Pathways by which mothers’ physiological arousal and regulation while caregiving predict sensitivity to infant distress

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Abstract:

Pathways by which maternal physiological arousal (skin conductance level [SCL]) and regulation (respiratory sinus arrhythmia [RSA] withdrawal) while parenting are linked with concurrent and subsequent maternal sensitivity were examined. Mothers’ (N = 259) SCL and RSA were measured during a resting baseline and while interacting with their 6-month-old infants during tasks designed to elicit infant distress. Then, mothers were interviewed about their emotional and cognitive responses to infant cues (i.e., cry processing) while caregiving using a video recall procedure. Maternal sensitivity was observed during the distressing tasks at 6 months and again when children were 1-year-old. Mothers who were well-regulated (higher RSA suppression from baseline to parenting tasks) engaged in less negative and self-focused cry processing while interacting with their infants, which in turn predicted higher maternal sensitivity at both time points. In addition, SCL arousal and RSA regulation interacted such that maternal arousal was associated with more empathic/infant focused cry processing among mothers who were simultaneously well-regulated, which in turn predicted maternal sensitivity, albeit only at 6 months. These effects were independent of a number of covariates demonstrating the unique role of mothers’ physiological regulation while caregiving on sensitivity. Implications for intervention are discussed.

Keywords: parenting | physiological regulation | social information processing | infant crying

Article:

The importance of maternal sensitivity to infant distress cues in relation to infants’ subsequent social-emotional adjustment has been demonstrated by a number of investigators (del Carmen, Pederson, Huffman, & Bryan, 1993; Leerkes, Nayena Blankson, & O’Brien, 2009; McElwain & Booth-LaForce, 2006). As such, identifying the factors that promote maternal sensitivity to infant distress has important applied implications. A vast body of literature demonstrates that family of origin experiences (e.g., child maltreatment), contextual factors (e.g., poverty, social support), personal characteristics (e.g., age, personality), and infant characteristics (e.g., temperament) predict individual variation in maternal sensitivity (see Belsky & Jaffee, 2006, for a review). It has been proposed that sensitivity in distressing contexts has different origins than sensitivity to nondistress (Leerkes, Weaver & O'Brien, 2012), but relatively few investigators have examined origins of this domain of maternal sensitivity.

Given infant crying is aversive, and it has been proposed that maternal arousal and regulation play an important role in promoting adaptive parenting (Dix, 1991), it seems highly likely that individual differences in physiological arousal and regulation while parenting may predict maternal sensitivity in distressing contexts. In this study, we examine the extent to which mothers' physiological arousal, as indexed by skin conductance level, and regulation, as indexed by vagal withdrawal, as well as the interaction between them, are associated with both concurrent and later sensitivity during distress-eliciting tasks. In addition, we test the possibility that such effects are direct or indirect via mothers' social information processing about infant cues (i.e., cry processing). Only two prior studies have examined links between joint patterns of arousal and regulation while parenting and adaptive parenting behavior (Sturge-Apple, Skibo, Rogosch, Ignjatovic & Heinzelman, 2011; Miller, Kahle, Lopez, & Hastings, 2015) and neither focused on sensitivity during contexts designed to elicit infant distress.

Direct Effects of Physiological Arousal and Regulation on Sensitivity

In his seminal paper on the links between affect and parenting, Dix (1991, p. 3) noted that "When invested in the interests of children, emotions organize sensitive/responsive parenting. Emotions undermine parenting, however, when they are too weak, too strong, or poorly matched to child-rearing tasks." In an effort to test this perspective, we focus on change in two physiological indices of affect from baseline to stressful parenting tasks, one reflecting arousal (SCL) and the other reflecting regulation (RSA withdrawal).

To elaborate, SCL, or the amount of sweat that rises from sweat ducts to the skin, reflects activation of the sympathetic nervous system (SNS) and is believed to index emotional arousal (Stern, Ray & Quigley, 2001). SCL reactivity has been linked to behavioral inhibition in aversive contexts (Gray, 1975) and to a greater focus on personal distress as opposed to empathy toward others (Eisenberg & Fabes, 1990). As such, it has been argued that heightened SCL in challenging parenting situations may undermine sensitive maternal behavior. In fact, high SCL in response to infant cry audiotapes or videotapes has been linked with harsh/abusive parenting (Frodi & Lamb, 1980; Joosen, Mesman, Bakermans-Kranenburg, & van IJzendoorn, 2013).

Vagal withdrawal, a parasympathetic nervous system (PNS) response, reflects vagal regulation of the heart when an individual is confronted with challenge and coping is required (Porges, 2007). Vagal regulation is indexed by decreases in RSA during challenging situations, a physiological process that allows a person to shift focus from internal demands to the generation of coping strategies that control affective arousal (Porges, 2007). Thus, vagal withdrawal reflects the behavioral activation system and promotes an approach orientation (Gray, 1975), which may facilitate mothers sensitive responding in times of challenge. Consistent with this view, RSA regulation when presented with cry stimuli (Ablow et al., 2013; Joosen, Mesman, Bakermans-Kranenburg, Pieper, Zeskind & van IJzendoorn, 2013) and during stressful parent–child interactions (Mills-Koonce et al., 2009; Moore et al., 2009) has been linked with more sensitive and less negative parenting behavior.

Although the results of most studies in this area are consistent with the expected main effects of RSA on parenting, some studies have reported null associations between SCL and sensitivity (Ablow et al., 2013; Emery, McElwain, Groh, Haydon & Roisman, 2014). One possible explanation for the discrepancy regarding SCL across studies is that the extent to which arousal is maladaptive may be dependent on concurrent levels of regulation. In fact, there has been interest in the extent to which joint patterns of SNS and PNS activity predict outcomes. That is, despite the common view that the SNS and PNS act in an antagonistic fashion such that if one is high the other is low, there are several distinct patterns of activation across the two (e.g., coactivation, coinhibition; dominance of one system over the other) with different implications for behavior and health (Berntson, Norman, Hawkley & Cacioppo, 2008). Drawing from this perspective and Dix's (1991) perspective on the role of affect in parenting, we posit that high SCL accompanied by low RSA withdrawal is a state in which emotions are "too strong" (i.e., dysregulated) prompting less sensitive maternal behavior. In contrast high SCL accompanied by high RSA withdrawal reflects well-regulated affect and should be conducive to sensitivity.

