MEASURING INFANT EMOTION REGULATION WITHIN THE STILL FACE PROCEDURE: A NOVEL APPROACH TO ASSESSING REGULATION DEVELOPMENT IN THE CONTEXT OF PRENATAL MATERNAL STRESS

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ABSTRACT

A growing body of literature demonstrates that prenatal maternal stress (PNMS) can influence infant and child outcomes across developmental domains. The timing of PNMS exposure may be particularly important, and *late* PNMS has predicted poorer emotion regulation outcomes in infancy and childhood. Behavioral indicators and measures of emotion regulation have differed widely in the existing PNMS literature, however. Additionally, despite the well-established use of the Still Face Procedure (SFP) to assess emotion regulation and infant-maternal interactions in the regulatory process, it has not been used within the context of PNMS. In the current research, the SFP was used in conjunction with a novel measurement of infant and maternal behaviors developed to assess infant emotion regulation in the context of maternal behavior *and* PNMS. A total of 100 infant-mother dyads were observed and coded during three, two-minute play episodes and two, two-minute Still Face episodes of the SFP via video recording. Both reinforcing (e.g., soothing/comforting) and non-reinforcing (e.g., punitive) maternal behaviors predicted numerous infant regulatory behaviors within the context of mostly early PNMS. In addition, late PNMS was found to differentially affect two regulatory behaviors based on infant sex.

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INTRODUCTION

Prenatal experiences shape and program fetal development, potentially having life-long consequences for the psychological and physiological health of the child. A large body of animal and human research has consistently found that prenatal maternal stress (PNMS) leads to an increase in the likelihood of adverse birth outcomes, such as low birthweight and preterm birth, as well as poorer developmental outcomes in infancy, childhood and adolescence (Dunkel Schetter & Tanner, 2015; Graignic-Philippe et al., 2014; Hilmert et al., 2016; Kingston & Tough, 2014; Stanevaa et al., 2015). Although birth outcomes account for a part of the variance in developmental outcomes, PNMS is predictive of poorer developmental outcomes, such as cognitive and motor delay in childhood, independent of birth outcomes (Moss et al., 2017). Thus, normal-weighted, full-term infants exposed to PNMS have a significantly higher likelihood of poorer developmental outcomes.

One relatively unexplored domain of development with ties to PNMS is infant emotion regulation. How an individual manages and copes with emotional experiences has been associated with developmental outcomes such as poorer social-emotional skills, increased problem behaviors and poorer mental health outcomes in adolescence and adulthood (Hermann et al., 2009). A better understanding of how emotion regulation skills and tendencies develop may help us better predict and prevent adverse developmental and health outcomes, as well as guide early interventions when needed.

Although mounting evidence suggests that PNMS predicts emotion regulation in early childhood (e.g., Yong Ping et al., 2015), the measures used thus far to assess emotion regulation have varied widely, including measures of cortisol, temperament, and crying/fussing behavior. Although these various indicators may help understand stress responses by the infant, a more comprehensive measure that incorporates multiple behavioral indicators to specifically target emotion regulation in infancy is needed to identify specific components of emotion regulation linked to PNMS. Furthermore, a more comprehensive measure of infant emotion regulation should explore the multi-faceted context (e.g., maternal behaviors, sex) in which PNMS may alter subsequent emotion regulation across childhood.

A continued understanding of child emotion regulation outcomes following PNMS helps guide future research directions aiming to identify underlying physiological mechanisms linking PNMS to emotion-related development. One study identified a specific gene variant that mediated the relationship between PNMS and emotion-related outcomes (Hill et al., 2013), and research links PNMS to functional disruptions in 1) the hypothalamic-pituitary-adrenal (HPA) axis (McGowan & Matthews, 2018), 2) brain regions such as the amygdala, hippocampus, and paraventricular nucleus of the hypothalamus (Levitt, Lindsay, Holmes, & Seckl, 1996), and 3) immune and vascular systems (Beijers et al., 2014). Precisely what these disruptions are and how they occur, however, remains unclear. Further exploration of emotion regulation within a multi-faceted framework is needed to identify physiological underpinnings within the seemingly complex association between PNMS and emotion-related outcomes.

Prenatal Maternal Stress and Childhood Emotion Regulation

In order to examine associations between PNMS and offspring emotion regulation, this project took a three-step approach. First, previous studies that have measured emotion regulation in infants and toddlers were reviewed to adapt and develop a measure of infant emotion regulation for the present study. Both infant and maternal behaviors were included, along with considerations for utilizing the Still Face Procedure (SFP) to assess regulation development.

Second, the timing of PNMS and corresponding regulatory outcomes were explored. Third, associations between infant sex and emotion regulatory behaviors were considered.

Defining Emotion Regulation

Emotion regulation, often referred to as stress regulation in early development (Poggi Davis et al., 2011) includes both automatic and controlled processes (Ochsner & Gross, 2005), and involves a child's attempts to manage and cope with emotional experiences by influencing internal arousal and the external environment. Physiological, behavioral, and cognitive processes regulate the emotional experience, and these mechanisms change and adapt with the developing person (Kopp, 1989). Thus, brain development dictates that "emotion regulation" is an evolving construct beginning early in development and continuing throughout the lifespan.

Emotion Regulation Measures and the Still Face Procedure

In order to measure infant emotion regulation researchers have utilized an emotion-provoking protocol. The Still Face Procedure (SFP) is a procedure that explores the notion that infants are aware of their social world and are active participants in it (Tronick et al., 1979). In this procedure, infants are observed with their caregiver during 1) play with the caregiver (baseline), 2) the 'still face' in which the caregiver no longer interacts with the child but instead is unresponsive, and 3) a reunion where the caregiver returns to her usual social interactions with the child.

The Infant Regulatory Scoring System (IRSS) was developed to assess infant behavior in response to the SFP. The IRSS is completed by carefully inspecting (in 1-sec. intervals) video recordings of infants responding to the SFP. The IRSS includes measures of infant gaze, vocalizations, gestures, self-comfort, distance, and autonomic indicators. This measure provides a framework for researchers to draw upon when assessing infant behavior in the SFP (Tronick & Weinberg, 1990; Weinberg & Tronick, 1994).

Findings from the SFP and IRSS have demonstrated that infants actively respond to their social world by using both internal and external cues in an interactive process. Infant responses include such behaviors as increased gaze aversion, decreased smiling and increased negative affect (e.g., Toda & Fogel, 1993). Infant responses within the SFP predict future attachment quality and behavior problems (Braungart-Rieker et al., 2001; Moore et al., 2001). Despite the established validity of the SFP and IRSS to measure infant regulatory behaviors, this paradigm had yet been used to assess infants in the context of PNMS exposure.

While the IRSS assesses the presence or absence of an extensive list of behavioral indicators of emotion regulation, it is not designed to consider the extent to which infant reengagement and maternal effort to engage during reunion episodes occurs. Because infant emotion regulation depends on many factors, including the quality of parental caregiving behaviors, maternal behaviors may be important to consider in assessing infant emotion regulation. Maternal sensitivity is a mother's ability to identify her infant's behavioral cues accurately and effectively respond in an appropriate and loving manner. This maternal caregiving behavior has been associated with better child emotion regulation (Crockenberg & Leerkes, 2000; de Wolff & van Ijzendoorn, 1997). The inclusion of such items in an assessment of infant emotion regulation would provide a more detailed account of behaviors related to emotion regulatory development and the moderating influence of the mother's behaviors.

In this project, the IRSS was updated and adapted to the Infant Emotion Regulation for Still Face Measure (IER-SFM). The IER-SFM was designed to code infant emotion regulation in 20-second epochs of the SFP. In contrast to the IRSS, the IER-SFM measure included dimensional measures of infant and maternal engagement behaviors during the reunion episodes, a time when the infant may be working hard to regulate emotions and to recapture the positive attention of the caregiver. See the Appendix for 1) the comprehensive emotion regulation measure, including infant presence/absence behaviors, infant dimensional behaviors, and maternal behaviors, and 2) descriptions of coding criteria for both the infant dimensional and maternal effort to engage behaviors that were created and used in the present research.

A Dimensional Infant Reengagement Measure

The time following maternal unavailability during the SFP, or the “still face” portion of the protocol, is a period of ‘reengagement’ between mother and infant. During this “reunion” time following maternal unavailability and potentially high stress (during the “still face” episode), the infant attempts to reconcile the events that just occurred using internal and external regulation strategies (Calkins & Fox, 2002; Fox & Calkins, 2003). During this time, infants and young children rely on the caretaker’s behaviors and interactions to aid the regulatory process (Calkins & Hill, 2007).

The dimensional coding system for infant reengagement in the present study was based on the Infant Reengagement Scale (Kogan & Carter, 1996). The Infant Reengagement Scale (Kogan & Carter, 1996) is based on the premise that infant responsivity and affective expressions are directly influenced by maternal responsiveness (Brazelton et al., 1974). The scale includes measures of *avoidance* (e.g., infant gaze aversion or turning away from mother), *resistance* (e.g., infant’s persistent fussing or squirming), and *attention seeking/maintenance* (infant initiative and responsiveness to mother). Findings using the Infant Reengagement Scale indicate that infants are more responsive, less avoidant, and less resistant during the reunion episode when mothers are higher in maternal sensitivity (Kogan & Carter, 1996). It has not been known if these reengagement-related behaviors are associated with PNMS or the timing of this stress.

The Timing of Prenatal Maternal Stress and Child Emotion Regulation

Stress can occur at any time during pregnancy. Research has demonstrated that the *timing* of PNMS determines which developmental outcomes may be affected. This is likely due to the progression of neurological development during gestation, which includes early neurogenesis and later synaptic rearrangement. For instance, early stress (e.g., first trimester) has been most predictive of adverse birth outcomes such as low birthweight and shortened gestation (Glynn et al., 2001). Earlier stress also predicted poorer cognitive development in several studies, such as decreased full and verbal IQ (Laplante et al., 2008) and general cognitive development as measured by the Bayley Scales of Infant Development (III) (Moss et al., 2017).

