Maternal physiological dysregulation while parenting poses risk for infant attachment disorganization and behavior problems

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Abstract:

The extent to which indices of maternal physiological arousal (skin conductance augmentation) and regulation (vagal withdrawal) while parenting predict infant attachment disorganization and behavior problems directly or indirectly via maternal sensitivity was examined in a sample of 259 mothers and their infants. Two covariates, maternal self-reported emotional risk and Adult Attachment Interview attachment coherence were assessed prenatally. Mothers' physiological arousal and regulation were measured during parenting tasks when infants were 6 months old. Maternal sensitivity was observed during distress-eliciting tasks when infants were 6 and 14 months old, and an average sensitivity score was calculated. Attachment disorganization was observed during the Strange Situation when infants were 14 months old, and mothers reported on infants' behavior problems when infants were 27 months old. Over and above covariates, mothers' arousal and regulation while parenting interacted to predict infant attachment disorganization and behavior problems such that maternal arousal was associated with higher attachment disorganization and behavior problems when maternal regulation was low but not when maternal regulation was high. This effect was direct and not explained by maternal sensitivity. The results suggest that maternal physiological dysregulation while parenting places infants at risk for psychopathology.

Keywords: maternal physiological dysregulation | infant attachment disorganization | infant behavior problems | maternal sensitivity

Article:

Infants whose relationships with their mothers are characterized by disorganization or who display elevated behavioral problems are at heightened risk for subsequent conduct problems, elevated internalizing and externalizing symptoms, and compromised relations with peers (Blandon, Calkins, Grimm, Keane, & O'Brien, 2010; Calkins, Blandon, Williford, & Keane, 2007; Lyons-Ruth & Jacobvitz, 2008). Thus, identifying maternal characteristics that confer risk for infant psychopathology has important implications for early screening to identify families at risk and for the creation of intervention efforts to promote infant well-being. In the current report, we examine the extent to which mothers' physiological arousal and regulation

while parenting at 6 months predict their infants' subsequent disorganized attachment status and behavior problems. We examine the extent to which relations of maternal arousal and regulation to infant outcomes are direct or indirect via sensitive maternal behavior. We begin with a brief overview of known antecedents of attachment disorganization and behavior problems and then elaborate on the possible contribution of maternal physiological dysregulation to these outcomes.

Antecedents of Attachment Disorganization and Behavior Problems

According to attachment theory (Ainsworth, Blehar, Waters, & Wall, 1978; Bowlby, 1973), most infants develop organized schema about themselves and the world around them based on their repeated interactions with their caregivers. Infants whose mothers are typically sensitive and responsive to their cues develop a secure working model characterized by positive feelings of self and trust in others to meet their needs. This is demonstrated behaviorally by taking pleasure in the mother's company as well as seeking the mother out and being comforted by her in times of stress. In contrast, infants whose mothers are not consistently sensitive or responsive develop an insecure working model characterized by negative feelings about self and distrust in others to meet their needs. This is demonstrated behaviorally by avoiding the mother in times of stress or a mix of seeking the mother out and resisting her calming efforts. A smaller group of infants, however, demonstrate disorganized behaviors that are not clearly goal directed, suggesting the absence of an organized schema about themselves and the world (Main & Solomon, 1990). Disorganization is characterized by engagement in contradictory behaviors such as walking toward the mother backward, freezing, and displaying apprehension/fear of the parent. Research has demonstrated that insensitive maternal behavior, anomalous behaviors, child maltreatment, and maternal psychiatric disorders predict infant attachment disorganization (Lyons-Ruth & Jacobvitz, 2008). It is believed that infant attachment disorganization may be the result of having mothers who are themselves frightened while caregiving and engage in frightening behavior toward the infant (Main & Hesse, 1990). Mothers who are affectively dysregulated while interacting with their infants may be particularly likely to engage in these behaviors, placing their infants at risk for attachment disorganization.