To our knowledge, joint patterns of SNS arousal and PNS regulation *while* caregiving in relation to parenting quality have been examined in only two studies to date, both of which used different methods than the current study. In the first, mothers who demonstrated a pattern of moderate arousal paired with recovery/regulation across episodes of the strange situation (as indexed by sympathovagal balance a measure or relative SNS/PNS activity) were observed to be more sensitive, less negative, and less disengaged with their children in a free play task than mothers who demonstrated patterns of hypo- or hyper-arousal (Sturge-Apple et al., 2011). In the second, mothers engaged in more observed negative parenting with their preschoolers when they demonstrated a pattern of high SNS dominance (Miller et al., 2015). In that study, SNS was indexed by cardiac pre-ejection period, PNS was indexed by RSA, and dominance was indexed by calculating their difference. The results of both studies support the view that simultaneous patterns of arousal and regulation while parenting may predict variation in maternal sensitivity.

Indirect Effects of Physiological Arousal and Regulation via Cry Processing

Although the effects of arousal and regulation on parenting may be direct, it is also possible that they influence how mothers think and feel while caregiving which in turn influences the quality of their parenting. This notion is consistent with the social information processing view that arousal and regulation during social interaction affect how social cues are perceived, which in turn affects social behavior (Lemerise & Arsenio, 2000). That increased SCL during a challenging mother–toddler interaction predicted mothers' more negative appraisals about their toddlers, which in turn predicted harsh discipline (Lorber & O'Leary, 2005), lends particularly strong support to the view that effects of physiological arousal while caregiving may be indirect via social information processing of child cues.

In terms of joint effects of arousal and regulation, Leerkes et al. (2015) argued that mothers who are aroused and well-regulated while caregiving are likely aware of, and empathize with their infant's state, promoting a focus on infant needs over their own, thereby enhancing sensitive maternal behavior. They referred to this pattern of social information processing as infant-oriented cry processing. In contrast, mothers whose arousal is poorly regulated may misinterpret infant cry signals, become irritated by them, and focus on their own needs to cope, prompting insensitive behavior. They referred to this pattern of social information processing as mother-oriented cry processing. This view was supported in that pregnant women who demonstrated high SCL arousal accompanied by poor vagal regulation when exposed to videos of crying infants engaged in more mother-oriented cry processing, which in turn predicted less sensitive maternal behavior when interacting with their own 6-month-old infant. However, no studies to date have examined the possibility that the interaction between arousal and regulation while caregiving has an indirect effect on parenting via social information processing. We anticipate that poorly regulated arousal will predict higher mother-oriented cry processing and lower infant-oriented cry processing, which in turn will predict less sensitive maternal behavior.

The Present Study

In sum, the goal of this study is to test pathways by which maternal arousal and regulation while caregiving are linked with sensitive maternal behavior both directly and through mothers' social–cognitive processing of infant cues. We test the following hypotheses: (a) mothers' physiological arousal and regulation while caregiving will interact such that arousal will be associated with higher mother-oriented cry processing and lower infant-oriented cry processing when regulation is low; (b) high infant-oriented cry processing and low mother-oriented cry processing will be linked with higher maternal sensitivity; (c) the interaction between physiological arousal and regulation in response to infant crying will have an indirect effect on maternal sensitivity via mothers' infant-oriented and mother-oriented cry processing. We test these pathways in relation to both concurrent (6 months) and subsequent (1 year) maternal sensitivity to determine if mothers' physiology during caregiving serves as a marker for parenting sensitivity generally or is related only to parenting in the moment.

Finally, we control for two key factors to rule out potential spurious effects. These include mothers' adult attachment security (indexed as attachment coherence of mind in this study) which has been associated with more sensitive maternal behavior (van Ijzendoorn, 1995) and women's emotional, cognitive and physiological reactions to infant cry stimuli (e.g., Ablow et al., 2013; Groh & Roisman, 2009; Leerkes et al., 2015). A second factor controlled for is mothers' broad emotional risk (i.e., heightened depressive symptoms, negative emotionality, neuroticism, emotion regulation deficits and low agreeableness and positive emotionality) because such characteristics have been linked also with physiological, cognitive, and emotional reactions to difficult parenting situations (Leung & Slep, 2006; Oppenheimer, Measelle, Laurent, & Ablow, 2013) and with less sensitive parenting (Belsky & Jaffee, 2006).

Method

Participants

Participants in the current study were 259 primiparous mothers (128 European American, 123 African American, 8 multiracial) and their infants from the southeastern United States. Mothers ranged in age from 18 to 44 years (*M* = 25.1) at recruitment. Twenty-seven percent had a high school diploma or less, 27% had attended but not completed college, and 46% had a 4- year college degree. The majority (71%) of mothers were married or living with their child's father, 11% were dating but not living with their child's father, and 18% were single or not living with the child's father. Annual family income ranged from less than $2,000 to over $100,000; median = $35,000. Although all mothers were primiparous, they varied in the extent to which they reported prior experience caring for infants: 22% reported no or little experience, 37% reported some, and 41% reported a lot of prior experience caring for infants. Of the initial 259 participants, 227 participated in either the 6-month (*n* = 211) or 1-year (*n* = 207) observation with their infant, and 191 participated at both time points. The primary reasons for not participating in the observations were inability to locate mothers, moving from the area or being too busy, and two infant mortalities. Infant gestational age ranged from 35 to 43 weeks (M = 39.5); no infants were reported to have serious health or developmental problems, and 51% were female.

Procedure

Expectant mothers were recruited at childbirth classes offered in local hospitals (*n* = 95) and the public health department (*n* = 28), breastfeeding classes through the Special Supplemental Nutrition Program for Women, Infants and Children (*n* = 100), obstetric practices (*n* = 12), and word of mouth (*n* = 24). Inclusion criteria included expecting a singleton and being African American or European American. Upon enrollment in the study, women were mailed consent forms and a packet of questionnaires including measures of demographics, personality, and emotional functioning. Women visited our laboratory for an interview 6 to 8 weeks prior to their due date to complete the Adult Attachment Interview. Dyads visited our laboratory for a videotaped observation of mother-infant interaction within two weeks of the infant's 6-month birthday and when infants were between 12 and 14 months old. Mothers received $50 and a gift at the completion of the prenatal and 6-month visit and $100 after the 1-year visit.