In contrast, a number of studies have found that PNMS that occurs *later* in gestation (i.e., during the second and third trimester) predicts impaired emotion regulation processes in infants and toddlers. These studies have used various behavioral and physiological indicators of emotion regulation. Such indicators have included personal-social skills, crying and fussing behavior, fear reactivity, negative emotionality, altered cortisol response to the heel-stick procedure (Bergman et al., 2010; Poggi Davis, Snidman, et al., 2004; Poggi Davis, Glynn, et al., 2011; Simcock et al., 2017; Werner et al., 2007; Wurmser et al., 2006;), and a more difficult overall temperament (Austin et al., 2005; Baibazarova et al., 2013; McMahon et al., 2013). In a 2010 study, Poggi Davis and Sandman measured maternal cortisol during pregnancy, an indicator of PNMS, and infant physiological and behavioral responses to stress. The key finding was an *increased infant cortisol response* to the hospital heel-stick blood draw in infants who were exposed to higher levels of maternal cortisol during the late second and third trimesters of pregnancy. These findings indicate that infants' physiological stress responses may be altered by late PNMS but it is not clear how this relates to infant emotion regulation behaviors.

Emotion-related processes, particularly those related to stress appear to be more vulnerable to later (i.e., second and third trimester) PNMS, and indicators of poorer emotion regulation in the first three years are predicted by later prenatal stress (Poggi Davis & Sandman, 2010). This is in contrast to a series of studies suggesting that earlier stress has, in general, a greater impact on maternal mental health and pregnancy outcomes (Glynn, et al., 2001; Hilmert et al., 2016) believed to be due to a progressively dampened maternal response to stress. Given that emotion regulation involves both cognitive and emotion-related processes, it is plausible that maternal stress at multiple time points across pregnancy may affect particular aspects of emotion regulation development. In the present study, associations between infant emotion regulation responses to the SFP and measures of PNMS taken in early and late pregnancy were considered.

Sex Differences in Infant Emotion Regulation

Although inconsistent, SFP research has found that males may have more difficulty with emotion regulation during the SFP (Weinberg et al., 1999). Within the PNMS literature, research indicates that PNMS differentially influences male and female offspring (Sutherland & Brunwasser, 2018; Van den Bergh et al., 2020). Both sexes are susceptible to alterations in hypothalamic-pituitary-adrenal (HPA) axis and autonomic nervous system development, potentially influencing emotion regulation development. Research on stress reactivity indicates that females may be more susceptible to alterations in physiology and behavior, leading to increased fear and anxiety through at least adolescence (Sandman et al., 2013). Therefore, it is possible that female offspring emotion regulation is more susceptible to the influence of PNMS, which may be evident in responses to the SFP.

The Current Study

Multiple measures of infant emotion regulation and indicators of maternal stress (e.g., Perceived Stress Scale) have demonstrated that infants exposed to prenatal maternal stress (PNMS) are more likely to have poorer emotion regulation-related outcomes. The current literature relies on different measures of emotion regulation, however, and a more comprehensive study of the specific components and complexities of emotion regulation in early childhood following PNMS is needed.

The current research aimed to address this gap in the literature by adapting, creating, and utilizing a more comprehensive measure of infant emotion regulation to identify the key components of infant emotion regulation affected by PNMS. This measure included the presence/absence of infant regulatory behaviors, dimensional infant reengagement behaviors, and maternal effort to engage with the child. Next, the multi-faceted nature of the PNMS-emotion regulation relationship was considered by examining how the 32 behaviors across five episodes were associated with PNMS timing (early vs. late), and infant sex. It was hypothesized that infant emotion regulation would be generally influenced by late PNMS and that female infants may exhibit a stronger influence of PNMS on emotion regulation.

METHODS

Participants

Pregnant mothers were recruited for the Pregnancy Experiences and Infant Development Study (PEIDS) study at Chapman University in 2012-2013 for prenatal maternal assessment, and 244 mother-child dyads continue to be followed longitudinally to date. The current study explores a 100-dyad subset of the mother-child data collected (57% male infants) prenatally and 6-months postpartum. Data includes prenatal and postpartum maternal data, and infant data at 6 months old. Because maternal and child data were collected as approved by the Chapman University IRB, no further IRB approval was sought for the current study.

Procedure

The current analyses involve a subset of participants in the PEIDS study at Chapman University. All participants in the present study provided prenatal maternal demographics information (age, parity, ethnicity, household income), and prenatal and postpartum maternal stress data. In addition, all infants and mothers included in the present analyses participated in a 6-month postpartum Still Face Procedure (SFP), described below. Infant birth weight was extracted from medical charts.

For the current study, maternal stress was measured at three timepoints. Measures of maternal perceived stress, state anxiety, and depression that were collected at 15 and 35 weeks gestation assessed early and late PNMS, respectively. Maternal perceived stress, state anxiety, and depression were also assessed at 6 months postpartum, and these measures were used to control for potential postpartum maternal stress influences on the outcomes of interest (i.e., infant emotion regulation).

The SFP was conducted at 6 months postpartum at Chapman University, concurrent with the maternal postpartum stress measures. The SFP with each dyad was video-recorded and access was granted for this study to all videos in full. The SFP involved five total 2-minute successive episodes, including 1) a baseline 2-minute playtime for mother and infant, 2) 2 minutes of Still Face, 3) 2 minutes of play ("reunion" time for mother and child), 4) 2 minutes of Still Face, and 5) a last 2 minutes of play (a second "reunion" time for mother and child). For playtime episodes, mother and child sat in chairs facing each other, and mothers were told to play with their infants during this time signaled by the experimenter announcing "playtime" over the loudspeaker. During Still Face episodes, mothers were told to find a spot to look at above the infant (and not at the infant), while not responding to the infant in any way. Still Face episodes were signaled by the experimenter announcing "still face" over the loudspeaker.

Measures

Prenatal Maternal Stress

Mothers completed multiple stress measures, including the 10-item version of the Perceived Stress Scale (PSS; Cohen et al., 1983), the State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983), and the 20-item Center for Epidemiologic Studies—Depression Scale (CES-D; Radloff, 1977; Santor & Coyne, 1997). The PSS, STAI, and CES-D are all considered to be valid, reliable, and widely used stress measures in both pregnant and general populations (Glynn et al., 2004; Marcus et al., 2003). All three measures were completed by mothers at 15 and 35 weeks of pregnancy.

Because these three measures were highly correlated (*ps* < .01), z-scores were created for each and a composite 'Prenatal Maternal Distress Index' was created for primary analyses. The creation of a composite index for these three scales is consistent with previous prenatal literature (Peterson et al., 2020).

Postpartum Maternal Distress

Similar to the Prenatal Maternal Distress Index, a Postpartum Maternal Distress Index was computed using the z-scores of PSS, STAI, and CES-D measures collected 6-months postpartum.

Infant Emotion Regulation

In collaboration with Chapman University, a novel infant emotion regulation measure was developed to be used with the SFP. The Infant Emotion Regulation during Still Face Measure (IER-SFM) included thirty-two infant and maternal emotion regulation-related behaviors identified from literature. The presence/absence measures of infant regulation strategies were adapted from the Infant Regulatory Scoring System (Tronick & Weinberg, 1990; Weinberg & Tronick, 1994), two dimensional measures of infant reengagement were based on the Infant Reengagement Scale (Conradt & Ablow, 2010; Kogan & Carter, 1996), and eight novel measures of maternal effort to engage the infant were selected by the research team. The IER-SFM was completed for each mother-infant dyad video of the SFP.

The presence/absence of infant behaviors was observed and recorded at 20-second intervals for all five 2-minute episodes of the SFP (Play 1, Still Face 1, Play 2, Still Face 2, Play 3). The infant dimensional scales of infant responsiveness and infant avoidance/resistance, were used to assess responses to the mother during play episodes (Play 1, Play 2, Play 3). Also, the presence/absence of eight maternal effort to engage behaviors was recorded for each two-minute play episode.

All IER-SFM items are listed in the Appendix. Specific infant presence/absence behaviors included infant gaze (mother's face, mother's body other than face, other item/place of gaze), vocalization (neutral, positive, negative/fussy, crying), smiling behavior, a bid to gain maternal attention, gesture (reaching, leaning forward, kicking), self-comfort (oral-self, oral-other than self or mother, oral-mother, touching-self, self-clasping, rocking), and distance (an effort to get away/escape, arching, pushing/pulling). The dimensional infant measure for infant reengagement included infant responsiveness to the mother and infant avoidance or resistance to her mother during play. Infant responsiveness behaviors included the frequency of the infant's response to his mother's attempt to engage by looking, vocalizing, smiling and/or reaching, whereas infant avoidance/resistance behaviors included the frequency of the infant withdrawing from his mother/mother's attempts to engage by looking away from mother's gaze, turning away, squirming or arching the back. These items were scored on a scale from 0-3 with higher values indicating a greater amount of infant responsiveness or avoidance/resistance behaviors. A 0-3 scale was chosen to align with previous infant reengagement measurement (Kogan & Carter, 1996).

A novel set of maternal behaviors was assessed during play to determine maternal effort to engage. These items were used to explore the role of maternal behaviors in the expression of infant emotion regulation behaviors. Maternal behaviors were recorded for presence or absence within each two-minute play episode, and included maternal soothing/comforting, acknowledging of emotion and engaging behavior, teaching or playing with the infant, punitive behavior (e.g., scolding the infant for being upset), minimizing or denial of the infant's emotion, incorrect or inappropriate responding (which also served as a 'catch-all' category when maternal behavior was odd but did not fall precisely into one category or another), and maternal distress behavior. See the Appendix for all three coding scheme variables/ recording sheets and dimensional descriptions.

The three novel scales (infant emotion regulation presence/absence behavioral scale, infant reengagement dimensional scale, and maternal effort to engage scale) were coded for 100 infant participants, with 17% of the infants also coded by a second researcher. All data points were double entered.

Data Analysis

Based on previous literature (e.g., Hilmert et al., 2008; MacKinnon et al., 2018; Poggi Davis et al., 2011), variables associated with pregnancy and developmental outcomes were included as controls in all regression analyses. These included maternal age, parity, total household income, parental cohabitation, ethnicity, and infant sex and birth weight. In order to focus on *prenatal* maternal stress, analyses involving this variable also controlled for maternal postpartum stress.