Early symptoms of behavior problems among infants include internalizing behaviors, such as anxiety, social withdrawal, and depression, and externalizing behaviors, such as aggression and destructive behaviors (Achenbach, Edelbrock, & Howell, 1987). Conceptualizations about the etiology of early behavior problems focus on multiple risk factors including child characteristics, such as negative temperamental traits and emotion regulation deficits, and environmental risks, such as insensitive parenting and maternal psychopathology (Cicchetti & Rogosch, 1996; Sroufe & Rutter, 1984). Mothers who become distressed themselves and respond insensitively when their infants are distressed likely contribute to escalated infant distress in the moment and the development of negative schemas about the control and expression of emotions. These in turn may inhibit the development of infants' adaptive self-regulation and contribute to behavior problems over time (Calkins, 1994; Leerkes, Blankson, & O'Brien, 2009). Thus, we assert that maternal physiological dysregulation while parenting is related to infant behavior problems over time because it contributes to insensitive maternal behavior and undermines infant regulation. In the following sections, we describe the physiological processes under consideration and summarize relevant literature.

Understanding Patterns of Maternal Physiology

The autonomic nervous system has two branches, each of which serve unique functions. The sympathetic nervous system (SNS) controls fight or flight responses when confronted with threats, whereas the parasympathetic nervous system (PNS) promotes homeostasis and restorative processes. In the current investigation, we focus on change from baseline in mothers' skin conductance level (SCL) and vagal withdrawal during parenting tasks designed to elicit infant distress. SCL, or the amount of sweat that rises from sweat ducts on the hands or feet, is linked with SNS activation. SCL is well known to increase when individuals are emotionally aroused, and as such is frequently used as an indicator of emotional arousal, although it also increases as a function of cognitive activity (Stern, Ray, & Quigley, 2001). In contrast, vagal withdrawal reflects vagal regulation of the heart when an individual is challenged, a PNS response. Such regulation is indexed by decreases in respiratory sinus arrhythmia (RSA) during situations where coping or regulation is required (Porges, 2007). This decrease in RSA is often described as the functioning of the "vagal brake" because a decrease, or withdrawal, in vagal input to the heart has the effect of stimulating increases in heart rate. During challenging or threatening tasks, such a response reflects physiological processes that allow the person to shift focus from internal homeostatic demands to other demands that require internal processing such as the generation of coping strategies to control affective arousal. Thus, we view vagal withdrawal from baseline to challenging parenting task as an indicator of physiological regulation. However, some have argued that high RSA or RSA augmentation is adaptive, particularly in social situations because it promotes social engagement (Hastings et al., 2008; Porges, 2007). Parenting is certainly social interaction, but because we focus on parenting during tasks designed to elicit infant distress, we believe that RSA withdrawal is the adaptive physiological response because infant crying is a stressor that requires maternal coping. Changes in SNS and PNS activity can both be viewed as regulatory because each contributes to behavioral change in response to environmental demands. Nevertheless, given the demonstrated functions of each, and the nature of our observational tasks, we refer to SCL augmentation as a measure of *arousal* and RSA withdrawal as a measure of *regulation*.

Although the SNS and PNS have often been viewed as interdependent systems that act in an antagonistic fashion (i.e., if one is high, the other is low), Berntson, Cacioppo, and Quigley (1991) have argued that the two systems can function independently, reciprocally (i.e., if one increases, the other decreases reflecting autonomic balance), or coactively (i.e., both can increase or decrease simultaneously reflecting coactivation). Thus, patterns of sympathetic and parasympathetic activity within the autonomic nervous system may ultimately prove most useful in predicting risk for psychopathology and maladaptive behavior because simultaneous patterns of sympathetic and parasympathetic activity reflect different underlying physiological states (Beauchaine, 2001). For example, high SCL augmentation accompanied by high RSA withdrawal may reflect a state in which arousal and regulation counterbalance one another. In contrast, high SCL augmentation accompanied by low RSA withdrawal may be viewed as underregulation. Mothers in this dysregulated state may be particularly likely to display negative affect in their infants' presence and to respond to them insensitively. Likewise, low SCL augmentation accompanied by high RSA withdrawal may be viewed as overregulation and may prompt flat affect and nonresponsiveness. Thus, although we consider main effects of both mothers' skin conductance augmentation and vagal withdrawal while parenting, we propose that

joint patterns of skin conductance and vagal regulation, that is, the interaction between SNS augmentation and PNS withdrawal, will be particularly relevant in relation to maternal sensitivity and infant adjustment as elaborated below.