6-month observation. During the 6-month visit, electrodes were placed on mothers' right collarbone and under each ribcage to record their heart rate, and two velcro strips were placed on the middle segments of two adjacent fingers of mothers' nondominant hand to record skin conductance level. These were connected to the Biolog (UFI, Morro Bay, CA), which stored physiological data from the entire observation for subsequent download to a computer. Once physiological recording devices were in place, infants were strapped in an infant seat and mothers sat in a chair to their right. Mothers were asked to sit quietly for 2 min to collect resting baseline measures; the assessor left the room during this period.

Then, mothers and infants participated in three distress-eliciting tasks. The first distress task was a 4 min arm restraint procedure designed to elicit infant frustration. The experimenter knelt in front of the infant seat and gently held the infant's forearms immobile while keeping her head down and not interacting with the infant. The second distress task was a novel toy approach designed to elicit infant fear. The infant was tucked into a table with a barrier that prevented the toy from touching the infant. A remote control-operated dump truck with flashing lights, motion, and sound and an action figure seated on top approached the infant three times. Then, the truck's horn, ignition, and a voice sounded, and music played while the truck vibrated and its lights flashed. Then, the silent and still truck remained within the infant's reach for 1 min. The entire task lasted 4 min. During the first minute of both tasks, the mother was instructed to remain uninvolved unless she wanted to end the activity. Then, the experimenter signaled the mother that she could interact with her infant as she pleased. The final distress eliciting task was the Still

Face procedure (Tronick, Als, Adamson, Wise, & Brazelton, 1978). Mothers' seats were moved across from their infant. Mothers were instructed to play with their infant as they normally would for 2 min, then to look at their infant with a still face for 2 min, and, finally, to play with their infant as they normally would for 2 min.

6-month cry processing interview. Immediately after the 6-month observation, the mother and experimenter moved to an adjacent room for the audiotaped video-recall interview while another research assistant cared for the infant. After viewing the videotapes of each task (arm restraint, novel toy, and still face reengagement), the experimenter asked the mother the same series of questions and asked her to complete the same series of questionnaires to assess infant-oriented and mother-oriented cry processing following procedures outlined by Leerkes et al., 2015. Details are presented in the Measures section.

1-year observation. During the1-year visit, mothers and infants participated in two distress-eliciting tasks. The first task was a 4-min attractive toy in a jar procedure designed to elicit infant frustration. The researcher offered the infant an interactive toy phone. Once the infant was interested in the phone, the researcher placed it in a clear plastic jar and closed the lid so the infant could see but not touch the toy. The researcher prompted the infant to open the jar. After 4 min, the researcher opened the jar and allowed the infant to play with the phone. Next, during the novel character approach designed to elicit fear, the researcher left the room and a research assistant dressed in a green monster costume entered the room and engaged in a series of approaches toward and attempts to interact with the infant for 4 min. During the first minute of both tasks, the mother was instructed to remain uninvolved unless she wanted to end the activity. Then, the experimenter signaled the mother that she could interact as she pleased.

Measures

Prenatal control measures. Prior to the prenatal interview, mothers completed self-report measures to assess emotional and personality characteristics that were used as indicators of emotional risk. The Center for Epidemiologic Studies–Depression Scale (Radloff, 1977) assesses depressive symptoms; items were summed. The Difficulties in Emotion Regulation Scale (Gratz & Roemer, 2004) assesses the extent to which mothers struggle in their awareness, clarity, acceptance and regulation of their negative emotions; items were averaged. The Differential Emotions Scale (Izard, Libero, Putnam, & Haynes, 1993) assesses the extent to which mothers typically experience positive and negative emotions in daily life; items were averaged within scale. The NEO Five-Factor Inventory (Costa & McCrae, 1985/1992) was administered to assess agreeableness (the sum of items reflecting being trusting, helpful, and forgiving) and neuroticism (the sum of items reflecting being anxious, hostile, and depressed). High scores reflect higher depressive symptoms, difficulties with emotion regulation, trait positive and negative emotionality, agreeableness and neuroticism, respectively.

At the prenatal visit, mothers were administered the Adult Attachment Interview (AAI; George, Kaplan, & Main, 1984-1996), a semistructured interview in which participants describe their early childhood relationships with their primary caregivers and the influences they perceive those experiences have had on them. We selected the coherence of mind rating, ranging from 1 (*not at all coherent*) to 9 (*very coherent*), which is a summary measure of participants' ability to describe early attachment experiences and their influence on current functioning in an organized manner as our measure of adult attachment security (Main & Goldwyn, 1998/2003). Interrater reliability was good, intraclass correlation = .75, $p < .001$, based on 50 double-coded transcripts.

6-month physiological arousal. SCL was continuously recorded in microsiemens on the Biolog at a sampling rate of 100Hz. These data files were exported to EXCEL and the average SCL scores during baseline, the mother involved portions of the arm restraint and novelty task, and the reengagement phase of the still face were calculated. Difference scores were calculated by subtracting the baseline SCL score from the SCL scores during the three caregiving tasks; high scores indicate increased arousal from baseline to caregiving tasks. Change scores were averaged to yield a single measure.

Physiological regulation. Mothers' electrocardiogram was recorded at a sampling rate of 1 kHz. A data file containing the interbeat intervals (IBI), or the time between R-waves, was transferred to a computer for artifact editing (resulting from movement) and analyzed using the CardioEdit software (Brain Body Center, University of Illinois at Chicago). Estimates of RSA were calculated using Porges' (1985) method. Heart period (HP) was derived from the IBI data then an algorithm was applied to the sequential HP data. A bandpass filter extracted the variance of HP within the frequency band of spontaneous respiration (.12–.40 Hz) in adults. RSA, in $msec^2$, was calculated for every 15-s epoch during baseline and during each of the tasks and was then averaged across epochs within a task of interest. Vagal withdrawal scores were calculated for each parenting task (involved arm restraint and novel toy, still face reengagement) by subtracting the average RSA during each parenting task from the average RSA during baseline. Change scores for each task were averaged to yield a single score. High scores indicate greater vagal withdrawal and better physiological regulation.