Primary analyses involved hierarchical regression analyses in which z-scored covariates were entered in step 1, z-scored predictor variables were entered in step 2, and, when appropriate, interaction variables (e.g., maternal effort x PNMS) were entered in step 3. Significant interactions were further investigated using predicted values plots and simple slopes analyses (Cohen et al., 2002).

RESULTS

Demographics

Demographics are shown in Table 1. Just more than half of mothers self-reported as Hispanic or Latino. Total household income ranged from $2,400 to $540,000 per year. A majority of mothers was cohabitating with the fathers (Table 1).

Table 1

Infant and Maternal Demographic Characteristics (N=100)

Infant Sex, *n(%)*	
Male	57(57.0%)
Female	42(42.0%)
Race, *n(%)*	
*White, European, North African, or Middle Eastern	24(24.0%)
Black or African American	5(5.0%)
Asian	7(7.0%)
Multi-Ethnic	9(9.0%)
Hispanic or Latino	54(54%)
Maternal age, *mean(SD), years*	28.41(5.74)
Household income, *mean(SD)*	61357.85(70666.20)
Cohabitating parents, *n(%)*	
Yes	89(89.0%)
No	10(10.0%)

Aim 1

The first study aim was to develop and implement a novel measure of emotion regulation during a Still Face paradigm. This measure of infant emotion regulation was used to identify key components of infant emotion regulation affected by PNMS (Aim 2). In the current study, the emotion regulation measure included 32 infant and maternal behaviors.

Interrater Reliability

Existing literature (e.g., Messinger et al., 2011; Poggi Davis et al., 2011) suggests that 15% of participants should be coded by two independent coders when using behavioral coding. Of the 100 participants included in the present research, 17% (n=17) were coded by a second researcher from the PEIDS study. Cohen's kappa was calculated to determine percentage of agreement. Interrater reliability was above 89% rater agreement for each set of dual-coded participants, exceeding the 80% 'substantial agreement' benchmark for Cohen's kappa (Landis & Koch, 1977).

Infant Emotion Regulation Scoring

Partial or full discontinuation of episodes by the experimenter and/or mother in the current research was not unusual (65%). Therefore, for dimensional measures the average rating across existing play episodes was computed, and for absent/present behaviors, the proportion (as opposed to sum) of 20-second epochs a behavior was present was computed to best represent the likelihood of a behavior occurring. Three sets of presence/absence behavior means were computed for 1) maternal-infant play episodes, 2) Still Face episodes, and 3) all episodes.

Means and standard deviations are reported for each of the 22 presence/absence infant and maternal behaviors in Table 2. Each mean represents the proportion of 20-second epochs that each behavior occurred in for all play episodes together (Play 1, 2, 3), all Still Face episodes together (Still Face 1, 2), and across all episodes. In addition, sex differences are reported for each behavior in Table 2.

For the two dimensional infant behaviors and eight maternal behaviors, mean ratings and standard deviations are reported in Table 3 for each play episode (Play 1, 2, 3) and the average rating across all play episodes. Also, significant sex differences are reported for each of the 10 behaviors in Table 3.

Table 2

Infant Emotion Regulation Coding: Presence/Absence Behavior in the Still Face Procedure (SFP), reported mean proportion of 20 second epochs a behavior was displayed (SDs)

	Play1	SF1	Play2	SF2	Play3	All Play	All SF	All Total	M/F
Gaze: Mother's face	.87(.21)	.75(.28)	.86(.25)	.76(.29)	.86(.27)	.85(.19)	.75(.27)	.81(.19)	---
Gaze: Mother-other	.64(.35)	.38(.39)	.59(.40)	.42(.42)	.54(.41)	.60(.33)	.40(.39)	.53(.33)	---
Gaze: Other	.78(.29)	.94(.16)	.76(.33)	.94(.16)	.73(.28)	.77(.25)	.94(.16)	.82(.20)	M < F
Vocalization: Neutral	.35(.29)	.47(.37)	.31(.29)	.34(.37)	.31(.28)	.31(.24)	.40(.32)	.33(.25)	---
Vocalization: Positive	.28(.32)	.04(.10)	.25(.32)	.03(.11)	.29(.32)	.26(.27)	.03(.08)	.18(.23)	M > F
Vocalization: Negative/fussy	.24(.32)	.46(.38)	.38(.37)	.54(.39)	.45(.36)	.38(.28)	.52(.34)	.45(.27)	---
Vocalization: Crying	.07(.20)	.14(.29)	.18(.36)	.22(.33)	.17(.30)	.18(.26)	.20(.30)	.20(.27)	---
Expression: Smiling	.54(.36)	.08(.15)	.48(.38)	.09(.20)	.51(.38)	.48(.33)	.07(.15)	.33(.25)	---
Bid to mom	.01(.07)	.24(.28)	.01(.05)	.23(.28)	.02(.13)	.02(.11)	.23(.25)	.10(.16)	---
Gesture: Reaches	.22(.31)	.16(.28)	.21(.31)	.24(.34)	.23(.36)	.25(.31)	.19(.30)	.25(.29)	---
Gesture: Leans forward	.15(.25)	.23(.32)	.15(.28)	.21(.34)	.14(.27)	.19(.26)	.23(.32)	.21(.27)	---
Gesture: Kicking	.40(.38)	.75(.34)	.42(.37)	.80(.33)	.49(.37)	.44(.33)	.78(.31)	.57(.29)	---
(Self-comfort): Oral-self	.22(.32)	.17(.23)	.15(.27)	.15(.21)	.19(.31)	.19(.29)	.17(.21)	.19(.26)	---
(Self-comfort): Oral-other	.04(.13)	.12(.24)	.08(.23)	.15(.27)	.03(.03)	.06(.17)	.13(.23)	.09(.20)	---

Table 2. Infant Emotion Regulation Coding: Presence/Absence Behavior in the Still Face Procedure (SFP), reported mean proportion of 20 second epochs a behavior was displayed (SDs) (continued)

	Play1	SF1	Play2	SF2	Play3	All Play	All SF	All Total	M/F
(Self-comfort): Oral-mom	.05(.17)	.00(.04)	.02(.09)	.00(.00)	.04(.18)	.05(.17)	.00(.02)	.04(.16)	---
(Self-comfort): Touch-self	.13(.22)	.37(.36)	.12(.23)	.31(.34)	.12(.23)	.13(.19)	.35(.32)	.21(.22)	---
(Self-comfort): Self-clasp	.06(.18)	.06(.15)	.03(.11)	.05(.11)	.07(.20)	.05(.15)	.06(.13)	.05(.13)	---
(Self-comfort): Rock	.00(.00)	.00(.00)	.00(.00)	.00(.00)	.00(.00)	.00(.00)	.00(.00)	.00(.00)	---
Distance: Get away/escape	.06(.18)	.16(.26)	.08(.20)	.18(.28)	.09(.18)	.09(.18)	.18(.25)	.13(.20)	---
Distance: Arch	.10(.21)	.20(.28)	.12(.24)	.19(.28)	.11(.21)	.14(.24)	.22(.27)	.18(.24)	---
Distance: Push/pull away	.05(.17)	.04(.16)	.14(.28)	.04(.18)	.09(.19)	.11(.23)	.05(.19)	.10(.23)	---
Mom blocking baby	.22(.35)	.06(.22)	.29(.36)	.06(.22)	.31(.40)	.26(.33)	.06(.21)	.20(.29)	---

[a] All behaviors measured in six 20-second epochs per episode (Play 1, 2, 3; SF 1, 2). [b] M/F significant t-test differences (All Total) between males (M) and females (F) for each behavior, $p < .05$.

Table 3

Infant Emotion Regulation Dimensional Coding: Infant and Maternal Behavior During Play in the Still Face Procedure (SFP), reported means(SDs)

	Play1	Play2	Play3	All Play	M/F
Infant Behavior					
Responsiveness	2.52(.83)	2.19(.93)	2.10(.93)	2.19(.80)	---
Avoidance/Resistance	.71(.87)	1.20(1.04)	1.22(.92)	1.12(.83)	---
Maternal Behavior					
Soothing/Comforting	.95(.22)	.98(.11)	.98(.13)	.96(.16)	---
Acknowledging/Engaging	.47(.50)	.58(.50)	.70(.46)	.57(.40)	---
Caretaking Behavior	.31(.47)	.30(.46)	.33(.47)	.32(.35)	---
Teaching/Playing	.97(.17)	.92(.28)	.97(.18)	.94(.19)	---
Punitive Behavior	.05(.22)	.09(.28)	.03(.18)	.08(.25)	---
Minimizing or Denial	.04(.20)	.06(.24)	.05(.22)	.08(.25)	---
Incorrect/Inappropriate	.06(.25)	.14(.35)	.12(.33)	.10(.25)	---
Distress Behavior	.02(.14)	.07(.26)	.05(.22)	.05(.17)	---

[a] Infant behavior intensity rating (0-3). [b] Maternal behavior presence/absence rating (1,0), means indicate proportion participants exhibiting the behavior during each episode. [c] M/F significant t-test differences (All Play) between males (M) and females (F) for each behavior, $p < .05$.

All but one behavior was observed. Infants did not perform a rocking behavior during the experiment session. All other behaviors showed considerable between-participant variability, suggesting there are significant individual differences in these emotion regulation-related behaviors. Therefore, the measure was deemed appropriate for addressing Aim 2.

Aim 2

The newly developed IER-SFM was used to explore male and female infant regulatory responses to a Still Face Procedure. Analyses considered associations with maternal behavior during play and the influence of early (15 weeks gestation) and late (35 weeks gestation) PNMS. For descriptive purposes, correlations among the predictor variables are presented in Table 4.

Table 4

Correlations Among Predictors

	Early PNMS	Late PNMS	Maternal PPD	Maternal RB	M/F
Early Prenatal Maternal Stress (PNMS)					---
Late Prenatal Maternal Stress (PNMS)	.641**				---
Maternal Postpartum Distress (PPD)	.593**	.606**			---
Maternal Reinforcing Behavior (RB)	-.192	-.235*	-.174		---
Maternal Non-Reinforcing Behavior	.058	.002	.069	-.104	---

*$p < .05$. **$p < .01$.
[a] M/F significant t-test differences between males (M) and females (F), $p < .05$.

