiety or depressive disorders; Grant et al., 2010a, 2010b; Kaplan et al., 2008). Reliance on a single timepoint assessment as well as diagnostic cut offs in a single disorder may not fully capture fetal exposure to maternal psychological distress for several reasons. First, there is compelling evidence that maternal distress across the spectrum and including in the nonclinical range is linked to child outcomes (Davis & Sandman, 2012; Glynn et al., 2018; Kingston, Tough, & Whitfield, 2012; Krueger & Markon, 2006; Lee et al., 2007). Second, women frequently experience comorbidity of stress and internalizing symptoms from multiple disorders, all of which may impact the fetus (Falah-Hassani, Shiri, & Dennis, 2016; Glynn et al., 2018). For these reasons, it is important to assess prenatal exposure to maternal anxiety, depression, and stress multiple times during gestation to create a reliable index of exposure to multiple types of maternal distress over the entire course of gestation and then evaluate the compensatory benefit of maternal care.

A recent study that addressed these limitations reported that high levels of maternal positive engagement at ages 2.5 to 5 years alleviated the cognitive delays associated with prenatal maternal distress and suggested that parental care may be an important target for intervention (Schechter et al., 2017). The present study extends the findings by Schechter et al. (2017) in two important ways. First, by assessing maternal care during the first postnatal year (6 and 12 months), a sensitive window for attachment formation, this study assesses a potential target for early intervention. Second, the current study assesses both child cognitive function and negative emotionality, two important indices of early child development. Specifically, the current prospective research characterized maternal psychological distress (anxiety, depression, and perceived stress) across five gestational intervals and four postpartum time points. This approach was used to address the question: Does the quality of maternal care mitigate the link between prenatal exposure to maternal psychological distress and child cognitive function and negative emotionality?

Method

Participants

Study participants included 136 mothers and their children (79 male, 57 female) participating in a longitudinal study evaluating

Table 1. Sample characteristics

Maternal characteristics (<i>N</i> = 136)	(<i>M</i> ± <i>SD</i>) (range) or (%) [*]
Age at delivery	30.28 ± 5.08 (19.06–44.63)
Cohabiting with child's father	91.0
Primiparous	43.4
Race and Ethnicity	
Non-Hispanic White	50.7
Hispanic/Latinx	29.4
African American or Black	2.9
Asian	8.1
Multi-ethnic	8.8
Household income	
\$0–\$30,000	20.6
\$30,001–\$60,000	25.7
\$60,001–\$100,000	33.8
Over \$100,000	19.9
Years of education	15.99 ± 2.35 (9–19)
Obstetric complications sum score	0.34 ± 0.56 (0–2)
Maternal sensitivity composite (6 months)	9.98 ± 1.06 (6.5–12.0)
Maternal sensitivity composite (12 months)	9.67 ± 1.67 (4.5–12.0)
Child characteristics (<i>N</i> = 136)	
Sex (% Male)	58.1, <i>n</i> = 79
Apgar score (5 min)	9.00 ± 0.27 (8–10)
Gestational age at birth (GAB)	39.44 ± 1.26 (35.29–42.57)
Birth weight percentile ^{**}	52.77 ± 27.90 (1–99)
Mental Developmental Index (MDI)	97.71 ± 16.39 (54–140)
Negative affectivity (ECBQ)	2.80 ± 0.58 (1.38–5.08)

^{*}Values presented as (means ± *SD*) or (%) where applicable.

^{**}Birth weight percentile was calculated according to the infant's sex and gestational age at birth.

ECBQ = Early Childhood Behavior Questionnaire

the role of early experiences on development. Pregnant women were recruited from a large university medical center in Southern California. At recruitment, inclusion criteria were: (a) adult (≥18 years of age), (b) English-speaking, and (c) intrauterine, singleton pregnancy. Exclusion criteria at recruitment were: (a) presence of uterine or cervical abnormalities, (b) conditions such as endocrine, hepatic, or renal disorders, or use of corticosteroid medication, and (c) self-reported abuse of tobacco, alcohol, or recreational drugs in the pregnancy. An additional postnatal inclusion criterion for the current study was gestational age of 34 weeks or greater at birth. Descriptive information for the sample is provided in Table 1. All mothers provided informed, written consent for themselves and their child as approved by the Institutional Review Board for Protection of Human Subjects.

Procedures

Measures of maternal psychological distress were collected at five time points prenatally and four time points postnatally. Maternal sensitivity was assessed at 6 and 12 months postpartum and child

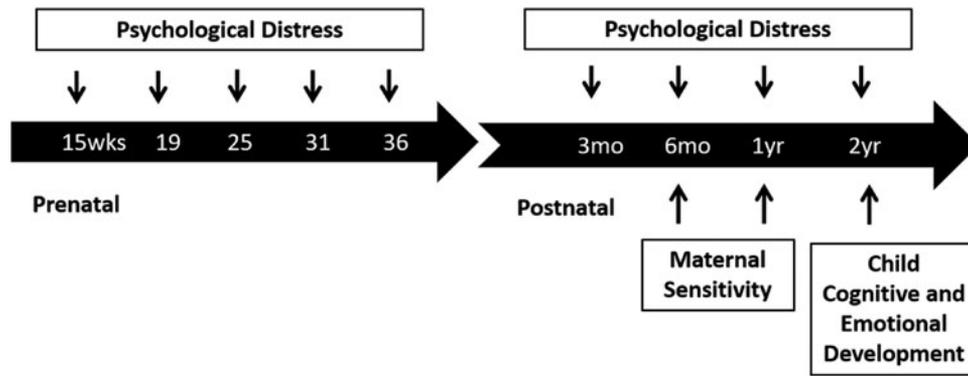


Figure 1. Study timeline.

cognitive and emotional outcomes were evaluated at 2 years (see Figure 1 for study timeline). Gestational and child ages at each assessment are presented in the Appendix Table 1. Appendix Table 6 shows missing data for each measure.

Measures

Maternal psychological distress

Maternal anxiety was assessed using the 10-item state anxiety subscale of the State-Trait Personality Inventory (STAI; Spielberger, 1983). Maternal depressive symptoms were assessed using the nine-item short form of the Center for Epidemiologic Studies Depression Inventory (CES-D; Santor & Coyne, 1997). Generalized or nonspecific perceptions of stress were assessed using the 12-item version of Cohen's Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983). The internal consistencies of the three measures across time points were good (STAI $\alpha = .87-.90$, CES-D $\alpha = .85-.88$, PSS $\alpha = .87-.91$ in the current sample). Mean levels of maternal depression, stress, and anxiety and distress composites at prenatal and postnatal time points are presented in the Appendix Table 2. The correlation between the three distress indicators and the pattern of association for anxiety, stress, and depression across pregnancy are presented in Appendix Tables 3–5.

Mean depression, perceived stress, and anxiety scores were standardized and averaged to create a composite prenatal distress and a composite postnatal distress score. This distress composite score was used as an index of prenatal exposure to multiple distress indicators, in order to provide a test of the ability of postnatal maternal sensitivity to compensate for prenatal maternal distress exposure. Prior research has indicated that the composite of anxiety, stress, and depression throughout pregnancy consistently predicts child outcomes (Glynn et al., 2018; Howland et al., 2020).