Cry processing. Each of the cry processing measures described below demonstrated predictive validity to maternal sensitivity in prior studies (Leerkes, 2010; Leerkes et al., 2015).

During the 6-month video-recall interview, mothers were asked to rate how strongly they felt 17 emotions (e.g., sad, concerned, sympathetic) during each interactive task on a 4-point scale ranging from 1 (*not at all*) to 4 (*very strongly*) using a paper questionnaire. Then, mothers were asked to describe verbally why they felt each emotion. Their reasons were coded as infant-oriented or mother-oriented (Dix, Gershoff, Meunier, & Miller, 2004); kappa based on 40 double coded transcripts was .94. *Empathy* was calculated by averaging mothers' intensity ratings for infant-oriented empathy, sympathy and sadness across the 3 tasks to yield a single score.

Second, mothers were asked to indicate how frequently infants were distressed during each interactive task on a 7-point scale from never to the whole time and to indicate all emotions the infant displayed during each task using a list of 20 emotion terms (e.g., happy, sad, angry). To score distress detection, mothers' responses about their infants' state were compared to ratings made by reliably trained infant affect coders (described below). If an infant was distressed according to our raters (a score of 5, 6, or 7), and the mother rated the infant as never distressed (underrating) or failed to indicate the infant felt specific negative emotions like sadness, fear, anger (underidentification), the number of seconds the infants was rated as distressed by us was recorded to reflect the egregiousness of her detection error. That is, not noting an infant was distressed if they cried for 30 s is a bigger error than not noting they only cried for 5 s. Mothers who did not make these errors were scored as 0. These scores were calculated for each caregiving task and then summed across tasks. The two types of detection errors correlated, $r(206) = .20$, $p < .01$, and were averaged. This score was multiplied by −1 so high scores reflect more accurate distress detection.

Third, mothers rated the extent to which they agreed with 18 statements about why their infant behaved as he or she did during each task on a 4-point scale ranging from 1 (*strongly disagree*) to 4 (*strongly agree*) to assess their causal attributions. Situational/emotional attributions is the mean of four items (upset by the situation, no one was helping my baby, trying to show he or she needs help; had no way to feel better) averaged across the 3 tasks. Emotion minimizing attributions is the mean of five items (having a bad day, in a bad mood, tired, hungry, not feeling well) averaged across the three tasks. Negative/internal attributions is the mean of 7 items (spoiled, difficult temperament, trying to make my life difficult, unreasonable, crying on purpose, selfish, just wanted attention) averaged across the three tasks.

Mothers completed the Infant Crying Questionnaire (Haltigan et al., 2012), a single time, to assess their beliefs about infant crying by rating the extent to which they believed 43 statements on a 5-point scale ranging from 1 (*never*) to 5 (*always*). Infant-oriented cry beliefs is the average of two subscales: Attachment (eight items; e.g., when my baby cries, I want to make my baby feel secure) and Crying as Communication (three items; e.g., when my baby cries, I think my baby is trying to communicate). Mother-oriented cry beliefs is the average of two subscales: Minimization (nine items; when my baby cries, I want my baby to stop because I cannot get anything else done) and Spoiling (three items; how I respond when my baby cries could spoil my baby).

Infant distress at 6 months and 1 year. Infant distress and maternal behavior were continuously rated/coded from digital media files using INTERACT 9 (Mangold, Arnstorf, Germany). Event based coding was used, meaning once a behavior was coded, it remained "on" until a new code was selected. Infant affect was rated on a 7-point scale ranging from 1 (*high positive affect*; i.e., intense smile, laughing or squealing) to 7 (*high negative affect*; screams, wails, sobs intensely). The average ratings of infant affect during the arm restraint task, novelty task, and still face reengagement episode were used as indicators of infant distress at 6 months. Given there were only two distress-eliciting tasks at 1 year, and the difficulty inherent in creating a latent factor from two indicators, a manifest variable reflecting average infant distress at 1 year across the toy in a jar and novel character approach tasks was calculated. Interrater reliability was good at 6 months and 1 year: weighted $\kappa = .76$ and $.75$ based on 34 and 30 double-coded tapes respectively. At 6 months, 96% of infants became distressed, and mean distress duration across the tasks was 2 min (range = 0 to 7.75 min). At 1 year, 91% percent of infants became distressed, and mean distress duration was 1 min (range = 0 to 4.45 min).

Maternal sensitivity to distress at 6 months and 1 year. Maternal behaviors during the distress-eliciting tasks were continuously coded using 12 mutually exclusive categories (negative, intrusive, mismatched affect, withdraw, distracted, persistent ineffective, monitor, task focused, calming, supportive, nontask focused engagement, routine care) described in Leerkes, 2010. Coders were blind to other data. The sensitivity of maternal behavior given the infant's affective state at that moment was rated on a 3-point scale ranging from 1 (*insensitive*) to 3 (*sensitive*). For example, monitoring a neutral infant is rated as sensitive because the infant is not signaling a need. Monitoring when an infant is distressed is rated as insensitive because the infant is signaling a clear need to which the mother does not respond. Sensitivity ratings for each discrete maternal behavior during infant positive, neutral and negative affect are described in Leerkes (2010). Thirty cases and 27 cases were double-coded for reliability at 6 months ($\kappa = .77$) and 1 year, respectively ($\kappa = .80$), and disagreements were resolved via consensus. Mothers' average rating of sensitivity during the mother-involved portions of the arm restraint and novel toy approach tasks and for the still face reengagement episode were used as separate indicators of maternal sensitivity to distress at 6 months. Given there were only two distress-eliciting tasks at 1 year, and their scores correlated ($r = .23$, $p < .01$) a manifest variable reflecting average sensitivity to distress at 1 year across the toy in a jar and novel character approach tasks was calculated. In prior research in this and other samples, maternal sensitivity scores derived from this approach correlated positively with global ratings of maternal sensitivity and demonstrated predictive validity to relevant child outcomes including infant attachment behavior (Leerkes, 2010; Leerkes, Parade, & Gudmundson, 2011).

Results

Preliminary Analyses

Mothers who participated in either the 6-month or 1-year observation did not differ from those who did not participate in either observation on maternal age, race, education, ethnicity, family income, measures of personality, and emotional functioning or attachment coherence. Missing data were handled in the primary analyses via full information maximum likelihood.