Maternal Behavior Indices

Table 5 shows correlations among the eight maternal behaviors. The lack of significant correlations among these items may be due, at least in part, to their low frequency of occurrence. This was especially true for maternal punitive and distress behaviors. To explore the moderating effects of maternal behaviors on infant emotion regulation behaviors during play episodes, the eight maternal behaviors were divided into two maternal behavior indices based on the reinforcing nature of the behaviors. Specifically, the maternal “reinforcing” behavior index included maternal soothing/comforting, acknowledging/engaging, caretaking, and teaching/playing. The maternal “non-reinforcing” behavior index included maternal punitive behavior, minimizing or denial, incorrect/inappropriate responding, and distress behavior. An average score for each index was computed for each dyad. Higher values on these indexes indicated that mom engaged in more reinforcing or non-reinforcing behaviors during play episodes.

Table 5

Maternal Effort to Engage: Correlational Comparisons

	Sooth/ Comf	Ack/ Engag	Care/ Behav	Teach/ Play	Punit Behav	Min/or Denial	Incorr/ Inapp
Acknowledging/Engaging	.211*						
Caretaking Behavior	-.039	-.128					
Teaching/Playing	-.041	-.081	.074				
Punitive Behavior	.080	.064	.080	.107			
Minimizing or Denial	-.331**	-.143	-.059	.031	.144		
Incorrect/Inappropriate	.044	.044	-.022	-.089	.414**	-.010	
Distress Behavior	-.049	.061	.088	-.209*	.192	.189	.063

*p < .05. **p < .01.

Regression Analyses: PNMS and Infant Emotion Regulation

Overview. Separate hierarchical regressions were conducted to examine 1) PNMS and maternal behavior predicting infant emotion regulation, and 2) PNMS and infant sex predicting infant emotion regulation, while controlling for maternal age, parity, total household income, parental cohabitation, ethnicity, and infant sex and birth weight, and maternal postpartum distress. Control variables were z-scored and entered in step 1, predictor variables (maternal distress at 15 weeks ("early") gestation and 35 weeks ("late") gestation; maternal reinforcing and non-reinforcing behaviors) were also z-scored and then entered in step 2, and interactions computed by multiplying z-scored variables (reinforcing maternal behavior x early PNMS; reinforcing maternal behavior x late PNMS; non-reinforcing maternal behavior x early PNMS; non-reinforcing maternal behavior x late PNMS) were entered in step 3 for all play episodes (total average of Play 1, 2 and 3). Analyses involving early and late PNMS x infant sex were completed for 1) all play episodes (total average of Play 1, Play 2 and Play 3), 2) all Still Face episodes (average of SF 1 and SF 2), and 3) all episodes (Play 1, SF 1, Play 2, SF 2, and Play 3) for each of the 21 infant presence/absence behaviors.

Several significant interactions were identified in the current data set. Predicted values and simple slopes were used to explore all significant interactions. Graphs depict predicted values at 1 SD above and below the mean for each of the predictor variables (Cohen et al., 2002).

Primary Analyses

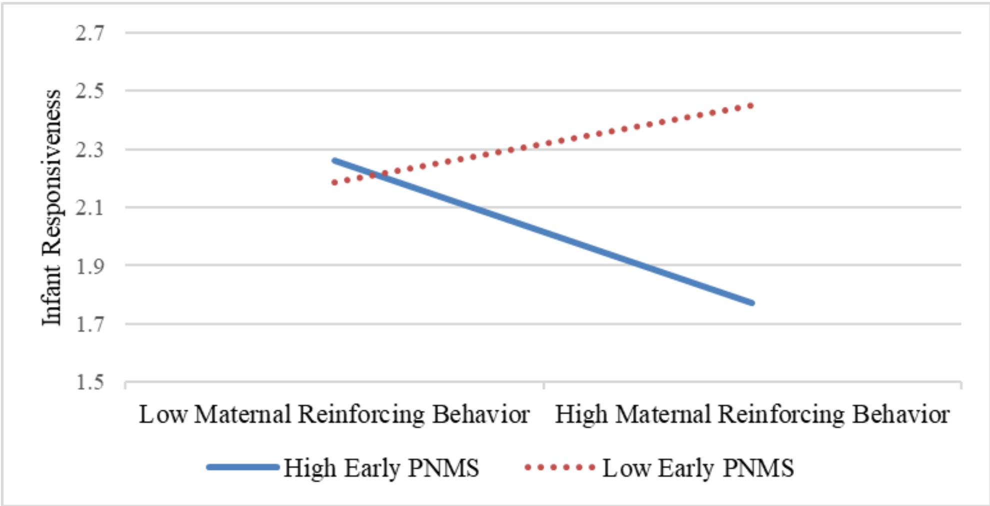
Results of primary analyses are organized below so that results involving early PNMS and late PNMS are presented separately. Within each PNMS section, results of analyses involving interactions with maternal behaviors are considered first, followed by interactions with infant sex. Results are then organized so that dimensional dependent variable analyses results are followed by presence/absence dependent variable results.

Early Prenatal Stress Analyses.

Early PNMS by maternal behaviors: Infant reengagement. In analyses involving maternal *reinforcing* behaviors and the early prenatal maternal distress index, postpartum distress had a significant negative association with infant responsiveness ($p < .05$). There were no significant main effects. However, maternal *reinforcing* behaviors interacted with the early prenatal maternal distress index to predict infant responsiveness (ß = -.242, t = -2.21, $p < .05$, $\Delta R^2 = .054$). This interaction is depicted in Figure 1. Simple slopes analyses indicated that when early PNMS was low, there was not a significant association between infant responsiveness and maternal reinforcing behaviors (ß = .169, t = 1.157, $p > .05$). When early PNMS was high, there was a marginally significant negative association between infant responsiveness and maternal reinforcing behaviors (ß = -.311, t = -1.931, $p = .057$).

Figure 1

Early PNMS x Maternal Reinforcing Behavior and Infant Responsiveness

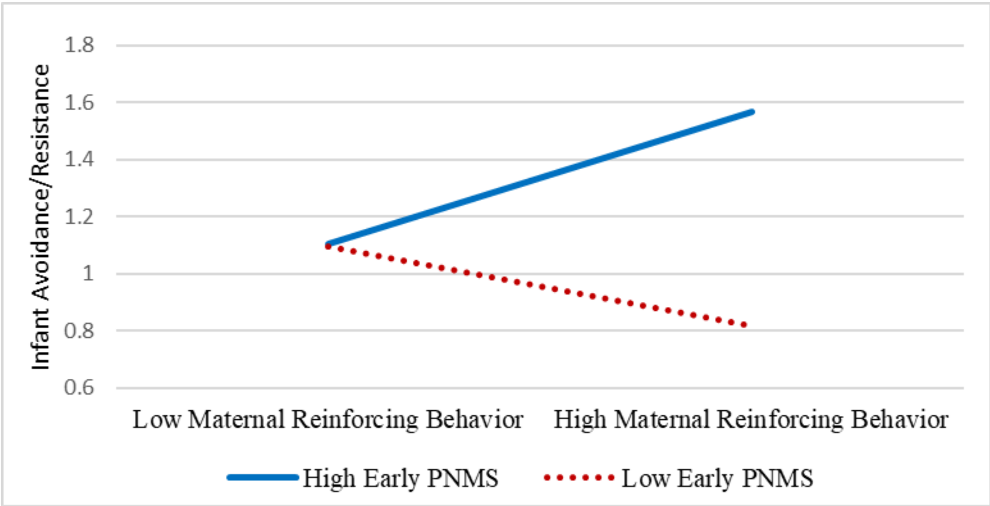


In parallel analyses involving maternal *non-reinforcing* behaviors and early PNMS predicting infant responsiveness, postpartum distress continued to have a significant negative association with infant responsiveness ($p < .05$). There was also a significant main effect of maternal non-reinforcing behavior on infant responsiveness, such that greater non-reinforcing behavior from the mother was associated with less infant responsiveness (ß = -.145, t = -4.326, $p < .001$). There were no other significant effects in this analysis (all *ps* > .05).

In analyses involving maternal *reinforcing* behaviors and the early prenatal maternal distress index, postpartum distress had a significant positive association with infant avoidance/resistance ($p < .05$). There was also a significant maternal *reinforcing* behaviors and early PNMS interaction effect (ß = .230, t = 2.15, $p < .05$, $\Delta R^2 = .049$). This interaction is depicted in Figure 2. Simple slopes analyses indicated that when early PNMS was low, there is not a significant association between infant avoidance/resistance and maternal reinforcing behaviors (ß = -.172, t = -1.201, $p > .05$). When early PNMS was high, there was a marginally significant association between infant avoidance/resistance and maternal reinforcing behaviors (ß = .285, t = 1.796, p = .076).

Figure 2

Early PNMS x Maternal Reinforcing Behavior and Infant Avoidance/Resistance



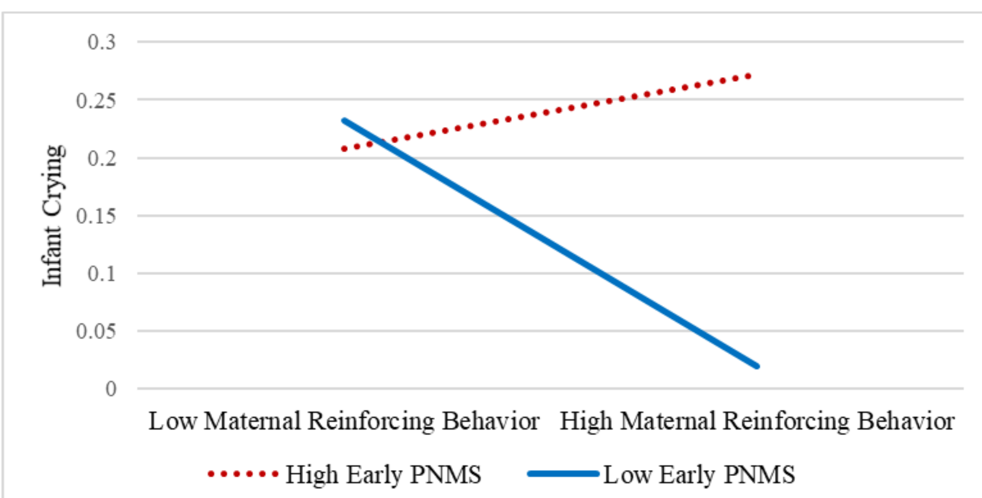
In the analyses involving maternal *non-reinforcing* behaviors and early PNMS predicting infant avoidance/resistance, postpartum distress had a significant positive association ($p < .05$). Also, there was a main effect of maternal non-reinforcing behavior, such that greater non-reinforcing behavior from the mother was associated with more infant avoidance/resistance (ß = .311, t = 3.055, $p < .05$). There were no other significant effects of this analysis (*ps* > .05).