Indirect Effects on Infant Outcomes Via Maternal Sensitivity

Existing conceptualizations suggest an indirect effect whereby maternal arousal and regulation may undermine sensitive maternal behavior, which in turn contributes to infant attachment disorganization and behavior problems. In particular, Dix (1991) theorized that parental negative emotions in response to child behavior increase the self-focus of parenting goals, which interferes with parents' ability to respond sensitively to children's needs, and subsequent research based on parental self-reports of emotion while parenting are consistent with this view (Dix, Gershoff, Meunier, & Miller, 2004; Leerkes, 2010). The notion that high SCL augmentation and low RSA withdrawal in response to cry stimuli or while parenting are linked with less adaptive parenting has been tested in recent research yielding somewhat mixed results.

For example, child abusers (Frodi & Lamb, 1980) and mothers who engage in high rates of harsh discipline (Joosen, Mesman, Bakermans-Kranenburg, & van IJzendoorn, 2013) demonstrate higher SCL augmentation relative to other mothers when presented with infant cry stimuli. In other studies, SCL augmentation while parenting (Lorber & O'Leary, 2005) and when exposed to cry stimuli (Ablow, Marks, Feldman, & Huffman, 2013; Emery, McElwain, Groh, Haydon, & Roisman, 2014) was unrelated to observed parenting. In studies of RSA in which mothers were presented with infant cry stimuli, low mean RSA (Ablow et al., 2013) and RSA withdrawal relative to baseline (Joosen, Mesman, Bakermans-Kranenburg, Pieper, et al., 2013; Joosen, Mesman, Bakermans-Kranenburg, & van IJzendoorn, 2013) predicted higher sensitivity and lower harsh discipline.

Moreover, RSA withdrawal while parenting has also been linked with adaptive concurrent parenting. For example, mothers rated as highly sensitive during the Still Face procedure demonstrated greater RSA withdrawal from baseline to the still-face reunion than less sensitive mothers (Moore, 2009), and nonabusive mothers demonstrated heightened positive parenting and reduced negative parenting immediately following reductions in RSA during a challenging joint problem-solving task (Skowron, Cipriano-Essel, Benjamin, Pincus, & Van Ryzin, 2013). Finally, mothers' RSA withdrawal while interacting with their infants during the Still Face reunion relative to a baseline was protective in relation to concurrent parenting as it attenuated the association between mothers' high cortisol and maternal negative intrusiveness (Mills-Koonce et al., 2009). In contrast, Lorber and O'Leary (2005) reported that decreased RSA from baseline to challenging parenting task was linked with more overreactive discipline. Different results across studies could be a function of methodological differences such as use of mean scores versus change scores and the extent to which observational contexts were emotionally charged, or they could be a function of untested interactions between RSA withdrawal and SCL augmentation.

Links between patterns of SNS and ANS responding during parent–child interaction and observed parenting have been examined in three prior studies. In the first, links between distinct profiles of sympathovagal balance (i.e., the ratio by which heart rate is controlled by the SNS versus the PNS) across Strange Situation episodes and observed parenting during a free play

were examined (Sturge-Apple, Skibo, Rogosch, Ignajatovic, & Heinzelman, 2011). Mothers who were hyperaroused, characterized by higher SNS control of the heart relative to PNS control particularly during the separation episodes with limited increases in PNS control (recovery) during the reunion, demonstrated the highest levels of harsh and intrusive parenting. Mothers who were hypoaroused, characterized by higher PNS control of the heart relative to SNS control and limited increases in SNS control (i.e., arousal) during the separation episodes, demonstrated the highest levels of disengagement. Mothers who were moderately aroused, characterized by a more balanced ratio of SNS and PNS activation during separations and recovery during reunion episodes, demonstrated significantly higher sensitivity and less negativity than the other groups. Thus, mothers with a flexible versus extreme pattern of arousal and regulation in a stressful parenting context were more sensitive.