Means, standard deviations, and Cronbach's alpha for key variables along with their intercorrelations are presented in Table 1. Next, potential covariates were identified by examining simple correlations between maternal education, prior experience with infants, infant gender, and observed infant distress and primary variables. Prior experience caring for infants was associated with marginally greater empathy and higher maternal sensitivity, $r(209) = -.13$ and .18, $p < .10$ and .05, respectively. Mothers who were more highly educated had *higher* coherence of mind, infant-oriented cry beliefs, SCL and sensitivity and lower emotional risk and mother-oriented cry beliefs, *r*s (207–257) = .40, .36, .14, .21, −.29, −.24, respectively, all $p < .05$. Mothers whose infants were less distressed during the observational tasks were rated as more sensitive at 6 months (see Table 1). Thus, maternal education, experience caring for infants, and infant distress were included as covariates, in addition to coherence of mind and emotional risk.

Analytic Strategy for Hypothesis Testing

Hypotheses were evaluated by conducting structural equation modeling (SEM) with Mplus version 7 (Muthén & Muthén, 2012). Two SEM models were conducted separately to predict maternal sensitivity at 6 month and 1 year. Both models included the observed variables of coherence of mind, maternal education, experience with infants, and mean-centered physiological arousal and regulation and their product term; and the latent variables of emotional risk and infant- and mother-oriented cry processing. In the 6-month model, maternal sensitivity and infant distress were specified as latent variables whereas in the 1-year model these two constructs were manifest variables. Latent variables for emotional risk and mother-oriented and infant-oriented cry processing were constructed following the approach used in Leerkes et al. (2015). Empathy, distress detection, situational-emotional attributions, and infant-oriented cry beliefs were specified as indicators of infant-oriented cry processing, and negative attributions, minimizing attributions, and mother-oriented beliefs were specified as indicators of mother-oriented cry processing. To account for method effects, error terms were correlated between subscales from common measures and between ratings of mothers and infants during the same task; any that were nonsignificant were removed from the final model. The residual errors for mother-oriented and infant-oriented cry processing were allowed to be correlated. Standardized loadings for each indicator and correlated error terms are presented in Table 2.

Table 1. Descriptive Statistics and Intercorrelations
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Table 2. Standardized Loadings and Residual Correlations for Measurement Model (N = 259)

Construct	Indicator	6M model	1 Y model
Emotional risk	→Depressive symptoms	.76**	.76**
	→Difficulties with emotion regulation	.67**	.67**
	→Trait negative emotions	.82**	.82**
	→Trait positive emotions	–.35**	–.35**
	→Agreeableness	–.49**	–.49**
	→Neuroticism	.77**	.77**
Infant-oriented cry processing	→Empathy	.69**	.68**
	→Accurate distress detection	.25**	.22**
	→Situational/emotional attributions	.86**	.83**
	→Infant-oriented cry beliefs	.21**	.25**
Mother-oriented cry processing	→Negative attributions	.36**	.36**
	→Minimizing attributions	.11†	.11†
	→Mother-oriented cry beliefs	1.00**	1.00**
Observed infant distress[a]	→Arm restraint	.52**	—
	→Novel toy approach	.52**	—
	→Still face re-engagement	.45**	—
Maternal sensitivity to distress[a]	→Arm restraint	.60**	—
	→Novel toy approach	.52**	—
	→Still face re-engagement	.41**	—
Residual correlations	Trait positive with negative emotions	.29**	.29**
	Negative with minimizing attributions	.45**	.45**
	Minimizing with situational attributions	.30**	.41**
	Negative with situational attributions	.36**	.39**
	Arm restraint infant with mother	–.28**	—
	Still face infant with mother	–.66**	—
	Situational attributions with infant distress	1.48**	—
	Empathy with infant distress	.74**	—
	Infant-oriented and mother-oriented cry processing	–.18**	–.14†

[a] At 1 year, maternal sensitivity and observed infant distress are manifest variables.
† $p < .10$. * $p < .05$. ** $p < .01$.

In the path models, physiological arousal and regulation and their interaction term were specified as predictors of maternal cry processing and sensitivity. Mother- and infant-oriented cry processing were specified as predictors of maternal sensitivity to distress. Mothers' coherence of mind, emotional risk, prior experience caring for infants, infant distress, and maternal education were included as covariates predicting maternal sensitivity. Hypotheses related to indirect associations and interaction effects were evaluated using bias-corrected bootstrapped 95% confidence intervals (CI) (MacKinnon, Lockwood, & Williams, 2004). Confidence intervals that do not include 0 reflect significant effects.

Predicting Maternal Sensitivity at 6 Months

The structural model demonstrated adequate fit to the data, $\chi^2(240) = 424.481$; $p < .001$; comparative fit index (CFI) = .861; root mean square error of approximation (RMSEA) = .057, 90% confidence interval (CI): .046, .063; standardized root mean square residual (SRMR) = .094. Although the chi-square value was statistically significant (which is common for models with large sample size) and the CFI slightly below typically accepted standards of "acceptable" fit (i.e., .90), the RMSEA and the chi-square/*df* ratio were indicative of acceptable model fit (Kline, 2010). Relatively low values of the CFI tend to occur in complex models where there are small correlations among variables. Given the small magnitude of a number of associations in the model (e.g., physiological arousal and regulation main effects are unrelated to a number of other variables in the model), a somewhat low CFI is not unexpected. Kenny (2014) suggests that since the CFI is an incremental fit index, CFI may not be a useful indicator of model fit in cases where a null model (no associations specified among the study variables) produces RMSEA values < .158; ours was .135. As such, despite the relatively low CFI, the overall model fit statistics suggest acceptable fit.

Standardized coefficients for the structural paths are presented in Figure 1. Consistent with the preliminary analyses, higher coherence of mind, prior experience with infants, and maternal education were associated with higher maternal sensitivity to distress, whereas higher infant distress was associated with lower maternal sensitivity. In contrast, emotional risk was not associated with maternal sensitivity. Neither physiological arousal nor physiological regulation were directly associated with maternal sensitivity; the interaction between them was also nonsignificant. Consistent with prediction, the interaction between physiological arousal and regulation was significantly related to infant-oriented cry processing, and this effect held across bootstrapping, $B = .015$, 95% CI [.004, .028]. Simple slope analysis indicated that physiological arousal was linked with higher infant-oriented cry processing when regulation was high (+1 *SD*, $\beta = .17$, B = .013, $p < .05$, 95% CI [.002, .027]) but was not when regulation was low (−1 *SD*, $\beta = -.11$, B = −.01, $p = .37$, 95% CI [−.028, .007]). Physiological regulation was associated with lower mother-oriented cry processing as a main effect, but the interaction effect between physiological arousal and regulation was not a significant predictor of mother-oriented cry processing. As predicted, infant-oriented cry processing was associated with higher maternal sensitivity, and mother-oriented cry processing was associated with lower maternal sensitivity.