Quality of maternal care

Maternal care was characterized in the present investigation using a maternal sensitivity index developed by the NICHD Early Child Care Study comprising of three indicators (a composite of positive regard, sensitivity to nondistress, and intrusiveness reverse-scored) that is a potent predictor of numerous child development outcomes (NICHD Early Child Care Research Network, 1997, 1999, 2001).

Mothers were video-recorded interacting with their infants in a semi-structured 10-minute play episode in the lab at 6 and 12 months of age. During this play interaction, mothers were given

a standard set of age-appropriate toys and told to play with their infants as they would at home. Maternal behavior was scored from video using a coding system developed for the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD) Study of Early Child Care and Youth Development (Glynn, Davis, Sandman, & Goldberg, 2016; NICHD Early Child Care Research Network, 1999). Based on standard procedures, a composite rating of maternal sensitivity was created by summing 4-point ratings of sensitivity to nondistress, positive regard, and intrusiveness (reverse-scored). A composite maternal sensitivity score was calculated by averaging 6- and 12-month scores. All coders were blind to other data gathered on study participants. Twenty percent of sessions were selected at random, without coder knowledge, and coded again by a second independent coder to obtain an index of inter-rater reliability. Reliability for each of the subscales were: sensitivity to nondistress (90%), intrusiveness reverse-scored (90%), and positive regard (93%).

Child cognitive function

The Bayley Scales of Infant Development, second edition (BSID-II) Mental Developmental Index (MDI) was administered to assess child cognitive function at 2 years of age (Bayley, 1993). Examiners were directly supervised by a clinical psychologist. Interrater reliability, calculated on 15% of the assessments at each age, was 93%.

Child negative emotionality

Child negative emotionality at 2 years of age was assessed via maternal report on the Early Childhood Behavior Questionnaire (ECBQ; Putnam, Gartstein, & Rothbart, 2006). Prior research demonstrates that the ECBQ Negative Affectivity scale at 2 years has demonstrated inter-rater reliability and longitudinal stability (Putnam et al., 2006). Within the current sample, the Negative Affectivity scale had excellent internal consistency ($\alpha = .95$).

Measurement of covariates

Sociodemographic characteristics

Maternal socioeconomic status (SES), age, cohabitation with child's father, and race and ethnicity were collected via maternal interview. Maternal SES was calculated as the sum of standardized numbers of year of maternal education and standardized household income.

Pregnancy and birth outcomes

Maternal obstetric complications, parity, infant sex, birth weight, and 5-minute Apgar score were abstracted from the medical record. Estimated date of delivery was calculated utilizing both early ultrasound measures and date of last menstrual period based on American College of Obstetricians and Gynecologists (ACOG) guidelines, and used to assess gestational age at birth (GAB; Committee on Obstetric Practice, the American Institute of Ultrasound in Medicine, and the Society for Maternal-Fetal Medicine, 2017). An obstetric complications score was calculated, indicating the presence or absence of any pregnancy-related complications, including: prenatal infection, pregnancy-induced hypertension, gestational diabetes, oligohydramnios, polyhydramnios, preterm labor, anemia, vaginal bleeding, or placenta previa (Hobel, 1982).

Maternal intelligence

Maternal intelligence was assessed at a subsequent visit via the Perceptual Organization Index (POI) of the Wechsler Adult Intelligence Scale (WAIS-III) once postnatally. The POI was a proxy of general intelligence, because it is highly correlated with the general factor *g* of intelligence ($r = .94$) (Deary, 2001). The WAIS and its subscales are widely used and valid measures of intelligence. Previous studies demonstrate the validity of the WAIS, as well as the reliability of the POI score ($r = .93$) (Wechsler, Coalson, & Raiford, 1997). The WAIS-III was administered at a postnatal visit ($M = 5.34$, $SD = 1.99$ years postdelivery).

Statistical analyses

Sociodemographic and obstetric covariates

Potential covariates were selected based on the literature (Blair et al., 2011; Polanska et al., 2017) and included infant characteristics (biological sex at birth, gestational age at birth (GAB), birth-weight percentile adjusted for sex, and 5-minute Apgar score), as well as obstetric (obstetric health-related factors, parity) and maternal characteristics (SES, age, cohabitation with infant's father, race and ethnicity, and the WAIS, an index of intelligence). All regression models included covariates associated ($p < .10$) with the child outcome. Thus, the following covariates were included in cognitive function analyses: maternal age, SES, parity, cohabitation with child's father, maternal index of intelligence (WAIS), sum of obstetric risk, ethnicity (Non-Hispanic White or Hispanic/Latinx), GAB, and child sex. Covariates included in negative emotionality analyses were maternal age, SES, cohabitation with child's father, maternal index of intelligence (WAIS), and ethnicity (Non-Hispanic White or Hispanic/Latinx). The correlations between all potential covariates, prenatal and postnatal distress, maternal sensitivity, and child outcomes are presented in Appendix Table 7.

Psychological distress, maternal care and child outcomes

Initial bivariate correlations were performed to test whether prenatal and postnatal maternal psychological distress were associated with child outcomes, cognitive function, and negative emotionality. The relations between the maternal sensitivity composite and child outcomes were also evaluated via bivariate correlation.

Moderation of prenatal psychological distress by maternal caregiving

Regression models tested the primary hypothesis that the maternal sensitivity composite moderates the relation between prenatal

maternal psychological distress and child outcome. Continuous predictor variables were mean-centered in the regression model. Significant interactions were probed by calculating and plotting simple slopes. Finally, to test the potential contribution of postnatal maternal psychological distress, regression models included it as an additional covariate.

Secondary analyses: Assessment of sex differences, individual distress indicators, and timing and subscales of maternal care

Sex differences: Secondary analyses were conducted in order to explore sex differences as follows (a) whether there are sex differences in the association between prenatal distress and child outcomes, (b) sex differences in the association between the maternal sensitivity composite and child outcomes, and (c) whether the interaction between prenatal psychological distress and maternal sensitivity was moderated by child sex (three-way interaction).

Individual distress indicators: To test whether the maternal sensitivity composite moderated the effect of each of the three distress indicators, regression models were conducted separately for prenatal anxiety, stress, and depression (see Appendix Tables 7–8).

Timing and subscales of maternal care: To evaluate whether care at 6 or 12 months was a more important moderator of prenatal distress (timing) interaction models were conducted with maternal sensitivity separately at 6 and 12 months (see Appendix Tables 9–10). Finally, to test the role of the individual subscales that comprise the sensitivity composite (positive regard, sensitivity to nondistress, and intrusiveness reverse-scored) in moderating the effect of prenatal maternal distress, moderation analyses were conducted separately with each of the three subscales (Appendix Tables 11–12).

Results

Child developmental outcomes

Descriptive information for the cognitive and emotional outcomes is shown in Table 1. Poorer child cognitive function was associated with higher child negative emotionality ($r = -.32$, $p < .001$).

Maternal distress, maternal care, and child cognitive function

Elevated prenatal psychological distress composite was associated with poorer cognitive function ($r = -.28$, $p = .001$) and as shown in Appendix Table 5, the pattern of association was similar across the five gestational timepoints. Further, elevated postnatal psychological distress was associated with poorer child cognitive function at 2 years of age ($r = -.26$, $p = .003$). In contrast, a higher maternal sensitivity composite score was associated with enhanced child cognitive function ($r = .47$, $p < .001$).