Early PNMS by maternal behaviors: Infant presence/absence behaviors. Maternal behaviors in the context of early PNMS also predicted infant *presence/absence* behaviors. Separate hierarchical regression analyses were performed for each of the presence/absence behaviors. In these analyses, postpartum distress had a negative association with gazing at mother-other (not mother's face) ($p < .05$) and a marginally negative association with gazing at mother's face ($p < .06$). Also, the following main effects were found without significant qualifying interactions. Negative infant vocalizations were positively associated with both maternal reinforcing behaviors during play (ß = .246, t = 2.222, $p < .05$) and non-reinforcing behaviors during play (ß = .382, t = 3.705, $p < .001$). Infant crying during play was more likely when maternal non-reinforcing behaviors were displayed (ß = .358, t = 3.463, $p = .001$). Maternal non-reinforcing behavior during play was also associated with more oral-mother behavior (ß = .393, t = 3.927, $p < .001$), infant arching (ß = .409, t = 3.964, $p < .001$), and infant push/pull behavior during play (ß = .475, t = 4.738, $p < .001$). There were no other significant effects in these analyses (*ps* > .05).

Early PNMS interacted with maternal *reinforcing* behaviors to predict infant crying (ß = .281, t = 2.62, $p = .01$, $\Delta R^2 = .073$). This interaction is depicted in Figure 3. Simple slopes analyses indicated that when early PNMS was low, there was a significant association between infant crying behavior in play episodes and maternal reinforcing behaviors (ß = -.429, t = -2.964, $p < .01$). When early PNMS was high, there was not a significant association between infant crying during play and maternal reinforcing behaviors (ß = .126, t = .80, $p > .05$).

Figure 3

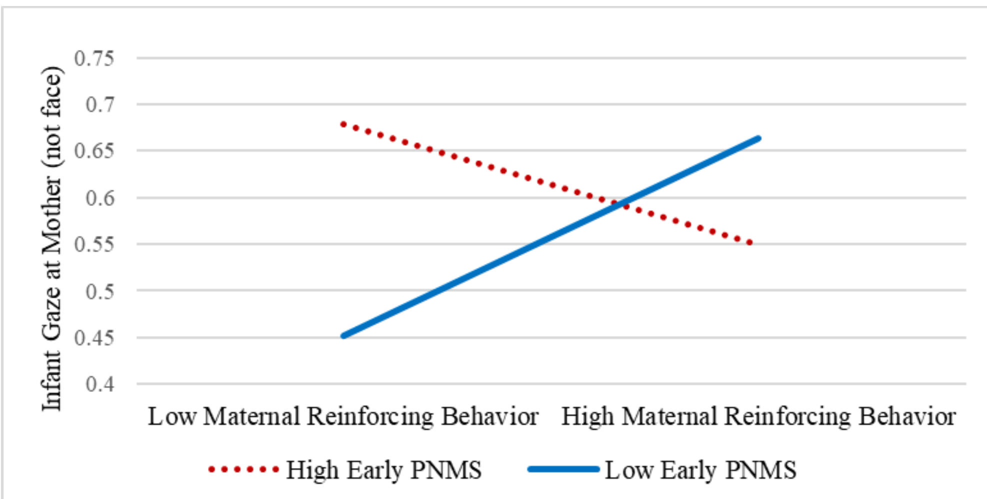
Early PNMS x Maternal Reinforcing Behavior and Infant Crying



Early PNMS and maternal *reinforcing* behaviors also interacted to predict infant gazing at mother (other than mother's face) (ß = -.261, t = -2.511, $p < .05$, $\Delta R^2 = .063$) during play episodes. This interaction is depicted in Figure 4. Simple slopes analyses indicated that when early PNMS was low, there is a significant association between infant gaze at the mother (other than mother's face) in play episodes and maternal reinforcing behaviors (ß = .323, t = 2.33, $p < .05$). When early PNMS was high, there was not a significant association between infant gaze at the mother (other than mother's face) during play and maternal reinforcing behaviors (ß = -.194, t = -1.259, $p > .05$).

Figure 4

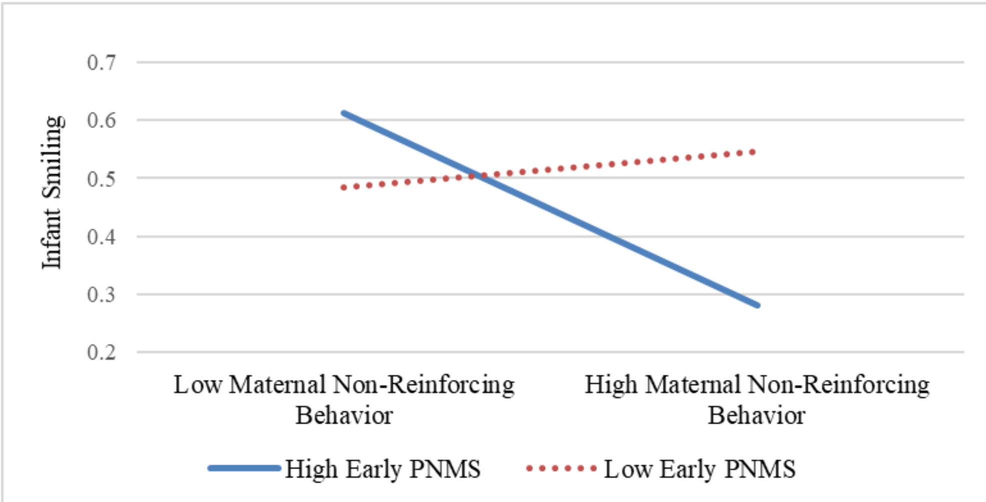
Early PNMS x Maternal Reinforcing Behavior and Infant Gaze-Mother (not face)



Early PNMS also interacted with maternal *non-reinforcing* behaviors to predict infant smiling during play (ß = -.239, t = -2.261, $p < .05$, $\Delta R^2 = .053$). This interaction is depicted in Figure 5. Simple slopes analyses indicated that when early PNMS was low, there was not a significant association between infant smiling behavior in play and maternal non-reinforcing behaviors (ß = .090, t = .614, $p > .05$). When early PNMS was high, there was a significant negative association between infant smiling during play and maternal non-reinforcing behaviors (ß = -.483, t = -2.642, p = .01).

Figure 5

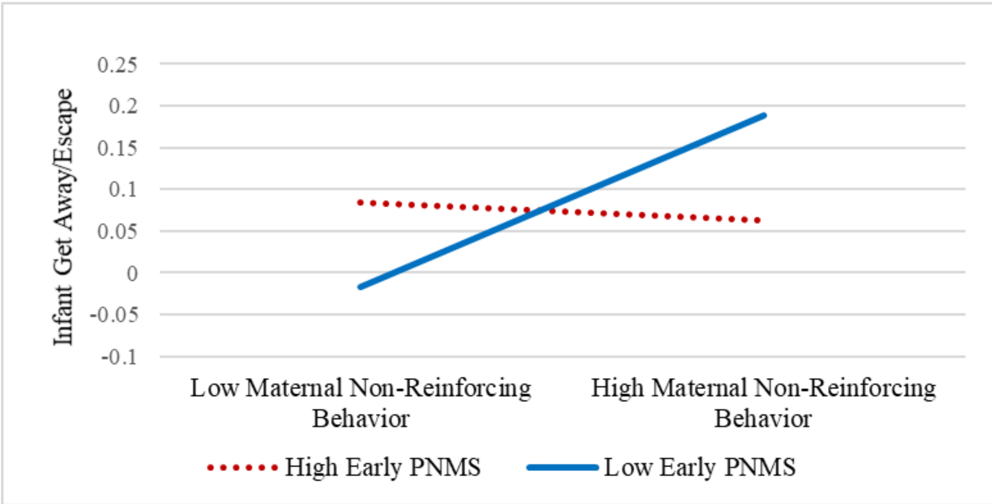
Early PNMS x Maternal Non-Reinforcing Behavior and Infant Smiling



In a separate analysis, maternal *non-reinforcing* behaviors predicted infant away/escape behavior (ß = .325, t = 2.964, $p < .01$). Further, maternal *non-reinforcing* behaviors interacted with early PNMS to predict infant away/escape behavior (ß = -.28, t = -2.631, p = .01, ΔR^2 = .074). This interaction is depicted in Figure 6. Simple slopes analyses indicated that when early PNMS was low, there was a significant positive association between infant get away/escape behavior in play episodes and maternal non-reinforcing behaviors (ß = .599, t = 4.039, $p < .001$). When early PNMS was high, there was not a significant association between infant get away/escape behavior during play and maternal non-reinforcing behaviors (ß = -.065, t = -.359, $p > .05$).

Figure 6

Early PNMS x Maternal Non-Reinforcing Behavior and Infant Away/Escape



Early PNMS by infant sex. Early PNMS did not interact with infant sex to significantly predict outcomes (all *ps* > .05). In the regression analyses, postpartum distress was significantly associated with infant responsiveness for males and infant avoidance/resistance for females, as well as gaze at mother's face for females and mother-other for females, and bids to gain mother's attention for males (all *ps* < .05). Also, separate analyses revealed main effects of infant sex that paralleled the t-test findings (see Tables 2 and 3). Specifically, there was a main effect of sex on infant gaze in which females were more likely than males to gaze at objects in the room other than mom in all episodes (ß = .217, t = 2.082, *p* < .05). Also, males were significantly more likely to than females engage in positive vocalizations across play episodes (ß = -.263., t = -2.545, *p* < .05) and across all total episodes (ß = -.244, t = -2.337, *p* < .05). No other significant associations were found for infant sex on infant reengagement or presence/absence behaviors (*ps* > .05).

Late Prenatal Stress Analyses.