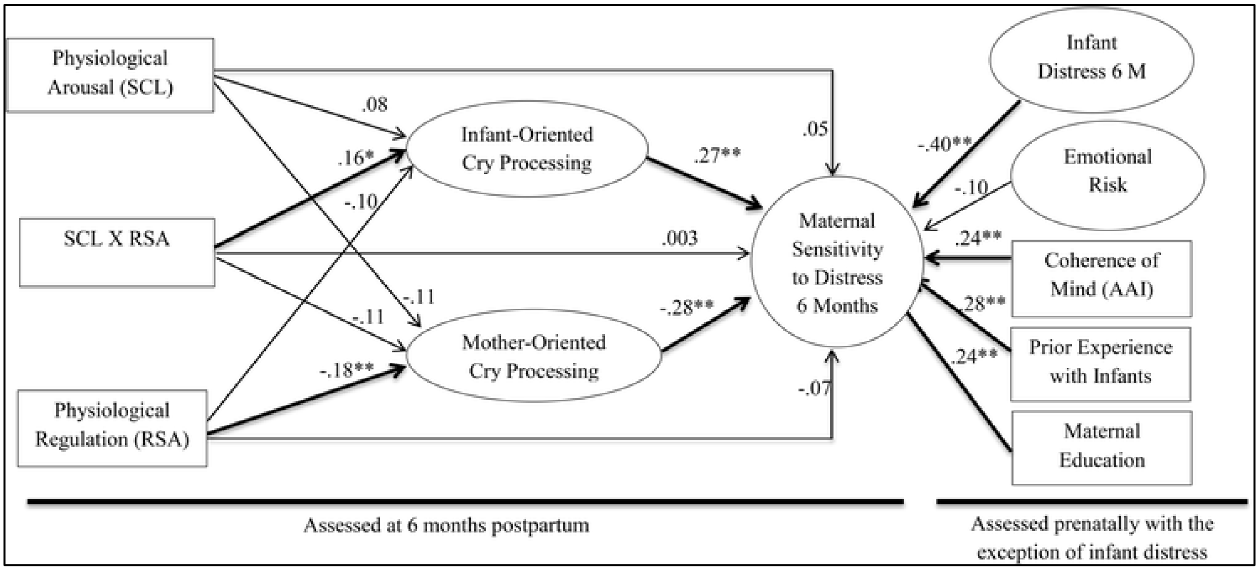

Figure 1. Structural model predicting 6-month maternal sensitivity to distress (concurrent model). Values are standardized coefficients. Statistically significant paths are bolded. $N = 259$. * $p < .05$. ** $p < .01$.

Results also indicated that the indirect effect of physiological regulation on maternal sensitivity via mother-oriented cry processing was significant, 95% CI [.01, .09], $\beta = .05$. The total indirect effect of the interaction between physiological arousal and physiological regulation on maternal sensitivity via mother's cry processing was also significant, 95% CI [.02, .14], $\beta = .08$. Thus, mothers who were highly aroused and well-regulated while interacting with their infants were more focused on their infants' needs and less on their own which in turn predicted more sensitive responses to their infants during distressing tasks.

Predicting Maternal Sensitivity at 1 Year

Similar to the 6-month model, the structural equation model predicting 1-year maternal sensitivity demonstrated adequate fit to the data, $\chi^2(166) = 285.684$; $p < .001$; CFI = .868; RMSEA = .053, 90% CI [.042, .063]; SRMR = .083. Standardized coefficients for the measurement model and correlated residual errors are displayed in Table 2 and standardized path coefficients are presented in Figure 2. Given the first half of the model is identical to the 6-month model as discussed above, other than trivial differences in the coefficients, we focus here on path coefficients in which 1-year sensitivity is the outcome. Similar to findings predicting 6-month maternal sensitivity, coherence of mind and maternal education were associated with higher maternal sensitivity to distress, and infant distress was associated with lower maternal sensitivity at 1 year. Emotional risk and prior experience caring for infants were not associated with maternal sensitivity at 1 year. Physiological arousal, physiological regulation, as well as their interaction, were not directly associated with maternal sensitivity at 1 year. However, mother's physiological regulation had a significant indirect effect on maternal sensitivity via mother-oriented cry processing, 95% CI [.004, .056], $\beta = .03$. Contrary to prediction, infant-oriented cry processing at 6 months did not predict maternal sensitivity to distress at 1 year.