In the second study, Miller, Kahle, Lopez, and Hastings (2015) used an approach to assess patterns of SNS/PNS activation proposed by Berntson, Norman, Hawkley, and Cacioppo (2008). They standardized separate indicators of mothers' SNS activation (cardiac preejection period) and PNS activation (RSA) during challenging joint problem-solving tasks with their children, and then calculated their sum and their difference. A low sum reflects low activation across systems, whereas a high sum reflects coactivation of PNS and SNS. A low difference score reflects ANS dominance, whereas a high difference score reflects PNS dominance. Mothers engaged in more observed negative parenting with their preschoolers when they demonstrated a pattern of high SNS dominance. In addition, mothers reported fewer negative parenting behaviors when SNS and PNS activity were both high (coactivation) than when both were low (coinhibition). Although these results suggest that patterns of SNS and PNS activity during parenting predict parenting quality, they are not consistent with our prediction that high arousal accompanied by high vagal withdrawal is adaptive. Rather, high RSA during parenting may be adaptive, at least in the context of a challenging, but not emotionally arousing, context.

Finally, in prior reports from this project, we measured maternal SCL and RSA during resting baselines, during exposure to videos of crying infants while participants were pregnant, and during caregiving tasks designed to elicit infant crying when their infants were 6 months old. We calculated difference scores to reflect change from baseline to parenting or cry stimuli. Then, we examined the extent to which SCL augmentation, RSA withdrawal, and their interaction predicted maternal sensitivity during distress-eliciting tasks when infants were 6 months and 1 year old. The results demonstrate that high SCL augmentation was indirectly linked with more sensitive maternal behavior when RSA withdrawal was high, but not when RSA withdrawal was low via a greater focus on infant needs and lesser focus on mother needs. A similar pattern was apparent when using the prenatal (Leerkes et al., 2015) and the postnatal (Leerkes et al., in press) measures of SCL and RSA responding. In the current report, we focus on maternal physiology when infants are 6 months old because that is a direct measure of maternal physiology while actively caregiving, and we are interested in the extent to which, and pathways by which, maternal arousal and regulation while caregiving may place infants at risk for subsequent maladjustment. Although the methods employed and pattern of results in these studies vary, they each lend support to the view that unique patterns of SNS/PNS activity have different implications for the quality of parenting.

If poorly regulated arousal does predict less sensitive behavior, as we predict, it may be indirectly linked with child outcomes because insensitive maternal behavior has been linked to both attachment disorganization (van IJzendoorn, Schuengel, & Bakermans-Kranenburg, 1999) and early behavior problems (Leerkes et al., 2009). We know of no prior studies that test indirect effects of maternal physiological arousal and regulation while parenting on child outcomes via parenting. However, studies of maternal self-reported arousal and regulation lend support to this perspective. For example, the positive association between parental emotion dysregulation and sons' emotion dysregulation was partly indirect via parents' use of inappropriate discipline (Kim, Pears, Capaldi, & Owen, 2009). Likewise, mothers' effortful control (which includes emotion regulation) was indirectly linked with infants' subsequent higher effortful control and lower negative affect via specific parenting practices and characteristics of the home environment (Bridgett, Burt, Laake, & Oddi, 2013; Bridgett et al., 2011). Finally, mothers' self-reported anger in response to infant crying was indirectly linked with infant attachment avoidance via mothers' punitive and minimizing responses to toddler distress (Leerkes, Parade, & Gudmundson, 2011).