Does postnatal care moderate the relation between prenatal psychological distress and child cognitive function?

The maternal sensitivity composite moderated the association between prenatal distress and child cognitive function even with the inclusion of covariates [$b = 2.80$, $t(119) = 2.25$, $p = .027$; see Table 2]. As shown in Figure 2, children exposed to elevated prenatal maternal distress and low maternal sensitivity exhibited the poorest cognitive performance, but children exposed to higher prenatal maternal distress who then received sensitive maternal care did not display deficits in cognitive function. This association remained

Table 2. Regression model examining the association between prenatal maternal psychological distress, maternal care and child cognitive function

Variable	Model 1: Prenatal distress			Model 2: Prenatal distress and sensitivity composite			Model 3: interaction		
	B	SE B	B	B	SE B	β	B	SE B	β
Maternal age	0.038	0.334	0.011	-0.062	0.333	-0.019	-0.042	0.327	-0.013
SES	2.159 [†]	1.139	0.225	1.771	1.138	0.185	1.839	1.120	0.192
Parity	-2.503	1.728	-0.125	-1.610	1.755	-0.080	-1.610	1.726	-0.080
Cohabitation with child's father	4.281	4.612	0.078	3.732	4.554	0.068	1.920	4.550	0.035
Index of intelligence (WAIS)	0.166 [†]	0.097	0.174	0.144	0.096	0.151	0.130	0.094	0.137
Obstetric complications	-1.925	2.831	-0.053	-1.795	2.792	-0.049	-1.921	2.746	-0.053
Non-Hispanic White	-1.764	3.191	-0.054	-1.951	3.148	-0.060	-2.611	3.109	-0.080
Hispanic/Latinx	-6.728 [†]	3.747	-0.189	-6.048	3.709	-0.170	-6.544 [†]	3.654	-0.184
Gestational age at birth (GAB)	0.863	1.017	0.066	0.641	1.008	0.049	0.458	0.995	0.035
Child sex (male)	-6.473*	2.464	-0.195	-6.244*	2.432	-0.188	-6.703**	2.400	-0.202
Prenatal distress	-1.376	1.616	-0.079	-1.301	1.594	-0.074	-1.425	1.568	-0.081
Sensitivity composite				2.599*	1.229	0.190	2.759*	1.211	0.201
Prenatal distress* Sensitivity composite							2.813*	1.245	0.161
R ²	0.379			0.401			0.426		
F	6.715***			6.705***			6.794***		

B = unstandardized coefficient; β = standardized coefficient; SES = socioeconomic status; WAIS = Wechsler Adult Intelligence Scale
[†]p < .10 *p < .05. **p < .01. ***p < .001.

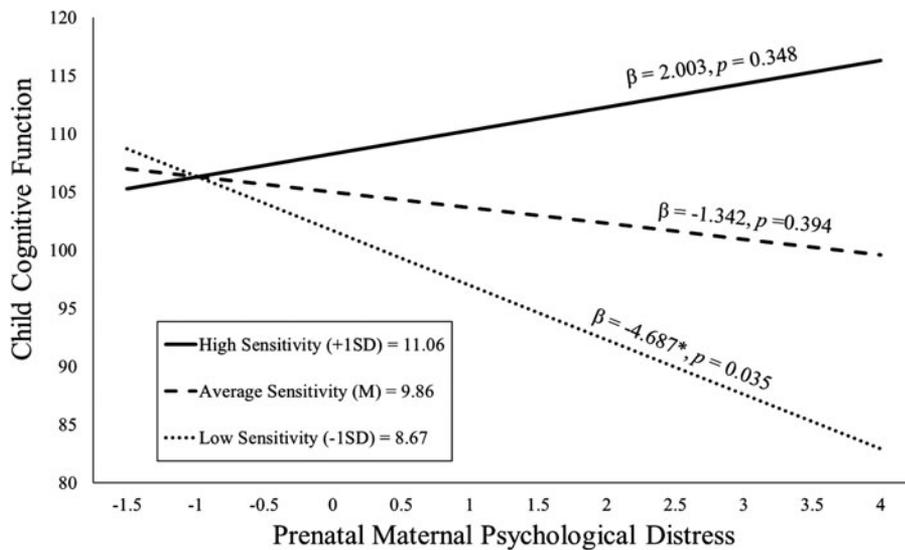


Figure 2. Maternal sensitivity composite was analyzed as a continuous variable using regression, but for illustrative purposes are depicted here as low (1 SD below the mean), average (at the mean), and high (1 SD above the mean) levels of maternal sensitivity. Prenatal maternal distress (on the x-axis) is the standardized composite of anxiety, depressive symptoms, and perceived stress scores. Children exposed to elevated prenatal maternal distress did not exhibit impaired cognitive function at age 2 if they received higher quality maternal caregiving.

when *postnatal* distress was additionally included as a covariate [*b* = 2.78, *t*(118) = 2.22, *p* = .028; see Appendix Table 13a].

Cognitive function secondary analyses: Assessment of sex differences, individual distress indicators, and timing of maternal care

Sex differences: Secondary analyses revealed that child sex did not moderate the effects of prenatal psychological distress (β = 0.070) or maternal sensitivity (β = 0.002) on child cognitive function;

additionally, the three-way interaction of child sex, prenatal distress, and maternal sensitivity was nonsignificant (β = 0.072) (*ps* > .52).

Individual distress indicators: The moderating effect of sensitivity on prenatal anxiety (β = 0.143), stress (β = 0.166), and depression (β = 0.114) examined separately yielded similar effect sizes (see Appendix Table 7).

Timing and subscales of maternal care: The moderating role of maternal sensitivity on child cognitive function was similar when maternal sensitivity was examined separately at 6 months

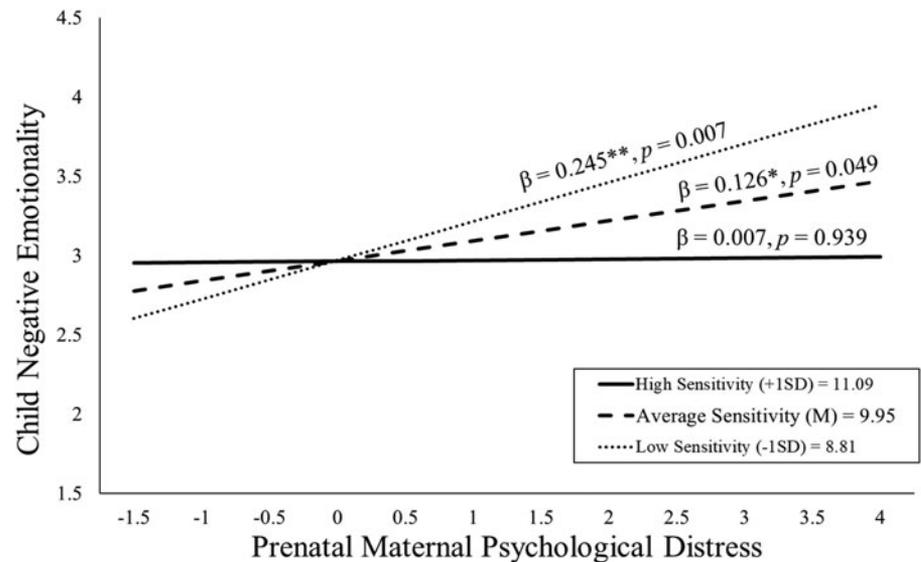


Figure 3. Maternal sensitivity composite was analyzed as a continuous variable using regression, but for illustrative purposes are depicted here as low (1 SD below the mean), average (at the mean), and high (1 SD above the mean) levels of maternal sensitivity. Prenatal maternal distress (on the x-axis) is the standardized composite of anxiety, depressive symptoms, and perceived stress scores. Children exposed to elevated prenatal maternal distress did not exhibit high negative emotionality at age 2 if they received higher quality maternal caregiving.