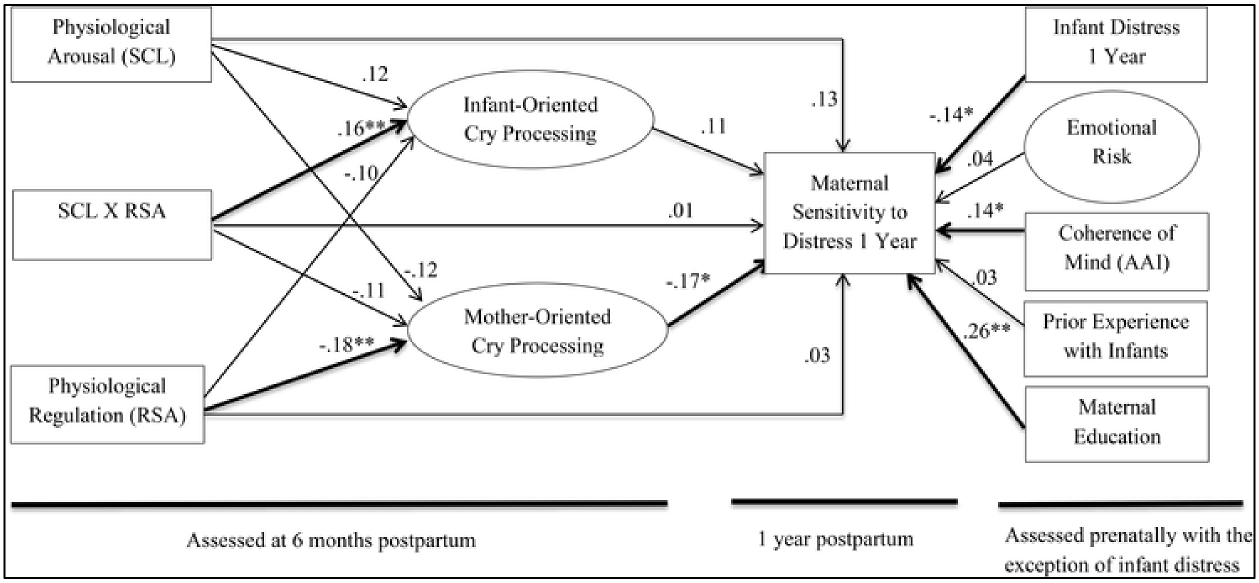

Figure 2. Structural model predicting 1-year maternal sensitivity to distress. Values are standardized coefficients. Statistically significant paths are bolded. $N = 259$. * $p < .05$. ** $p < .01$.

Discussion

The primary goal of this study was to examine the pathways by which mothers' physiological arousal and regulation while parenting predict maternal sensitivity concurrently and longitudinally. The results demonstrate that physiological regulation while caregiving is indirectly linked with more sensitive responding as a main effect via mother-oriented cry processing and by buffering mothers from the negative effects of heightened arousal on mother-oriented cry processing which in turn predicted sensitive behavior.

Links Between Physiology and Sensitivity

In contrast to prior research, there was no evidence of direct effects of maternal arousal, regulation, or their interaction on concurrent maternal sensitivity (e.g., Miller et al., 2015; Moore et al., 2009; Sturge-Apple et al., 2011). However, there were indirect effects whereby mothers' physiological responses to their infants during the distress tasks were linked to mothers' cry processing, which in turn predicted maternal sensitivity to distress. Mothers who demonstrated better physiological regulation in the moment were less likely to focus on their own needs by making negative/nonemotional attributions about their infants or endorsing mother-oriented beliefs and goals, which in turn predicted more sensitive maternal behavior. This indirect effect is highly consistent with Lemerise and Arsenio's (2000) proposition that physiology is a factor that influences social behavior via the encoding and interpretation of social partners' cues.

In addition, maternal arousal and regulation interacted such that physiological arousal was associated with higher infant-oriented cry processing when regulation was also high. This pattern is consistent with prior research linking joint patterns of arousal and regulation to patterns of social information processing among pregnant women presented with videos of crying infants (Leerkes et al., 2015) but is the first study to demonstrate the physiology *while* parenting operates in this manner. Mothers who are highly aroused are likely tuned in to their infants' cues, and simultaneously high regulation may facilitate empathic responding in contrast to low regulation which may prompt a greater focus on the mother's own distress and related cognitions (Eisenberg & Fabes, 1990). In turn, infant-oriented cry processing predicted more sensitive maternal behavior in the moment suggesting a benefit of well-regulated arousal in relation to concurrent sensitivity. This pattern converges with recent findings linking joint patterns of ANS/SNS activation during parenting with the quality of parenting among mothers of toddlers and preschoolers (Miller et al., 2015; Sturge-Apple et al., 2011), although they demonstrated direct effects on parenting, whereas we demonstrate indirect effects via cry processing.

In the longitudinal analyses predicting maternal sensitivity at 1 year, one pathway was significant: physiological regulation was linked with maternal sensitivity via lower mother-oriented cry processing. That this pathway was significant concurrently and longitudinally suggests it may be particularly robust, and both physiological regulation and mother-oriented cry processing while caregiving may be markers for compromised parenting beyond just the moment in which they are assessed. Both may be salient targets for interventions designed to promote maternal sensitivity. In contrast, infant-oriented cry processing was only linked with concurrent sensitivity. Perhaps negative, mother-oriented cognitions about infant behavior are a stable maternal trait, whereas empathic, infant-oriented responses may be influenced more by the current context, particularly infant state (Sprecher & Fehr, 2005).

The results add to the accumulating evidence that RSA withdrawal during challenging parenting tasks is adaptive as a main effect (e.g., Moore et al., 2009) and a moderator of links between arousal and parenting (Mills-Koonce et al., 2009). That the relation between SCL and parenting depends on concurrent levels of regulation is consistent with prior research (Leerkes et al., 2015) and Dix's (1991) assertion that affect undermines parenting if it is too strong.

Covariates and Sensitivity

The associations between covariates and maternal sensitivity are of interest also. First, that concurrent infant distress is linked with lower sensitivity is consistent with the view that responding to infant distress is challenging and suggests that adaptive physiological regulation and positive cry processing may be particularly important among mothers of temperamentally reactive children. Second, that broad emotional and personality risk factors were not significantly associated with sensitivity in the structural models may indicate that they undermine parenting via their effect on social information processing (Belsky & Jaffee, 2006). In contrast, the positive association between attachment coherence and higher sensitivity at both time points remained significant over and above the other predictors in the model, a finding consistent with prior research (e.g., Ablow et al., 2013; Leerkes et al., 2015) that points to the continued need to identify the mechanisms by which adult attachment influences parenting. That prior experience caring for children was linked with higher sensitivity at 6 months but not at 1 year suggests that the benefits of prior caregiving experiences among new mothers wane as experience parenting one's own infant accrues. Controlling for education reduces the likelihood that the link between cry processing and sensitivity is driven by better communication skills, an important point given cry processing was assessed via an interview.