Direct Effects of Maternal Dysregulation on Infant Outcomes

Maternal arousal and regulation while parenting may also be directly related to infant outcomes through several distinct mechanisms of transmission. First, infants whose mothers tend to become dysregulated when confronted with a stressor may be at heightened risk for dysregulation, and subsequent maladjustment, via genetic transmission. Negative affect and effortful control have both been demonstrated to be moderately to highly heritable (Lemery-Chalfant, Kao, Swann, & Goldsmith, 2013), as are physiological indices of sympathetic arousal and parasympathetic regulation (De Geus, Kupper, Boomsma, & Snieder, 2007; Lensvelt-Mulders & Hettema, 2001). Second, mothers' dysregulation while parenting may increase infant distress in the moment via emotion contagion, whereby infants copy adult facial expressions and then feel a matching internal state (Hatfield, Cacioppo, & Rapson, 1994), a response that is particularly likely to occur when infants are in stressful or ambiguous situations in which they engage in social referencing to their mothers for clues as to how to feel and behave (Hornik, Risenhoover, & Gunnar, 1987). Third, in the context of proximal caregiving, the physiological components of mothers' affective dysregulation (e.g., rapid breathing, irregular heart rate, and bodily tension) may contribute to infants' physiological dysregulation via synchronization of biological rhythms (Feldman, 2007). Chronic exposure to maternal dysregulation may prompt persistent activation of infants' stress response systems and less effective regulation over time (Moore, 2009), contributing to behavioral problems. In addition, maternal dysregulated affect may be frightening to infants, contributing to attachment disorganization (Main & Hesse, 1990).

To our knowledge, longitudinal relations between mothers' physiological dysregulation (i.e., concurrent high arousal and low regulation) while parenting and their children's subsequent outcomes have not been tested in prior research, but related evidence supports this possibility. For example, mothers' self-reports of emotion regulation difficulties and proneness to negative emotions have predicted infant dysregulation (Gratz et al., 2014), attachment insecurity (Izard, Hayne, Chisholm, & Baak, 1991), and adult sons' emotional/behavioral dysregulation (Kim et al., 2009) independent of parenting. However, the extent to which parents' global emotion dysregulation is related to their dysregulated affect while parenting is unclear. Thus, studies of parenting-related affect are of greatest relevance to the current investigation.

In one such study, observed maternal negative affect while toddlers were distressed was linked with toddlers' elevated externalizing symptoms (Martin, Clements, & Crnic, 2011). Likewise, two teams of investigators have examined maternal affect while parenting in relation to attachment insecurity, but not disorganization. Observed maternal negative affect during mother–infant interaction tasks was linked with less attachment security in one (Main, Tomasini, & Tolan, 1979) and greater attachment security in the other (Pauli-Pott & Mertesacker, 2009). These findings suggest that the impact of maternal arousal on child adjustment may be dependent on other factors, including the extent to which a mother effectively regulates her negative arousal. The nature of the interactive context may also play a role. That is, maternal dysregulation may be particularly maladaptive for infants in distressing contexts, when the infant requires maternal assistance to regulate. Consistent with this view, mothers who reported feeling anxious in response to videotapes of crying infants prenatally had infants who were rated as more resistant during the Strange Situation independent of multiple measures of maternal sensitivity (Leerkes et al., 2011). Of particular relevance, mothers who responded to audiotapes of a crying infant with heart rate acceleration had infants who were more likely to be classified as insecurely attached 1 year later (Donovan & Leavitt, 1989). In addition, some studies have demonstrated concurrent associations between maternal physiological dysregulation (high RSA/low RSA withdrawal) and less adaptive functioning such as attachment insecurity (Hill-Soderlund et al., 2008) and negative engagement with the mother during the reengagement phase of the still-face paradigm (Ham & Tronick, 2009). Thus, prior research supports the view that maternal dysregulation while parenting may be directly linked with infant maladjustment.