Late PNMS by maternal behaviors: Infant reengagement. In analyses involving late PNMS, postpartum distress continued to have significant negative associations with outcomes as reported above (*ps* < .05). Additionally, main effects of maternal behaviors on infant reengagement behaviors persisted. Specifically, there was a significant main effect of maternal non-reinforcing behavior on infant responsiveness, such that greater non-reinforcing behavior from the mother was associated with less infant responsiveness (*ß* = -.461, t = -4.633, *p* < .001). In analyses involving maternal non-reinforcing behaviors and the late prenatal maternal distress index, there was a main effect of maternal non-reinforcing behavior on infant avoidance/resistance, such that greater non-reinforcing behavior from the mother was associated with more infant avoidance/resistance (*ß* = .325, t = 3.073, *p* < .01). There were no other significant effects of these analyses (all *ps*>.05).

Late PNMS by maternal behaviors: Infant presence/absence behaviors. In the context of late PNMS, controlling for covariates, maternal behaviors predicted infant *presence/absence* behaviors. In these analyses, postpartum distress had a negative association with gazing at mother-other and mother's face (*p* < .05). Separate analyses revealed main effects of maternal behaviors on infant behaviors similar to those reported above. Specifically, maternal non-reinforcing behaviors were positively associated with negative infant vocalizations during play episodes (ß = .467, t = 4.549, *p* < .001). Additionally, both maternal reinforcing and non-reinforcing behavior significantly predicted infant crying during play, with reinforcing behaviors predicting less and non-reinforcing behaviors predicting more crying behavior (ß = -.251, t = -2.134, *p* < .05 and ß = .371, t = 3.438, *p* = .001, respectively). Maternal non-reinforcing behaviors predicted more infant kicking during play (ß = .222, t = 1.991, *p* = .05) and more oral-mother behavior during play (ß = .428, t = 4.118, $p < .001$). Also, maternal non-reinforcing behavior predicted more infant away/escape behavior (ß = .375, t = 3.384, $p = .001$), infant arching (ß = .464, t = 4.511, $p < .001$), and infant push/pull behavior (ß = .503, t = 4.973, $p < .001$) during play. There were no other main effects in these analyses (all *ps* > .05).

Late PNMS interacted with maternal behavior to significantly predict two similar infant behaviors. In separate analyses, the interaction between maternal *non-reinforcing* behaviors and late PNMS significantly predicted infant touch-self behavior (ß = -.278, t = -2.142, $p < .05$, $\Delta R^2 = .058$; see Figure 7) and infant self-clasp behavior (ß = -.314, t = -2.481, $p < .05$, $\Delta R^2 = .074$; see Figure 8) during play episodes. Simple slopes analyses indicated that when late PNMS was low, there was a significant positive association between maternal non-reinforcing behaviors and infant touch-self (ß = .55, t = 2.565, $p = .01$). Similarly, when late PNMS was low maternal non-reinforcing behaviors was positively associated with infant self-clasp (ß = .532, t = 2.538, $p = .01$). Conversely, when late PNMS was high, there was not a significant association between maternal non-reinforcing behaviors and infant touch-self during play (ß = -.161, t = -.837, $p > .05$) or maternal non-reinforcing behaviors and infant self-clasp during play (ß = -.273, t = -1.450, $p > .05$).

Figure 7

Late PNMS x Maternal Non-Reinforcing Behavior and Infant Touch-Self

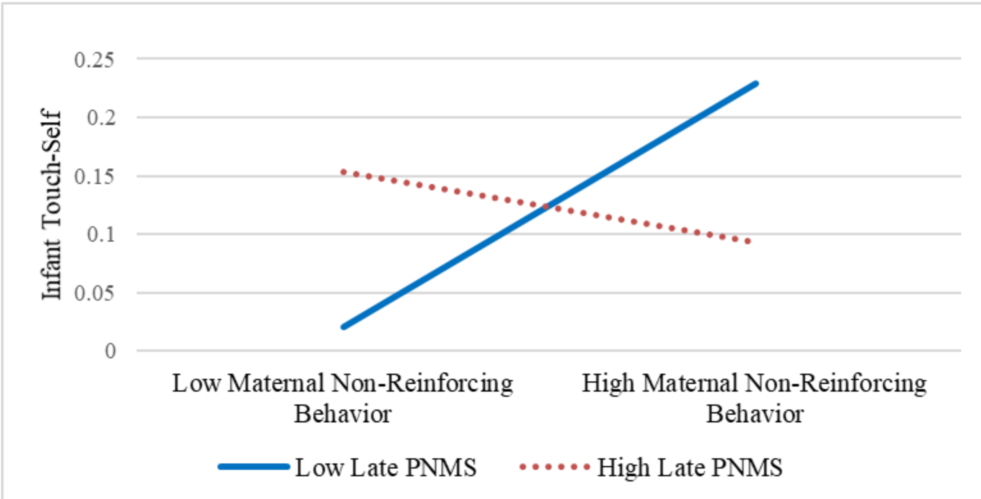
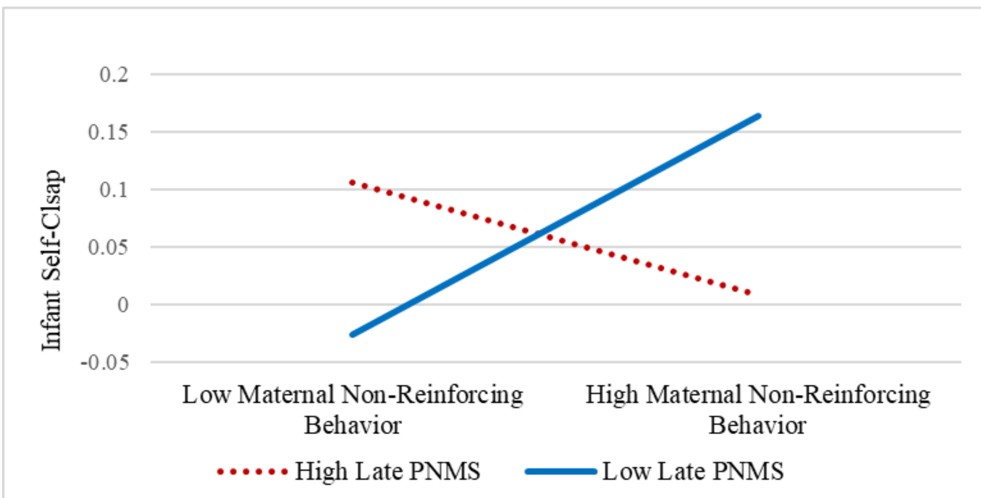


Figure 8

Late PNMS x Maternal Non-Reinforcing Behavior and Infant Self-Clasp



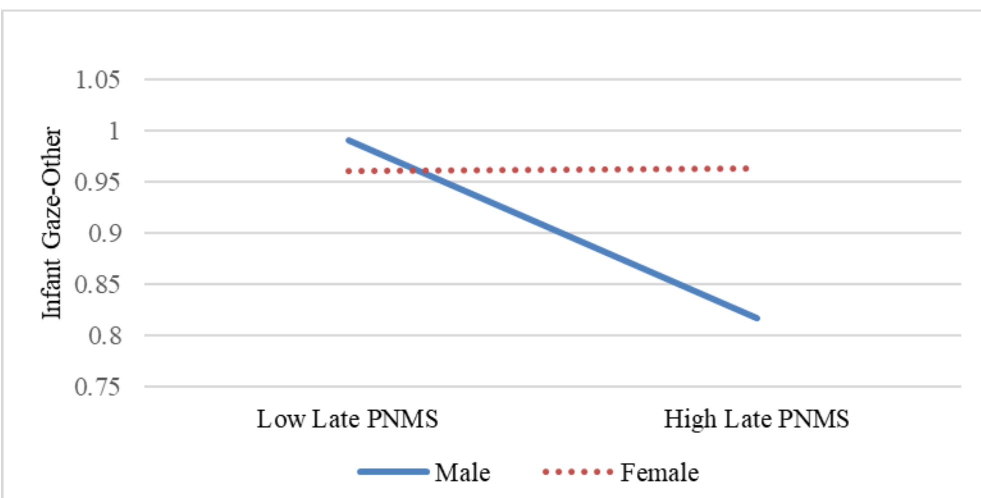
Late PNMS by infant sex. In regression analyses examining the associations of late PNMS and infant sex with infant emotion regulation behaviors, postpartum distress was associated with infant responsiveness for males and infant avoidance/resistance for females, as well bids to gain mother's attention for males (all *ps* < .05). There were no other significant effects of the analyses predicting infant responsiveness or infant avoidance/resistance.

In separate regressions including late PNMS as a predictor, some unqualified main effects emerged. Males were significantly more likely than females to engage in positive vocalizations across play episodes (ß = -.272, t = -2.584, p = .01) and across total episodes (ß = -.262, t= -2.474, $p < .05$). In addition, males engaged in more smiling behavior than females across play episodes (ß = -.213, t = -2.009, $p < .05$), and across all episodes (ß = -.227, t = -2.163, $p < .05$).

In the analyses involving late PNMS and sex, there was a significant interaction predicting infant gaze at the self or objects (other than mom) during Still Face episodes (ß = .299, t = 2.189, $p < .05$, $\Delta R^2 = .072$). This interaction is depicted in Figure 9. Simple slopes analyses indicated that when early PNMS was high, males were significantly less likely than females to gaze at objects in the room or oneself (ß = -.587, t = -2.523, $p < .05$). When early PNMS was low, there was not a significant association between infant sex and infant gazing at objects in the room or oneself (ß = .005, t = .023, $p > .05$).