Table 3. Regression model examining the association between prenatal maternal psychological distress, maternal care and child negative emotionality

Variable	Model 1: Prenatal distress			Model 2: Prenatal distress and sensitivity composite			Model 3: Interaction		
	B	SE B	β	B	SE B	β	B	SE B	β
Maternal age	-0.012	0.011	-0.105	-0.012	0.011	-0.105	-0.014	0.011	-0.121
SES	-0.023	0.041	-0.065	-0.021	0.042	-0.061	-0.023	0.041	-0.065
Cohabitation with child's father	-0.172	0.193	-0.079	-0.173	0.194	-0.080	-0.122	0.193	-0.056
Index of intelligence (WAIS)	-0.003	0.003	-0.100	-0.003	0.004	-0.097	-0.003	0.003	-0.087
Non-Hispanic White	-0.258*	0.127	-0.223	-0.258*	0.128	-0.224	-0.233 [†]	0.127	-0.201
Hispanic/Latinx	0.152	0.152	0.117	0.148	0.154	0.114	0.182	0.153	0.141
Prenatal distress	0.125*	0.060	0.201	0.124*	0.061	0.199	0.126*	0.060	0.204
Sensitivity composite				-0.008	0.048	-0.016	-0.003	0.047	-0.006
Prenatal distress*Sensitivity composite							-0.105*	0.052	-0.164
R^2	0.280			0.280			0.306		
F	6.173***			5.358***			5.342***		

B = unstandardized coefficient; β = standardized coefficient; SES = socioeconomic stress; WAIS = Wechsler Adult Intelligence Scale

[†] $p < .10$ * $p < .05$. ** $p < .01$. *** $p < .001$.

($\beta = 0.181$) and 12 months ($\beta = 0.158$) (Appendix Table 9). In addition, the moderating effect of the individual subscales that comprise the sensitivity composite, including positive regard ($\beta = 0.154$), sensitivity to nondistress ($\beta = 0.151$), and intrusiveness reverse-scored ($\beta = 0.022$), revealed similar effect sizes (Appendix Table 11).

Maternal distress, maternal care, and child negative emotionality

Elevated prenatal maternal psychological distress was associated with higher child negative emotionality at 2 years of age ($r = .28$, $p = .002$), and as shown in Appendix Table 5, the pattern of association was similar across the five gestational timepoints. Elevated

postnatal maternal psychological distress ($r = .25$, $p = .005$) was associated with higher child negative emotionality at 2 years of age. A higher maternal sensitivity composite score was associated with lower child negative emotionality ($r = -.24$, $p = .008$).

Does postnatal care moderate the relation between prenatal psychological distress and child negative emotionality?

As shown in Figure 3, children exposed to elevated prenatal distress and who received high-quality maternal caregiving exhibited low negative emotionality even after consideration of covariates [$b = -0.11$, $t(109) = -2.01$, $p = .047$; see Table 3]. With the addition of postnatal maternal distress as a covariate this association remained statistically significant [$b = -0.11$, $t(108) = -2.03$, $p = .045$; see Appendix Table 13b].

Negative emotionality secondary analyses: Assessment of sex differences, individual distress indicators, and timing of maternal care

Sex differences: Secondary analyses revealed that child sex did not moderate the effects of prenatal psychological distress ($\beta = 0.065$) or maternal sensitivity ($\beta = -0.133$) on child negative emotionality; additionally, the three-way interaction of child sex, prenatal distress, and maternal sensitivity was nonsignificant ($\beta = 0.104$) ($ps > .29$).

Individual distress indicators: The moderating effect of sensitivity on prenatal anxiety ($\beta = -0.135$), stress ($\beta = -0.136$), and depression ($\beta = -0.165$) examined separately yielded similar effect sizes (see Appendix Table 8).

Timing and subscales of maternal care: The moderating role of maternal sensitivity on child negative emotionality was similar when maternal sensitivity was examined separately at 6 ($\beta = -0.162$) and 12 months ($\beta = -0.176$) (Appendix Table 10). In addition, the moderating effect of the individual subscales that comprise the sensitivity composite, including positive regard ($\beta = -0.083$), sensitivity to nondistress ($\beta = -0.151$), and intrusiveness reverse-scored ($\beta = -0.166$), revealed similar effect sizes (Appendix Table 12).

Discussion

Consistent with the fetal programming literature, we show that prenatal exposure to maternal psychological distress (anxiety, depression, and perceived stress) is associated with child cognitive and emotional vulnerabilities (Buss, Davis, Muftuler, Head, & Sandman, 2010; Davis et al., 2007, 2019; Davis & Sandman, 2010; Glynn et al., 2018; Kingston et al., 2012; Van den Bergh et al., 2017). Further, our findings are consistent with decades of research that have established the importance of parental care during sensitive periods, such as the first postnatal year, for promoting optimal developmental outcomes (Ainsworth, 1979). The present study provides new evidence that high-quality maternal care during the first postnatal year ameliorates the negative cognitive and emotional outcomes that follow exposure to prenatal maternal distress. These findings remained after considering potential confounding factors including SES, postnatal maternal distress, and maternal intelligence scores. These data indicate that consequences of fetal programming are malleable and that prenatal and postnatal experiences synergistically impact child development. Specifically, we find that high-quality caregiving can compensate for the impact of prenatal maternal distress by altering developmental trajectories and improving child mental health.

The present study addresses a key issue in the fetal programming literature by demonstrating that the consequences of prenatal exposures are modifiable by postnatal experiences. Our data are consistent with experimental rodent models that report manipulations of maternal care compensate for prenatal adversity (Bogoch et al., 2007; Lemaire et al., 2006; Raineki et al., 2014; Wakshlak & Weinstock, 1990) as well as studies showing that infants with a secure attachment relationship to their mother do not show behavioral problems following prenatal stress (Ali et al., 2020; Bergman, Sarkar, Glover, & O'Connor, 2008). There are several important contributions of our project to the relatively small human literature evaluating whether maternal behavior towards her infant mitigates the consequences of prenatal stress (Grant et al., 2010a, 2010b; Kaplan et al., 2008; Schechter et al., 2017; Sharp et al., 2012, 2015). First, maternal distress was assessed repeatedly throughout gestation and we have shown

previously that this composite measure of anxiety, stress, and depression symptoms predicts both cognitive and emotional outcomes through childhood and adolescence (Glynn et al., 2018; Howland et al., 2020). Second, we assessed a composite of maternal sensitivity twice during the first postnatal year, a sensitive window for attachment formation (Ainsworth, 1979). Thus, our design is a rigorous test of the hypothesis that high-quality maternal care can offset the impact of prenatal distress exposure after covarying for confounding factors including postnatal maternal distress. Third, we characterize both child cognitive and emotional function. Finally, these data provide evidence that infancy may be a sensitive window when maternal care can mitigate the consequences of prenatal maternal distress, thereby identifying a plausible target for early intervention following prenatal adversity.