The Current Study

In sum, our goal was to examine the extent to which mothers' physiological arousal and regulation while parenting at 6 months predict infants' subsequent attachment disorganization at 14 months and behavior problems at 27 months. Our primary hypothesis is that SCL augmentation and RSA withdrawal interact such that high SCL augmentation is linked with maladaptive infant outcomes only when concurrent maternal RSA withdrawal is low; we believe this pattern reflects an underregulated state during which mothers may be particularly likely to display their distress to their infants or behave insensitively. Maternal insensitivity then contributes to infant dysregulation in the moment and compromises infant well-being over time. We test direct effects of maternal physiology (SCL augmentation, RSA withdrawal, and their interaction term) on infant outcomes and indirect pathways of these physiological responses through observed maternal sensitivity during distressing tasks at 6 and 14 months. We propose that maternal arousal while caregiving will be linked with attachment disorganization and higher behavior problems, directly or through compromised maternal sensitivity, when maternal regulation is low, but not when maternal regulation is high. We control for global indices of maternal affective dysregulation to increase our confidence that observed associations are a function of maternal affective processes while parenting and not trait maternal affect. Likewise, we control for maternal attachment coherence because adult attachment has been demonstrated to predict maternal physiology, sensitivity, and infant attachment outcomes in prior research (Ablow et al., 2013; van IJzendoorn et al., 1999). Finally, given known mean differences in a number of the constructs under investigation as a function of race, the fact that much of the prior literature on early parenting and child outcomes has focused on European American families

raises questions about generalizability, but 50% of our sample is European American and 50% is African American, and we test race as a potential moderator of the proposed model. Consistent with prior research, we anticipated mean differences in some variables based on race, but we did not anticipate that the pattern of associations would vary by race (Leerkes et al., 2015; Mesman, van IJzendoorn, & Bakermans-Kranenburg, 2012).

Method

Participants

Participants in the current study were 259 primiparous mothers (128 European American, 131 African American) 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. At recruitment, 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. Of the initial 259 participants, 230 provided data related to infant outcomes (n = 203 for attachment disorganization, n = 209 for problem behavior). The primary reasons for missing child outcomes data were inability to locate or contact mothers, moving from the area, or being too busy. All participating infants were full term and healthy; 51% were female.

Procedure

Expectant mothers were recruited at childbirth classes offered in the local hospital and public health department; breastfeeding classes offered through the Special Supplemental Nutrition Program for Women, Infants and Children; and obstetric practices. 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 (AAI; George, Kaplan, & Main, 1984/1985/1996). Mothers and infants visited our laboratory for a videotaped observation of mother–infant interaction within 2 weeks of the infant's 6-month birthday (M = 6.39, SD = 0.72) and when infants were 14 months old (M = 13.9, SD = 0.98). The Strange Situation was also conducted in the laboratory at 14 months. Mothers completed the Brief Infant–Toddler Social Emotional Assessment (BITSEA) mailed to their home when infants were about 27 months old (M = 27.32, SD = 2.52). Mothers received $50 and a gift at the completion of the prenatal and 6-month visit, $100 after the 14-month visit, and $120 for completing measures when children were 27 months.

Measures

Emotional risk. Prior to the prenatal interview, mothers completed self-report measures to assess emotional and personality characteristics that pose risk for insensitive maternal behavior; this construct was planned to serve as a covariate. The Center for Epidemiologic Studies—Depression Scale (Radloff, 1977) was administered to assess depressive symptoms; Cronbach α = 0.87. The Difficulties in Emotion Regulation Scale (Gratz & Roemer, 2004) was administered

to assess the extent to which mothers struggle in the awareness, clarity, acceptance, and regulation of their negative emotions; α = 0.91. The Differential Emotions Scale (Izard, Libero, Putnam, & Haynes, 1993) was administered to assess the extent to which mothers typically experience positive (α = 0.78) and negative emotions (α = 0.91) in daily life. The NEO Five-Factor Inventory (Costa & McCrae, 1992) was administered to assess agreeableness (12 items that reflect the extent to which the mother is trusting, helpful, and forgiving; α = 0.79) and neuroticism (12 items that reflect the extent to which the mother is anxious, hostile, and depressed; α = 0.81). All items from these scales were standardized and averaged (items assessing positive emotions from the Differential Emotions Scale and agreeableness from the NEO Five-Factor Inventory were reverse coded) to create a composite variable representing global emotional risk. The Cronbach α value for this composite measure is 0.95.