Figure 9

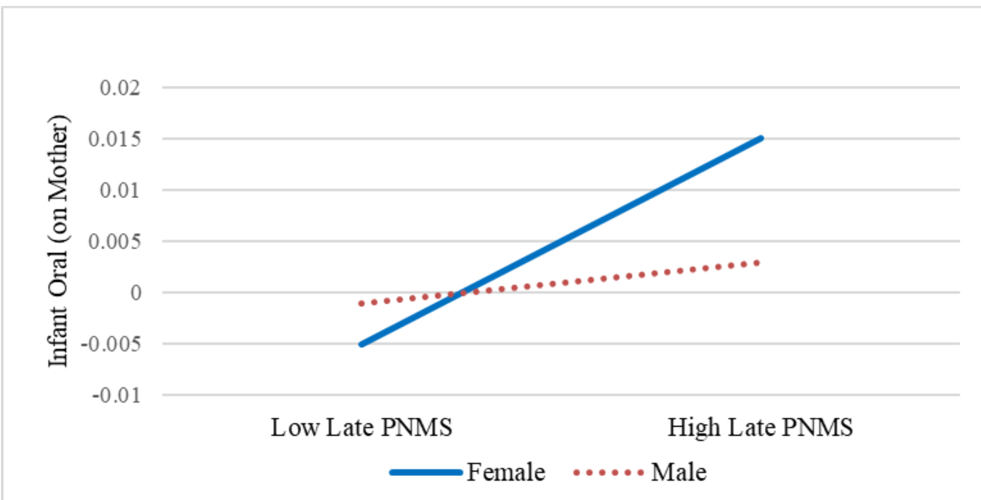
Late PNMS x Infant Sex: Infant Gaze-Other



Late PNMS also interacted with infant sex to significantly predict oral-mom behavior during the Still Face episodes (ß = -.25, p = -2.026, $p < .05$, $\Delta R^2 = .054$). This interaction is depicted in Figure 10. Simple slopes analyses indicated that when late PNMS was high there was a significant association between infant sex and oral-mom behavior such that females were more likely to exhibit this behavior (ß = .528, t = 2.563, $p = .01$). When late PNMS was low, there was not a significant association between infant sex and oral-mom behavior (ß = .038, t = .210, $p > .05$). No other significant main effects or interactions were found for any other presence/absence infant behaviors (*ps* > .05).

Table 10

Late PNMS x Infant Sex: Infant Oral-Mother



Post Hoc Analyses

Because of the relatively high correlations between the PPD Index and PNMS indexes, including the PPD Index as a covariate may have obscured associations between PNMS and infant emotion regulation. Therefore, analyses were re-run excluding the PPD Index as a covariate. These analyses resulted in statistically significant main effects of early PNMS, such that early PNMS was positively associated with infant avoidance/resistance in play and positive vocalizations in Still Face episodes. Additionally, late PNMS was positively associated with infant oral-mom behavior in the Still Face and negatively associated with gazing at mother-other during play (all *ps* $< .05$). This suggests that these infant behaviors may be differentially affected by PNMS (early or late), but that PPD is accounting for the same variance associated with PNMS. In these instances, untangling the influence of prenatal and postnatal stress is challenging and beyond the scope of this paper.

DISCUSSION

Past PNMS research has largely relied on indirect and incomplete measures of ‘emotion regulation,’ such as temperament or a single behavior (e.g., crying behavior). This has limited what is known about how infants regulate in emotionally stressful events following PNMS exposure. The current study aimed to fill this gap by developing a more comprehensive measure of emotion regulation to better measure and ultimately better understand infant emotion regulation in the context of PNMS.

IER-SFM Development

The emotion regulation measure developed for this study was designed to be implemented in scoring behavioral responses to the Still Face Procedure. It included 21 individual infant behaviors measured in 20-second epochs across each of three play episodes and two Still Face episodes, and 2 dimensional infant behaviors across three two-minute play episodes. The behaviors included were based on previous literature from the areas of prenatal maternal stress, postpartum maternal mental health, and child development. A unique component of the IER-SFM is the inclusion of maternal behaviors. That is, during play episodes, eight maternal behaviors were scored so that infant emotion regulation behaviors could be considered in the context of how the mother was behaving. All behaviors were directly measured through observation of mothers and infants together via video recording and didn’t rely on maternal report or indirect measures of emotion or stress regulation.

To improve the IER-SFM, data suggest the “rocking” infant behavior may be excluded as it did not occur at all in the present study. Rocking behavior was included based on research by the developers of the Still Face Procedure as a valid indication of infant regulation (Tronick & Weinberg, 1990). It is possible that rocking is a low frequency behavior that the current study sample size of 100 was not large enough to detect. On the other hand, this may not be an informative behavior in the current paradigm and could be considered for omission. Given the nascent quality of the instrument, future studies employing the IER-SFM should assess rocking behavior with this in mind.

The inclusion of a maternal effort to engage or maternal behaviors portion of the IER-SFM was largely exploratory, with little previous literature to guide its development (see the Appendix for maternal behavior descriptions). Correlations among these items indicated that mothers who were likely to soothe and comfort their infants during play were likely to also be engaging and acknowledging the baby's emotions, and significantly less likely to minimize/deny the infant's emotional experience (Table 5). Mothers who displayed distress behavior were less likely to teach/play with their infants, and mothers who were punitive were much more likely to respond inappropriately or incorrectly to their infants. Because there appeared to be a pattern emerging in which mothers' behaviors were either aimed at "reinforcing" the infants' behaviors or not reinforcing them, these items were consolidated into two separate maternal behavior indices.

The four "non-reinforcing" behaviors (punitive behavior, minimizing/denial of the infant's distress, incorrect/inappropriate responding, distress behavior) were relatively low in frequency (*Ms* $< .10$ of the play episodes). The "reinforcing" behaviors were more common, with caretaking behaviors occurring for about one-third of play episodes (M=.32), acknowledging/engaging in more than half of the play episodes (M=.57), and maternal soothing/comforting and teaching/playing behavior occurring with very high frequency (*Ms* $>$ .94). This difference in frequency may be related to the nature of the task in which mothers were told to play with their infants and the mothers know that they are being observed by a researcher.

Therefore, the laboratory context may have reduced maternal "non-reinforcing" behaviors limiting our data on infant responses to such behaviors. Research may want to consider focusing on emotion regulation responses to maternal "non-reinforcing" behaviors in the future.

Prenatal Maternal Stress Influences

The SFP is an established method for observing infant behavior in an emotionally challenging and interactive social context (Weinberg & Tronick, 1994). The current study utilized the SFP as a novel approach to measure infant regulation-related behavior *and* maternal behavior in the context of PNMS. In addition, best understand PNMS influences, potential postpartum stress influences on infant behavior were also measured.

In this study, postpartum stress accounted for variance in a number of regulatory behaviors. For example, maternal postpartum stress predicted less infant responsiveness and more avoidance/resistance in *all* analyses examining infant reengagement behaviors. Of the 21 infant presence/absence behaviors across both play and Still Face episodes, however, postpartum distress only predicted less gazing at mother's face and any other part of mother (such as her hand) during play episodes (during both reinforcing and non-reinforcing maternal behavior). Postpartum distress accounted for just a few sex differences in infant behavior, with differing associations for both female and male.

It was hypothesized that *late* PNMS would predict poorer infant regulation development. This was largely unsupported. Interestingly, neither early nor late PNMS had significant main effects on infant regulatory behaviors in the current study. However, when considered in the context of maternal behaviors or infant sex, six findings emerged involving interactions with *early PNMS.* First, infants who had been exposed to early PNMS had unanticipated responses to maternal reinforcing behaviors (e.g., teaching/playing). Specifically, under conditions of high early PNMS more maternal reinforcing behaviors was significantly associated with less infant responsiveness and more avoidance/resistance. It may be that early PNMS predisposes the infant to respond to mother's soothing/comforting and teaching/playing behaviors by withdrawing. Conversely, under conditions of low early PNMS, maternal reinforcing behaviors were associated with less infant crying and more gazing at the mother (but not her face). Clearly, early PNMS is influencing how infants are responding to maternal behaviors. It's not clear why it was the mother's *reinforcing* behavior that is eliciting different infant responses. This may be in part due to the fact that non-reinforcing behaviors rarely occurred, whereas reinforcing behaviors were quite common. Thus, it may be that the stressful fetal environment prepared the infant for a hostile postnatal environment, increasing the likelihood of withdrawal from potential threats, including maternal reinforcing behaviors during play episodes of the SFP.

Although maternal non-reinforcing behaviors occurred in fewer than 10% of episodes, there was still some indication that early and late PNMS may have influenced infant responses to these behaviors. Specifically, under conditions of high early PNMS infants responded to more maternal non-reinforcing behaviors with less smiling. There was no association between non-reinforcing behaviors and smiling when early PNMS was low. Under conditions of low early PNMS, infants responded to non-reinforcing behaviors with more away/escape behavior. There was no association between non-reinforcing behaviors and infant away/escape responses when early PNMS was high. Together, these results further suggest that early PNMS has prepared the infant for a hostile environment leading to a decrease in smiling in response to non-reinforcing (e.g., punitive, inappropriate) behaviors, possibly indicating acceptance. This is in contrast to the infants with low early PNMS, who actively sought to escape, possibly to regulate a negative emotional experience.

Late PNMS only interacted with maternal behaviors to predict two infant emotion regulation behaviors. Both behaviors were “self-comforting” behaviors, self-touch and self-clasp, that tended to increase in response to non-reinforcing maternal behaviors, but only under conditions of low late PNMS. When late PNMS was high, there were no such associations, possibly indicating a disruption in these potentially regulating behaviors. It’s also possible that high late PNMS affected development so that maternal non-reinforcing behaviors (i.e., a potentially antagonizing environment) are not upsetting, and therefore, elicit less emotion regulation from the infant in the form of self-touch and self-clasp.

Previous research suggests that males and females may be differentially affected by PNMS (Sutherland & Brunwasser, 2018; Van den Bergh et al., 2020), and females may be more vulnerable to fetal programming following PNMS (Sandman et al., 2013). Conversely, SFP research has found that males may have more difficulty with emotion regulation during the SFP, although these findings have been inconsistent (Weinberg et al., 1999). In the current research, it was hypothesized that females *may* be more influenced by PNMS exposure, however male and female infants differed very little behaviorally. Only two interactions between infant sex and PNMS emerged.

Specifically, following late PNMS exposure, during the Still Face episodes male infants were significantly less likely than females to gaze at objects in the room other than the infant’s mother (e.g., at one’s hand or the wall). In addition, following late PNMS exposure, during the Still Face episodes female infants were significantly more likely than males to engage in oral behavior on mom (e.g., suck on her finger). This data supports the notion that PNMS may differentially affect the emotion regulatory system of the developing child depending on sex. However, the pattern of oral-mother behavior may also indicate different maternal tendencies to respond to male and female infants during a SFP. Continued attention to PNMS-sex associations is needed for further understanding.