Maternal care that is warm, sensitive, and responsive to infant's signals (Ainsworth, Blehar, Waters, & Wall, 1978), may play a particularly important role in child neurodevelopment and long-term developmental outcomes (Malmberg et al., 2016; Spinrad & Stifter, 2002; Wang et al., 2019). Thus, it is highly plausible that high-quality maternal care during the first postnatal year may alter neurodevelopmental trajectories following prenatal exposures towards more optimal outcomes. We show that maternal care at 6 and 12 months similarly moderated the association between prenatal maternal distress and child outcomes, suggesting that care throughout the first postnatal year may be important for ameliorating the impact of prenatal distress (Appendix Tables 9–10). The maternal sensitivity composite in the current study measured positive regard, sensitivity to nondistress, and intrusiveness reverse-scored, key aspects of maternal behavior that influence development. Findings suggest that all of these components of maternal sensitivity captured by this measure contribute to positive child development following prenatal maternal distress (see Appendix Tables 11–12). Future research could consider other aspects of positive parenting and paternal parenting behaviors that may ameliorate the impact of prenatal maternal distress.

There are a number of potential mechanisms by which prenatal maternal psychological distress may have consequences for child cognitive and emotional development, including alterations to fetal neurodevelopment (Sandman, Class, Glynn, & Davis, 2015; Sandman, Glynn, Davis, Kisilevsky, & Reissland, 2016; Schuurmans & Kurrasch, 2013; Wu et al., 2020). Animal studies demonstrate changes in offspring brain structure following prenatal stress exposure, such as reduced hippocampal volume and neurogenesis (Bogoch et al., 2007; Charil, Laplante, Vaillancourt, & King, 2010). Children exposed to prenatal maternal psychological distress show reduced gray matter volume and thickness in frontal, temporal, and limbic areas, as well as reduced total gray matter density (Adamson, Letourneau, & Lebel, 2018; Buss et al., 2010; Davis et al., 2019; Demers et al., 2021; Sandman, Buss, Head, & Davis, 2015). Cross-species studies provide mechanistic evidence that dendritic atrophy may be a pathway by which prenatal maternal distress disrupts offspring brain development (Curran, Sandman, Davis, Glynn, & Baram, 2017; Sandman et al., 2018). These neural systems impacted by prenatal exposures may be modifiable by high-quality postnatal maternal care. The first year postpartum continues to be a sensitive window of heightened neuroplasticity and rapid neural growth (Gee, 2016; Gilmore, Knickmeyer, & Gao, 2018; Knickmeyer et al., 2008) and maternal care may modify developmental trajectories. Consistent with this possibility, high-quality maternal care is associated with enhanced child hippocampal volume growth; this growth

trajectory is further associated with improved child emotion regulation (Luby, Barch, Whalen, Tillman, & Belden, 2017) as well as with greater child gray matter volume at 8 years (Kok et al., 2015). Experimental animal and cross species research provide strong evidence that maternal care directly impacts neural circuits underlying cognitive and emotional vulnerabilities that are impacted by prenatal maternal distress (Gee, 2016; Granger et al., 2021; Liu, Diori, Day, Francis, & Meaney, 2000; Rao et al., 2010).

The current study has several limitations. Although the use of a community sample highlights the importance of subclinical variation in maternal psychological symptoms of distress, the range of observed maternal psychological distress and maternal sensitivity is constrained. Because of this, the current study may underestimate the associations among prenatal distress, maternal sensitivity, and child outcomes. We also cannot completely disentangle the role of genetic influences. However, evidence from experimental animal research consistently reports the effects of maternal care on offspring outcomes are independent from effects of genetics, and provides experimental evidence that maternal care can compensate for prenatal exposures (Francis, Diorio, Liu, & Meaney, 1999; Liu et al., 2000).

Decades of research have confirmed the prenatal period as a time of enhanced responsiveness to environmental input, when maternal psychological distress can have a profound influence on child development (Bush et al., 2017; Davis et al., 2007, 2018; Davis & Sandman, 2010, 2012; Doyle et al., 2015; Van den Bergh et al., 2017; Vehmeijer, Guxens, Duijts, & Marroun, 2019). Few studies have directly assessed processes that promote resilience following prenatal adversity (Atzl, Grande, Davis, & Narayan, 2019; Davis & Narayan, 2020; D'Anna-Hernandez & Rivera, 2014; Røsand, Slinning, Eberhard-Gran, Røysamb, & Tambs, 2011). Our findings, coupled now with those from Schechter et al. (2017), provide strong support for postnatal prevention and intervention efforts to reduce the consequences of prenatal adversity. Efficacious interventions exist to support the transition to parenthood, and the development of positive parenting skills (Bick & Dozier, 2010; Eshel, Daelmans, Mello, & Martines, 2006; Nillni, Mehralizade, Mayer, & Milanovic, 2018). Thus, interventions to promote maternal psychological health and sensitive, responsive caregiving has enduring benefits that could thus mitigate the life-long cognitive and emotional consequences of prenatal psychological distress.

Supplementary Material. The supplementary material for this article can be found at <https://doi.org/10.1017/S0954579421000286>

Acknowledgments. We wish to thank the families who participated in this project. The assistance of Megan Faulkner, Natalie Hernandez, and Kendra Leak of the Women and Children's Health and Well-Being Project, Department of Psychiatry & Human Behavior, University of California and the Department of Psychology, Chapman University is gratefully acknowledged.

Funding Statement. This research was supported by the National Institutes of Health [R01 HD065823; P50 MH096889; R03 MH86062; R01 HD51852; R01 NS041298].

Conflicts of Interest. None.