AAI. At the prenatal visit, mothers were administered the AAI (George et al., 1984/1985/1996), 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. AAI transcripts were coded by trained coders reliable with the lab of Dr. Mary Main using the AAI Scoring and Classification System (Main & Goldwyn, 1998). In prior research, infant attachment disorganization has been predicted by mothers' unresolved status on the AAI (Madigan et al., 2006), but only 10 mothers in our sample were unresolved. Thus, we selected the coherence of mind rating (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. Interrater reliability on the coherence rating was good (intraclass correlation = 0.75, $p < .001$), based on 50 double-coded transcripts.

6-Month observation of mother behavior. During the 6-month visit, electrodes were placed on mothers' right collarbones and under their 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 for subsequent download to a computer. Once physiological recording devises were in place, infants were strapped into an infant seat, and mothers sat in a chair to their right. Mothers were asked to sit quietly for 2 min to collect a resting baseline measure; 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. While immobile in front of the infant, the truck's horn, ignition and a voice sounded, and music played while the truck vibrated and its lights flashed; this sequence was repeated twice. 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 neutral and 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 so they were at eye level. 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.

SCL augmentation. SCL was continuously recorded in microsiemens on the Biolog at a sampling rate of 100 Hz, and average SCL during each task was calculated. Difference scores were calculated for the mother-involved portions of the arm restraint and novel toy task and the reengagement phase of the still face by subtracting the baseline SCL score from the SCL scores during these segments. High scores indicate an increase in arousal from baseline to parenting tasks. Change scores for each task were averaged to yield a single measure ($\alpha = 0.96$).

RSA withdrawal. Mothers' electrocardiogram was recorded at a sampling rate of 1 kHz. A data file containing the interbeat intervals, 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 interbeat interval data, and 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 (0.12–0.40 Hz) in adults. RSA (ms^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, and still face reengagement episode) 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 ($\alpha = 0.81$). High scores indicate greater vagal withdrawal and better physiological regulation.

14-Month observation of mother behavior. During the 14-month visit, mothers and infants participated in two distress-eliciting tasks used previously by Leerkes and Wong (2012). The first distress 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 tightly so it was impossible for the infant to open. The researcher placed the jar near the infant and encouraged the infant to open the jar with verbal prompts. After 4 min, the researcher opened the jar and allowed the infant to play with the phone. Next, during the *novel character approach* task 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 neutral and uninvolved unless she wanted to end the activity. Then, the experimenter signaled the mother that she could interact with her infant as she pleased for the remaining 3 min.

Maternal sensitivity. Maternal behavior and infant affect were continuously rated/coded from digital media files using INTERACT 9 (Mangold, Arnstorf, Germany). Event-based coding was used such that a behavior was coded at the moment it first occurred and the onset of the next behavior served as its offset. Maternal behaviors during the distress-eliciting tasks at 6 and 14 months were coded using 12 mutually exclusive categories (negative, intrusive, mismatched

affect, withdraw, distracted, persistent ineffective, monitor, task focused, calming, supportive, nontask focused engagement, and routine care) described in Leerkes (2010). Coders were blind to other data. Thirty cases were double-coded for reliability at 6 months ($\kappa = 0.77$) and 27 cases at 14 months ($\kappa = 0.80$); disagreements were resolved via consensus. A different team of coders rated infant affect during these tasks on a 7-point scale ranging from 1 = *high positive affect* (intense smile, laughing, or squealing) to 7 = *high negative affect* (screams, wails, or sobs intensely). Interrater reliability for infant affect at 6 months and 1 year were as follows: weighted $\kappa = 0.76$ and 0.75 based on 34 and 30 double-coded tapes, respectively.