Conclusions, Limitations and Future Research

In this research, *early and late* PNMS predicted numerous infant emotion regulation outcomes with early PNMS predicting more infant emotion regulation behaviors overall. This differs from the hypothesis in the current research, as well as previous literature which has consistently demonstrated that late PNMS is predictive of emotion regulation-related outcomes. One reason for this discrepancy could be that the new, IER-SFM is more comprehensive and more sensitive to the influence of early PNMS. However, it may also be that infant emotion regulation behaviors influenced by early PNMS are most evident when considered in the context of, or in response to maternal behaviors. This explanation addresses the results involving early PNMS found in the current study. However, this cannot explain why we found few associations between late PNMS and infant emotion regulation behavior.

It could also be that the time points included in this study as “early” (15 weeks) and “late” (35 weeks) differed enough from other studies that have identified “late” as second and third trimester stress (e.g., Poggi Davis & Sandman, 2010), or 25 weeks gestation for example. Utilizing the IER-SFM developed in this study in conjunction with three measured PNMS time points of 15 weeks, 25 weeks and 35 weeks, may help further define the timing of PNMS in predicting emotion regulation.

Conversely, the notion that early PNMS may be more predictive of infant outcomes *is* consistent with findings that maternal mental health and pregnancy outcomes may be most impacted by early PNMS (Glynn, et al., 2001; Hilmert et al., 2016), when the maternal physiological stress response is strongest. Future research should consider specific maternal physiological responses to stress throughout pregnancy and the subsequent implications for the outcomes of the developing child.

There were limitations to the current study. First, over 200 hundred regressions were run to explore the influence of early and late PNMS, maternal reinforcing and non-reinforcing behaviors, and infant sex on 23 infant emotion regulation behaviors. Because of the exploratory nature of this initial implementation of the IER-SFM a correction for multiple analyses was not used. It is possible that spurious associations emerged given the high number of analyses. Our results should be viewed with this in mind. This study was also limited by the use of the SFP. Specifically, our results suggest that accounting for maternal behavior may be critical to the study of emotion regulation development, however, in the SFP, maternal behavior is guided by specific instructions to "play with" the child or to refrain from such behavior. We may be able to get a better picture of infant emotion regulation and its association with PNMS if maternal behavior is more spontaneous, perhaps reflecting the influence of PNMS on relevant maternal behaviors. The potential use of the IER-SFM outside of a SFP should be considered by future research.

The current research considered average rate of behavior occurring across multiple play, Still Face, and all episodes. It may be important for future research to examine emotion regulation behaviors within a particular episode, or to compare behaviors of one episode to another. For example, infant behavior during the second Still Face episode may differ from that in the first Still Face episode due to more or less effective adaptation to the repeated stressor. PNMS may play a role in determining how effectively an infant is able to adapt. Also, future research should consider additional moderators of associations between PNMS and emotion regulation behaviors. For instance, infant temperament has been found to be associated with late

PNMS (e.g., Baibazarova et al., 2013). It could be that including temperament as a moderator may help understand the influence of PNMS on emotion regulation behaviors in the context of maternal reinforcing and non-reinforcing behaviors.

This research addresses a current social need. One in six children beginning school exhibit developmental delay (Kershaw et al., 2010), with prevalence that increases over time (Hertzman, 1998, 2009). To exacerbate the problem, delays in one area of development typically lead to delay in other areas of development (Masten et al., 2004). For example, a delay in emotion regulation has the potential to affect a child's ability to communicate with peers, leading to increased internalizing and externalizing behaviors. Further, difficulty with emotion regulation is a key component in a variety of psychological disorders. Mood, anxiety, and personality disorders, such as major depressive disorder, generalized anxiety disorder, and borderline personality disorder could be unfortunate outcomes related to altered emotion regulation systems (Buckholdt et al., 2015; Hermann et al., 2009) due to PNMS.

This research is the first to consider infant emotion regulation behaviors during a SFP in the context of early and late PNMS, maternal behaviors, and infant sex. Our results suggest that it is important to account for maternal behaviors and perhaps, social interactions in general when examining the influence of PNMS on infant emotion regulation behaviors. In other words, emotion regulation does not occur in a vacuum, but rather it occurs in response to one's immediate environment. In infancy a critical component of the immediate environment often involves interaction with one's mother. Identifying the specific components of emotion regulation that may be influenced by PNMS and better understanding the complex relationship between offspring emotion regulation, maternal behaviors, and PNMS guides prevention and intervention efforts in pregnancy and early childhood.

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APPENDIX. INFANT EMOTION REGULATION STILL FACE MEASURE (IER-SFM)

Infant Emotion Regulation and the Still Face Procedure Coding

Subject ID# _______________

Scorer: ___________________

Date scored: ______________

Shirt color (child): ______________

Shirt color (mom): ______________

At start of first playtime:

Baseline State: 1= tired/drowsy
2= alert
3= fussy
4= crying

Video Quality: 1 = good 2= fair 3= poor
Sound: Yes/No

Were any of the episodes ended early by the experimenter?
0 = no
1 = yes
Specify which episode(s) were ended early: ______________

Was the Still Face activity discontinued?
0 = no
1 = discontinued by mother
2 = discontinued by experimenter

Notes:____

____

	Episode 1 (Play)						**Episode 2 (Still Face)**						**Episode 3 (Play)**						**Episode 4 (Still Face)**						**Episode 5 (Play)**					
Start time (begin)																														
Gaze: mother's face																														
Gaze: mother-other																														
Gaze: other																														
Vocalization: neutral																														
Vocalization: positive																														
Vocalization: negative/fussy																														
Vocalization: crying																														
Expression: smiling																														
Bid to mom																														
Gesture: reaches																														
Gesture: leans forward																														
Gesture: kicking																														
(Self-comfort) Oral-self																														
(Self-comfort) Oral-other																														
(Self-comfort) Oral-mom																														

	Episode 1 (Play)						Episode 2 (Still Face)						Episode 3 (Play)						Episode 4 (Still Face)						Episode 5 (Play)					
(Self-comfort) Touch-self																														
(Self-comfort) Self-clasp																														
(Self-comfort) Rock																														
Distance: get away/escape																														
Distance: arch																														
Distance: push/pull away																														
Mom blocking baby																														

Still Face Dimensional Coding: ***Infant Reengagement (intensity rating 0-3)***

	Episode 1 (baseline play) *time:* ____________	Episode 3 (play) *time:* ____________	Episode 5 (play) *time:* ____________
Infant Responsiveness			
Infant Avoidance/Resistance			

Still Face Dimensional Coding: ***Maternal Effort to Engage (presence/absence)***

	Episode 1 (baseline play) *time:* ____________	Episode 3 (play) *time:* ____________	Episode 5 (play) *time:* ____________
Soothing/Comforting Behavior			
Acknowledging/Engaging Behavior			
Caretaking Behavior			
Teaching/Playing Behavior			
Punitive Behavior			
Minimizing or Denial Behavior			
Incorrect/Inappropriate Responding			
Distress Behavior			

Dimensional Coding Descriptions

<u>Dimensions:</u>

1. **Infant Reengagement**
2. **Maternal Effort to Engage**

<u>Variables to be coded:</u>

Dimension 1: Infant Reengagement

1. Infant Responsiveness
2. Infant Avoidance/Resistance

Definitions of variables:

1. Intensity of infant responsiveness:

0 = **not responsive** to mother's attempt to engage

1 = **somewhat responsive to mother;** responds *occasionally* to mother's attempt to engage by looking, vocalizing, smiling and/or reaching

2 = **moderately responsive to mother;** responds *more than occasionally but not most of the time* to mother's attempt to engage by looking, vocalizing, smiling and/or reaching

3 = **very responsive to mother;** responds *most/all of the time* to mother's attempt to engage by looking, vocalizing, smiling and/or reaching

2. Intensity of infant avoidance/resistance

0 = **not avoidant/resistant** to mother's attempt to engage

1 = **somewhat avoidant/resistant to mother**; withdraws or resists *occasionally* to mother/mother's attempts to engage by looking away from mother's gaze, turning away, squirming or arching the back

2 = **moderately avoidant/resistant to mother**; withdraws or resists *more than occasionally but not most of the time* to mother/mother's attempts to engage by looking away from mother's gaze, turning away, squirming or arching the back

3 = **very avoidant/resistant to mother**; withdraws or resists *most/all of the time* to mother/mother's attempts to engage by looking away from mother's gaze, turning away, squirming or arching the back

Dimension 2: Maternal Effort to Engage (Y/N presence/absence of behavior)

1. Soothing/Comforting Behavior: Mother displays affection to her infant through proximity, touch, gaze and/or vocalizations, such as leaning close, stroking an arm, kissing, engaging in face-to-face contact, making eye contact, talking or singing. This may include distraction activities to comfort the infant.

2. Acknowledging/Engaging Behavior: Mother accurately identifies and acknowledges her infant's distress through such behaviors as stating the correct emotion expressed, empathizing with the infant's emotion or mirroring the infant's facial expression.

3. Caretaking Behavior: Mother engages in caretaking activities such as wiping the child's face, or adjusting the infant's positioning or chair straps.

4. Teaching/Playing Strategies: Mother attempts to engage her child through play or teaching play. Mother seems to have a 'tool kit' of engagement strategies.

5. Punitive Behavior: Mother responds to her infant's distress with irritation or lack of caring, such as scolding the child for being upset.

6. Minimizing or Denial Behavior: Mother rejects or minimizes her infant's distress, through such behaviors as vocalizations dismissing the distress or pretending as though her child is not upset. This may include avoiding or distancing herself from her infant in position or gaze.

7. Incorrect or Inappropriate Responding: Mother identifies a different emotion than that being expressed by her infant or responds to infant's distress in an odd manner, such as laughing when her infant displays a sad facial expression. *If unclear whether punitive, minimizing/denial or incorrect/inappropriate responding behavior, incorrect/inappropriate responding will be coded.*

8. Distress Behavior: Mother appears highly distressed herself. She may exhibit a host of stress behaviors, such as fidgeting, sighing, displaying negative facial expressions (which are not mirroring her infant's expressions), or vocalizing about her distress.