References

- Adamson, B., Letourneau, N., & Lebel, C. (2018). Prenatal maternal anxiety and children's brain structure and function: A systematic review of neuroimaging studies. *Journal of Affective Disorders*, 241, 117–126. doi:10.1016/j.jad.2018.08.029
- Ainsworth, M. S. (1979). Infant–mother attachment. *American Psychologist*, 34, 932–937.
- Ainsworth, M., Blehar, M., Waters, E., & Wall, S. (1978). *Patterns of attachment: Assessed in the strange situation and at home*.
- Ali, E., Letourneau, N., Benzie, K., Ntanda, H., Dewey, D., Campbell, T., & Giesbrecht, G. (2020). Maternal prenatal anxiety and children's externalizing and internalizing behavioral problems: The moderating roles of maternal-child attachment security and child sex. *Canadian Journal of Nursing Research*, 52, 88–99. doi:10.1177/0844562119894184
- Atzl, V. M., Grande, L. A., Davis, E. P., & Narayan, A. J. (2019). Perinatal promotive and protective factors for women with histories of childhood abuse and neglect. *Child Abuse & Neglect*, 91, 63–77. doi:10.1016/j.chiabu.2019.02.008
- Barker, D. (1998). In utero programming of chronic disease. *Clinical Science*, 95, 115–128.
- Bayley, N. (1993). *Bayley scales of infant development*. San Antonio, TX: Psychological Corporation.
- Bergman, K., Sarkar, P., Glover, V., & O'Connor, T. G. (2008). Quality of child-parent attachment moderates the impact of antenatal stress on child fearfulness. *Journal of Child Psychology and Psychiatry*, 49, 1089–1098. doi:10.1111/j.1469-7610.2008.01987.x
- Bick, J., & Dozier, M. (2010). Mothers' concentrations of oxytocin following close, physical interactions with biological and nonbiological children. *Developmental Psychobiology*, 52, 100–107. doi:10.1002/dev.20411
- Blair, M. M., Glynn, L. M., Sandman, C. A., & Davis, E. P. (2011). Prenatal maternal anxiety and early childhood temperament. *Stress*, 14, 644–651.
- Bogoch, Y., Biala, Y. N., Linial, M., & Weinstock, M. (2007). Anxiety induced by prenatal stress is associated with suppression of hippocampal genes involved in synaptic function. *Journal of Neurochemistry*, 101, 1018–1030.
- Bush, N. R., Jones-Mason, K., Coccia, M., Caron, Z., Alkon, A., Thomas, M., Coleman-Phox, K., Wadhwa, P. D., Laraia, B. A., Adler, N. E., & Epel, E. S. (2017). Effects of pre- and postnatal maternal stress on infant temperament and autonomic nervous system reactivity and regulation in a diverse, low-income population. *Development and Psychopathology*, 29, 1553–1571. doi:10.1017/S0954579417001237
- Buss, C., Davis, E. P., Muftuler, L. T., Head, K., & Sandman, C. A. (2010). High pregnancy anxiety during mid-gestation is associated with decreased gray matter density in 6–9-year-old children. *Psychoneuroendocrinology*, 35, 141–153. doi:10.1016/j.psyneuen.2009.07.010
- Charil, A., Laplante, D. P., Vaillancourt, C., & King, S. (2010). Prenatal stress and brain development. *Brain Research Reviews*, 65, 56–79.
- Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior*, 24, 385–396.
- Committee on Obstetric Practice, the American Institute of Ultrasound in Medicine, and the Society for Maternal-Fetal Medicine. (2017). Committee opinion No 700: Methods for estimating the due date. *Obstetrics and Gynecology*, 129, 150–154.
- Curran, M. M., Sandman, C. A., Davis, E. P., Glynn, L. M., & Baram, T. Z. (2017). Abnormal dendritic maturation of developing cortical neurons exposed to corticotropin releasing hormone (CRH): Insights into effects of prenatal adversity? *PLoS One*, 12, e0180311. doi:10.1371/journal.pone.0180311
- D'Anna-Hernandez, K., & Rivera, K. D. (2014). Understanding and alleviating cultural stressors and health disparities in the perinatal outcomes of Mexican-American women. *Zero to Three*, 34, 37–45.
- Davis, E. P., Glynn, L. M., Schetter, C. D., Hobel, C. J., Chic-DeMet, A., & Sandman, C. A. (2007). Prenatal exposure to maternal depression and cortisol influences infant temperament. *Journal of the American Academy of Child Adolescent Psychiatry*, 46, 737–746.
- Davis, E. P., Hankin, B. L., Glynn, L. M., Head, K., Kim, D. J., & Sandman, C. A. (2019). Prenatal maternal stress, child cortical thickness, and adolescent depressive symptoms. *Child Development*. doi:10.1111/cdev.13252
- Davis, E. P., Hankin, B. L., Swales, D. A., & Hoffman, M. C. (2018). An experimental test of the fetal programming hypothesis: Can we reduce child ontogenetic vulnerability to psychopathology by decreasing maternal depression? *Development and Psychopathology*, 30, 787–806. doi:10.1017/S0954579418000470