Applied Implications and Conclusion

Links between maternal physiological regulation and adaptive parenting in this and other studies (Ablow et al., 2013; Mills-Koonce et al., 2009; Moore et al., 2009) underscore the promise of mindfulness and stress regulation training as two approaches that may enhance maternal sensitivity in distressing contexts. Encouraging mothers to be mindful of their own arousal and training them to regulate their distress when confronted with challenging parenting situations may enhance their ability to focus on their infants' needs rather than their own. Interventions aimed at reducing mothers' negative beliefs and attributions about infant crying, in addition to enhancing their cue detection and empathy, may be particularly effective. Many of these components are built in to existing interventions such as Attachment and Biobehavioral Catch-Up (Bick & Dozier, 2013), the Circle of Security (Cassidy et al., 2010), and the Video-Feedback Intervention to Promote Positive Parenting (Juffer, Bakermans-Kranenburg, & van IJzendoorn, 2008). Although the intervention studies conducted to date demonstrate these approaches are effective at enhancing maternal sensitivity and infant outcomes, it is not clear which of the targeted underlying skills such as cue detection and maternal emotion regulation have in fact been enhanced as they have not been directly measured. In the future, precise work of this nature could shed important insights on enhancements to existing interventions and inform basic science about the predictors of sensitive parenting. The methods used to assesses physiology and cry processing in the current study could be useful in this regard.

An important limitation of our research is that the observations of maternal sensitivity to distress were relatively brief at each time point. In addition, our methods to assess cry processing and sensitivity are novel. Therefore, replication of this work using other measurement approaches is warranted to ensure they are not merely an artifact of our approach. However, three features of the design are particularly noteworthy. First, relatively few studies have incorporated concurrent indices of sympathetic and parasympathetic activation during caregiving (Lorber & O'Leary, 2005; Miller et al., 2015; Sturge-Apple et al., 2011). By doing so, we demonstrate that patterns of affective arousal and regulation while caregiving are useful predictors of social information processing and sensitive parenting over and above main effects. Second, we included a number of covariates to rule out competing explanations for observed findings. Of note, the reported links between physiology, cry processing, and sensitivity are independent of mothers' adult attachment coherence and their dispositional emotional characteristics. Third, our sample was relatively large and more diverse than prior samples increasing confidence in the generalizability of results. As such, we can conclude that mothers who are physiologically well regulated during distress eliciting caregiving tasks are more likely to respond sensitively to their infants by virtue of more adaptive social information processing.

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Table 1. Descriptive Statistics and Intercorrelations

Variables	*M*	*SD*	α	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1. Coherence of mind	5.31	1.46	—	—																						
2. Depressive symptoms	13.64	8.71	.87	.04	—																					
3. Emotion reg. difficulties	1.87	.43	.91	.02	.51**	—																				
4. Trait negative emotions	1.94	.53	.91	.01	.65**	.51**	—																			
5. Trait positive emotions	3.36	.55	.78	.13*	–.29**	–.23**	–.13*	—																		
6. Agreeableness	44.50	6.15	.79	.16*	–.28**	–.32**	–.40**	.23**	—																	
7. Neuroticism	30.07	7.01	.81	–.15*	.55**	.58**	.63**	–.23**	–.40**	—																
8. Physiological arousal	3.23	2.26	.96	.25**	–.14	–.04	–.14*	.08	.14*	–.16*	—															
9. Physiological regulation	.38	.73	.81	–.05	–.05	.02	–.02	.03	–.01	–.00	–.10	—														
10. Empathy	1.27	.25	.74	.11	–.01	.10	.07	.05	.09	–.00	.08	–.08	—													
11. Distress detection	7.86	13.87	—	.09	–.08	.01	.03	.07	.13	–.01	.03	–.07	.14*	—												
12. Situation attributions	2.04	.60	.83	.03	–.07	–.04	.02	.06	.05	–.02	.08	–.07	.62**	.19**	—											
13. IO cry beliefs	4.60	.42	.84	.07	–.19**	–.11	–.17*	.25**	.25**	–.12	.10	–.02	.16*	.06	.15*	—										
14. Negative attributions	1.30	.29	.83	–.19**	.16*	.07	.13	–.08	–.24**	.18**	–.09	–.04	.13	–.04	.22**	–.26**	—									
15. Minimizing attributions	1.42	.43	.86	–.03	.09	.12	.13	.09	–.15*	.20**	–.04	–.04	.21**	.01	.31**	–.16*	.46**	—								
16. MO cry beliefs	2.55	.55	.78	–.12	.23**	–.03	.16*	–.05	–.24**	.23**	–.09	–.18*	–.10	–.11	–.08	–.27**	.41**	.15*	—							
17. I distress arm restraint	4.11	.37	—	–.04	.11	–.05	.02	–.08	–.11	.02	–.04	–.08	.31**	–.12	.37**	–.05	.14*	.29**	.17*	—						
18. I distress novel toy	4.09	.31	—	.03	.00	–.13*	–.06	.05	.08	–.06	.03	–.04	.27**	–.03	.45**	.08	.02	.07	–.03	.34**	—					
19. I distress still face	4.70	.88	—	–.15*	.03	.07	.09	–.01	–.10	.15*	.07	–.15*	.39**	.08	.51**	.07	.21**	.33**	.10	.29**	.14*	—				
20. MSen arm restraint 6M	2.75	.26	—	.20**	–.15*	–.06	–.07	.08	.16*	–.10	.14*	–.04	.03	.23**	.00	.06	–.14	–.09	–.22**	.38**	–.16*	–.08	—			
21. MSen novel toy 6M	2.47	.27	—	.19**	–.12	–.02	–.14*	.11	.19**	–.15*	.04	.06	.17*	.18*	.11	.14*	–.15*	–.15*	–.30**	–.06	–.16*	–.12	.36**	—		
22. MSen still face 6M	2.68	.31	—	.27**	–.12	–.11	–.13*	.09	.30**	–.27**	.09	.09	–.24**	–.02	–.22**	–.00	–.23**	–.34**	–.23**	–.24**	.01	–.67**	.24**	.28**	—	
23. I distress total 1 Y	4.19	.27	—	–.07	.05	–.05	.09	.03	–.03	.02	.08	–.07	–.02	–.07	.05	–.09	.09	.15*	.16*	–.08	–.12	.13	.04	–.17*	–.17*	—
24. MSen total 1Y	2.37	.25	—	.27**	–.15*	–.02	–.08	–.11	.19**	–.20**	.18*	.02	.20**	.19**	.08	.14*	–.16*	–.14*	–.28**	–.18*	–.00	–.05	.40**	.27**	.22**	–.09

Note. n ranges from 191 to 259. Reg = regulation; IO = infant-oriented; MO = mother-oriented; I = infant; MSen = maternal sensitivity; 6M = 6 months; 1Y = 1 year. * $p < .05$. ** $p < .01$.