- Davis, E. P., & Narayan, A. J. (2020). Pregnancy as a period of risk, adaptation, and resilience for mothers and infants. *Development and Psychopathology*, 32(5), 1625–1639. doi:10.1017/S0954579420001121
- Davis, E. P., & Sandman, C. A. (2010). The timing of prenatal exposure to maternal cortisol and psychosocial stress is associated with human infant cognitive development. *Child Development*, 81, 131–148. doi:10.1111/j.1467-8624.2009.01385.x
- Davis, E. P., & Sandman, C. A. (2012). Prenatal psychobiological predictors of anxiety risk in preadolescent children. *Psychoneuroendocrinology*, 37, 1224–1233.
- Davis, E. P., Stout, S. A., Molet, J., Vegetabile, B., Glynn, L. M., Sandman, C. A., Heins, K., Stern, H., & Baram, T. Z. (2017). Exposure to unpredictable maternal sensory signals influences cognitive development across species. *Proceedings of the National Academy of Sciences*, 114, 10390–10395. doi:10.1073/pnas.1703444114
- Deans, C. L. (2018). Maternal sensitivity, its relationship with child outcomes, and interventions that address it: A systematic literature review. *Early Child Development and Care*, 1–24. doi:10.1080/03004430.2018.1465415
- Deary, I. J. (2001). Human intelligence differences: A recent history. *Trends in Cognitive Sciences*, 5, 127–130. doi:10.1016/S1364-6613(00)01621-1
- Demers, C. H., Aran, O., Glynn, L. M., & Davis, E. P. (2021). Prenatal programming of neurodevelopment: Imaging and structural changes. In A. Wazana, T. Oberlander, & E. Szekel (Eds.), *Prenatal stress and child development* (pp. 193–242). Cham, Switzerland: Springer.
- Doyle, C., Werner, E., Feng, T., Lee, S., Altemus, M., Isler, J. R., & Monk, C. (2015). Pregnancy distress gets under fetal skin: Maternal ambulatory assessment & sex differences in prenatal development. *Developmental Psychobiology*, 57, 607–625. doi:10.1002/dev.21317
- Eshel, N., Daelmans, B., Mello, M. C. D., & Martines, J. (2006). Responsive parenting: Interventions and outcomes. *Bulletin of the World Health Organization*, 84, 991–998.
- Falah-Hassani, K., Shiri, R., & Dennis, C. L. (2016). Prevalence and risk factors for comorbid postpartum depressive symptomatology and anxiety. *Journal of Affective Disorders*, 198, 142–147. doi:10.1016/j.jad.2016.03.010
- Fan, A., Buka, S., Kosik, R. O., Chen, Y. S., Wang, S. J., & Eaton, W. W. (2014). Association between maternal behavior in infancy and adult mental health: A 30-year prospective study. *Comprehensive Psychiatry*, 55, 283–289.
- Farrell, A. K., Waters, T. E. A., Young, E. S., Englund, M. M., Carlson, E. E., Roisman, G. I., & Simpson, J. A. (2019). Early maternal sensitivity, attachment security in young adulthood, and cardiometabolic risk at midlife. *Attachment & Human Development*, 21, 70–86. doi:10.1080/14616734.2018.1541517
- Feldman, R. (2007). Parent–infant synchrony and the construction of shared timing: physiological precursors, developmental outcomes, and risk conditions. *Journal of Child Psychology and Psychiatry*, 48, 329–354. doi:10.1111/j.1469-7610.2006.01701.x
- Francis, D., Diorio, J., Liu, D., & Meaney, M. J. (1999). Nongenomic transmission across generations of maternal behavior and stress responses in the rat. *Science*, 286, 1155–1158.
- Gee, D. G. (2016). Sensitive periods of emotion regulation: Influences of parental care on frontoamygdala circuitry and plasticity. In H. J. V. Rutherford & L. C. Mayes (Eds.), *Maternal brain plasticity: Preclinical and human research and implications for intervention. New directions for child and adolescent development* (Vol. 153, pp. 87–110). doi: wiley.com/10.1002/cad.20166
- Gilmore, J., Knickmeyer, R., & Gao, W. (2018). Imaging structural and functional brain development in early childhood. *Nature Reviews Neuroscience*, 19, 123–137.
- Glynn, L. M., Davis, E. P., Sandman, C. A., & Goldberg, W. A. (2016). Gestational hormone profiles predict human maternal behavior at 1-year postpartum. *Hormones and Behavior*, 85, 19–25. doi:10.1016/j.yhbeh.2016.07.002
- Glynn, L. M., Howland, M., Sandman, C. A., Davis, E. P., Phelan, M., Baram, T. Z., & Stern, H. (2018). Prenatal maternal mood patterns predict child temperament and adolescent mental health. *Journal of Affective Disorders*, 228, 83–90.
- Granger, S. J., Glynn, L. M., Sandman, C. A., Small, S. L., Obenaus, A., Keator, D. B., ... Davis, E. P. (2021). Aberrant maturation of the uncinate fasciculus follows exposure to unpredictable patterns of maternal signals. *Journal of Neuroscience*, 41(6), 1242–1250. doi:10.1523/JNEUROSCI.0374-20.2020
- Grant, K. A., McMahon, C., Reilly, N., & Austin, M. P. (2010a). Maternal sensitivity moderates the impact of prenatal anxiety disorder on infant responses to the still-face procedure. *Infant Behavior and Development*, 33, 453–462.
- Grant, K. A., McMahon, C., Reilly, N., & Austin, M. P. (2010b). Maternal sensitivity moderates the impact of prenatal anxiety disorder on infant mental development. *Early Human Development*, 86, 551–556. doi:10.1016/j.earlhumdev.2010.07.004
- Hobel, C. J. (1982). Identification of the patient at risk. In R. J. Bolognese, R. H. Schwarz, & J. Schneider (Eds.), *Perinatal medicine: Management of the high risk fetus and neonate*. Baltimore, MD: Williams & Wilkins.
- Howland, M. A., Sandman, C. A., Davis, E. P., Stern, H. S., Phelan, M., Baram, T. Z., & Glynn, L. M. (2020). Prenatal maternal mood entropy is associated with child neurodevelopment. *Emotion*. doi:10.1037/emo0000726
- Kaplan, L. A., Evans, L., & Monk, C. (2008). Effects of mothers' prenatal psychiatric status and postnatal caregiving on infant biobehavioral regulation: Can prenatal programming be modified? *Early Human Development*, 84, 249–256. doi:10.1016/j.earlhumdev.2007.06.004
- Kingston, D., Tough, S., & Whitfield, H. (2012). Prenatal and postpartum maternal psychological distress and infant development: A systematic review. *Child Psychiatry and Human Development*, 43, 683–714.
- Knickmeyer, R., Gouttard, S., Kang, C., Evans, D., Wilber, K., Smith, J. K., Hamer, R. M., Lin, W., Gerig, G., & Gilmore, J. (2008). A structural MRI study of human brain development from birth to 2 years. *Journal of Neuroscience*, 28, 12176–12181.
- Kok, R., Thijssen, S., Bakermans-Kranenburg, M. J., Jaddoe, V. W. V., Verhulst, F. C., White, T., van IJzendoorn, M. H., & Tiemeier, H. (2015). Normal variation in early parental sensitivity predicts child structural brain development. *Journal of the American Academy of Child & Adolescent Psychiatry*, 54, 824–831. doi:10.1016/j.jaac.2015.07.009
- Korja, R., Nolvi, S., Grant, K. A., & McMahon, C. (2017). The relations between maternal prenatal anxiety or stress and child's early negative reactivity or self-regulation: A systematic review. *Child Psychiatry & Human Development*, 48, 851–869. doi:10.1007/s10578-017-0709-0
- Krueger, R. F., & Markon, K. E. (2006). Reinterpreting comorbidity: A model-based approach to understanding and classifying psychopathology. *Annual Review of Clinical Psychology*, 2, 111–133. doi:10.1146/annurev.clinpsy.2.022305.095213
- Lee, A. M., Lam, S. K., Sze Mun Lau, S., Chong, C., Chui, H., & Fong, D. (2007). Prevalence, course, and risk factors for antenatal anxiety and depression. *Obstetrics and Gynecology*, 110, 1102–1112.
- Lemaire, V., Lamarque, S., Le Moal, M., Piazza, P.-V., & Abrous, D. N. (2006). Postnatal stimulation of the pups counteracts prenatal stress-induced deficits in hippocampal neurogenesis. *Biological Psychiatry*, 59, 786–792. doi:10.1016/j.biopsych.2005.11.009
- Liu, D., Diorio, J., Day, J. C., Francis, D. D., & Meaney, M. J. (2000). Maternal care, hippocampal synaptogenesis and cognitive development in rats. *Nature Neuroscience*, 3, 799.
- Luby, J. L., Barch, D., Whalen, D., Tillman, R., & Belden, A. (2017). Association between early life adversity and risk for poor emotional and physical health in adolescence: A putative mechanistic neurodevelopmental pathway. *JAMA Pediatrics*, 171, 1168–1175.
- Madigan, S., Oatley, H., Racine, N., Fearon, R. M. P., Schumacher, L., Akbari, E., Cooke, J. E., & Tarabulsy, G. M. (2018). A meta-analysis of maternal prenatal depression and anxiety on child socioemotional development. *Journal of the American Academy of Child & Adolescent Psychiatry*, 57, 645–657.e8. doi:10.1016/j.jaac.2018.06.012
- Mahrer, N., Ramos, I., Guardino, C., Davis, E., Ramey, S., Shalowitz, M., & Schetter, C. (2019). Pregnancy anxiety in expectant mothers predicts offspring negative affect: The moderating role of acculturation. *Early Human Development*, 141, 104932. doi:10.1016/j.earlhumdev.2019.104932
- Malmberg, L. E., Lewis, S., West, A., Murray, E., Sylva, K., & Stein, A. (2016). The influence of mothers' and fathers' sensitivity in the first year of life on children's cognitive outcomes at 18 and 36 months. *Child: Care, Health and Development*, 42, 1–7. doi:10.1111/cch.12294
- NICHD Early Child Care Research Network. (1997). The effects of infant child care on infant-mother attachment security: Results of the NICHD study of early child care. *Child Development*, 68, 860–879. doi:10.2307/1132038

- NICHD Early Child Care Research Network. (1999). Child care and mother-child interaction in the first three years of life. *Developmental Psychology*, 35, 1399–1413.
- NICHD Early Child Care Research Network. (2001). Nonmaternal care and family factors in early development: An overview of the NICHD study of early child care. *Journal of Applied Developmental Psychology*, 22, 457–492. doi:10.1016/S0193-3973(01)00092-2
- Nillni, Y. I., Mehralzade, A., Mayer, L., & Milanovic, S. (2018). Treatment of depression, anxiety, and trauma-related disorders during the perinatal period: A systematic review. *Clinical Psychology Review*, 66, 136–148. doi:10.1016/j.cpr.2018.06.004
- Polanska, K., Krol, A., Merez-Kot, D., Jurewicz, J., Makowiec-Dabrowska, T., Chiarotti, F., Calamandrei, G., & Hanke, W. (2017). Maternal stress during pregnancy and neurodevelopmental outcomes of children during the first 2 years of life. *Journal of Paediatrics and Child Health*, 53, 263–270. doi:10.1111/jpc.13422
- Putnam, S. P., Gartstein, M. A., & Rothbart, M. K. (2006). Measurement of fine-grained aspects of toddler temperament: The early childhood behavior questionnaire. *Infant Behavior & Development*, 29, 386–401. doi:10.1016/j.infbeh.2006.01.004
- Raineki, C., Lucion, A., & Weinberg, J. (2014). Neonatal handling: An overview of the positive and negative effects. *Developmental Psychobiology*, 56, 1613–1625.
- Rao, H., Betancourt, L., Giannetta, J. M., Brodsky, N. L., Korczykowski, M., Avants, B. B., Gee, J. C., Wang, J., Hurt, H., Detre, J. A., & Farah, M. J. (2010). Early parental care is important for hippocampal maturation: Evidence from brain morphology in humans. *NeuroImage*, 49, 1144–1150. doi:10.1016/j.neuroimage.2009.07.003
- Rosand, G. B., Slinning, K., Eberhard-Gran, M., Røysamb, E., & Tambs, K. (2011). Partner relationship satisfaction and maternal emotional distress in early pregnancy. *BMC Public Health*, 11, 161. doi:10.1186/1471-2458-11-161
- Sandman, C. A., Buss, C., Head, K., & Davis, E. P. (2015). Fetal exposure to maternal depressive symptoms is associated with cortical thickness in late childhood. *Biological Psychiatry*, 77, 324–334. doi:10.1016/j.biopsych.2014.06.025
- Sandman, C. A., Class, Q. A., Glynn, L. M., & Davis, E. P. (2015). Neurobehavioral disorders and developmental origins of health and disease. In C. S. Rosenfeld (Ed.), *The epigenome and developmental origins of health and disease* (pp. 235–266). Academic Press/Elsevier.
- Sandman, C. A., Curran, M. M., Davis, E. P., Glynn, L. M., Head, K., & Baram, T. Z. (2018). Cortical thinning and neuropsychiatric outcomes in children exposed to prenatal adversity: A role for placental CRH? *American Journal of Psychiatry*, 175, 471–479. doi:10.1176/appi.ajp.2017.16121433
- Sandman, C. A., & Davis, E. P. (2010). Gestational stress influences cognition and behavior. *Future Neurology*, 5, 675–690. doi:10.2217/fnl.10.35
- Sandman, C. A., Glynn, L. M., Davis, E. P., Kisilevsky, B. S., & Reissland, N. (2016). Neurobehavioral consequences of fetal exposure to gestational stress. In *Fetal development: Research on brain and behavior, environmental influences and emerging technologies* (pp. 229–265). Springer.
- Santor, D. A., & Coyne, J. C. (1997). Shortening the CES-d to improve its ability to detect cases of depression. *Psychological Assessment*, 9, 233–243.
- Schechter, J. C., Brennan, P. A., Smith, A. K., Stowe, Z. N., Newport, D. J., & Johnson, K. C. (2017). Maternal prenatal psychological distress and pre-school cognitive functioning: The protective role of positive parental engagement. *Journal of Abnormal Child Psychology*, 45, 249–260.
- Schuurmans, C., & Kurrasch, D. (2013). Neurodevelopmental consequences of maternal distress: What do we really know? *Clinical Genetics*, 83, 108–117. doi:10.1111/cge.12049
- Sharp, H., Hill, J., Hellier, J., & Pickles, A. (2015). Maternal antenatal anxiety, postnatal stroking and emotional problems in children: Outcomes predicted from pre- and postnatal programming hypotheses. *Psychological Medicine*, 45, 269–283.
- Sharp, H., Pickles, A., Meaney, M., Marshall, K., Tibu, F., & Hill, J. (2012). Frequency of infant stroking reported by mothers moderates the effect of prenatal depression on infant behavioural and physiological outcomes. *PLoS One*, 7(10), e45446. <https://doi.org/10.1371/journal.pone.0045446>.
- Spielberger, C. (1983). *Manual for the state-trait anxiety inventory*. Palo Alto, CA: Consulting Psychologists Press, Inc.
- Spinrad, T. L., & Stifter, C. A. (2002). Maternal sensitivity and infant emotional reactivity: Concurrent and longitudinal relations. *Marriage & Family Review*, 34, 243–263. doi:10.1300/J002v34n03_03
- Van den Bergh, B. R. H., Mulder, E. J. H., Mennes, M., & Glover, V. (2005). Antenatal maternal anxiety and stress and the neurobehavioural development of the fetus and child: Links and possible mechanisms. A review. *Neuroscience & Biobehavioral Reviews*, 29, 237–258. doi:10.1016/j.neubiorev.2004.10.007
- Van den Bergh, B. R. H., Van Den Heuvel, M., Lahti, M., Braeken, M., Rooij, S., Entringer, S., Hoyer, D., Roseboom, T., Raikonen, K., King, S., & Schwab, M. (2017). Prenatal developmental origins of behavior and mental health: The influence of maternal stress in pregnancy. *Neuroscience & Biobehavioral Reviews*. <https://www.ncbi.nlm.nih.gov/pubmed/28757456>
- Vehmeijer, F. O. L., Guxens, M., Duijts, L., & Marroun, H. E. (2019). Maternal psychological distress during pregnancy and childhood health outcomes: A narrative review. *Journal of Developmental Origins of Health and Disease*, 10, 274–285. doi:10.1017/S2040174418000557
- Wakshlak, A., & Weinstock, W. (1990). Neonatal handling reverses behavioral abnormalities induced in rats by prenatal stress. *Physiology & Behavior*, 48, 289–292. doi:10.1016/0031-9384(90)90315-U
- Wang, Q., Zhang, H., Wee, C.-Y., Lee, A., Poh, J. S., Chong, Y.-S., Tan, K. H., Gluckman, P. D., Yap, F., Fortier, M. V., Rifkin-Graboi, A., & Qiu, A. (2019). Maternal sensitivity predicts anterior hippocampal functional networks in early childhood. *Brain Structure and Function*, 224, 1885–1895. doi:10.1007/s00429-019-01882-0
- Wechsler, D., Coalson, D. L., & Raiford, S. E. (1997). *WAIS-III: Wechsler adult intelligence scale*. San Antonio, TX: Psychological Corporation.
- Wu, Y., Lu, Y.-C., Jacobs, M., Pradhan, S., Kapse, K., Zhao, L., Niforatos-Andescavage, N., Vezina, G., du Plessis, A. J., & Limperopoulos, C. (2020). Association of prenatal maternal psychological distress with fetal brain growth, metabolism, and cortical maturation. *JAMA Network Open*, 3, e1919940–e1919940. doi:10.1001/jamanetworkopen.2019.19940