Next, the maternal behavior and infant affect code files were merged, and the sensitivity of maternal behavior at each moment given the infant's concurrent affective state was rated on a 3-point scale (1 = *insensitive*, 2 = *moderately sensitive*, and 3 = *sensitive*). For example, monitoring (i.e., watching but not interacting) 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 need to which the mother is not responding. Sensitivity ratings for each discrete maternal behavior during infant positive, neutral, and negative affect are described in Leerkes (2010). Mothers' average rating of sensitivity during the mother-involved portions of the distress-eliciting tasks at 6 and 14 months correlated positively ($r = .40$, $p < .01$) and were averaged to create a variable reflecting sensitivity during distress tasks over the first year.

Strange Situation at 14 months. Infant–mother attachment security was assessed using the Strange Situation procedure (Ainsworth et al., 1978). The Strange Situation was administered according to standard procedures, and videotapes of all Strange Situations were coded by E. Carlson. Strange Situations were scored using the standard three-way classifications of secure, insecure–avoidant, and insecure–resistant. Then, the presence of disorganized behaviors was rated on a 9-point scale, and children receiving a score of 5 or higher were classified as disorganized following procedures developed by Main and Solomon (1990). Thirty cases were double-coded for reliability, and there was 87% agreement for the disorganized classification ($\kappa = 0.60$). A binary variable representing infant attachment disorganization was created such that 0 = *not disorganized* ($n = 159$) and 1 = *disorganized* ($n = 44$).

Infant behavior problems at 27 months. Mothers reported on 31 items from the BITSEA (Briggs-Gowan, Carter, Irwin, Wacthel, & Cicchetti, 2004) that assessed infant problem behaviors. These items tap externalizing, internalizing, and general social/emotional dysregulation symptomatology. All items were scored 0 = *not true/rarely* to 2 = *very true/often.* The BITSEA total problems scale has demonstrated convergent validity with the Child Behavior Check List total problem scale (Briggs-Gowan et al., 2004). A summary score was created by summing across all items to represent total infant behavior problems, $\alpha = 0.81$.

Results

Preliminary analyses

Mothers for whom infant outcome data were available were rated as having higher coherence of mind than mothers for whom infant outcome data were missing, $t(257) = 2.32$, $p < .05$. They did not differ on maternal age, education, family income, ethnicity, emotional functioning,

physiological arousal and regulation, or sensitivity. Missing data were handled via full information maximum likelihood, which takes all available data into account.

Next, potential demographic covariates (maternal education, race, and infant gender) were identified by examining their correlations with the primary variables. Mothers who were more educated and who were European American (relative to African American) were rated higher on coherence of mind and sensitivity, became more physiologically aroused during the tasks, and reported lower infant behavior problems. Infant gender was not associated with any primary variables. Thus, maternal education and race were included as covariates in addition to the planned covariates: global emotional risk and attachment coherence. As anticipated, high maternal emotional risk and low attachment coherence were linked with lower maternal arousal, less sensitive maternal behavior, and higher mother-reported child behavior problems. Means, standard deviations, and intercorrelations for all variables are presented in Table 1.

Table 1. Descriptive statistics and intercorrelations

	M	***SD***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1. Maternal education	3.81	1.79	—								
2. Race[a]	49.40%	—	.33**	—							
3. Prenatal emotional risk	0.00	1.00	–.29**	–.10	—						
4. Prenatal coherence of mind	5.31	1.46	.40**	.25**	–.09	—					
5. 6-month SCL augmentation	3.23	2.26	.21**	.37**	–.16*	.25**	—				
6. 6-month RSA withdrawal	0.38	0.73	.02	.07	–.02	–.05	–.10	—			
7. 6-/14-month maternal sensitivity composite	2.52	0.20	.42**	.23**	–.23**	.34**	.14*	.03	—		
8. 14-month attachment disorganization[b]	21.70%	—	–.10	.05	.05	.05	.11	–.00	–.13	—	
9. 27-month problem behavior	9.10	6.00	–.35**	–.36**	.39**	–.23**	–.17*	–.01	–.32**	.02	—

Note: n = 203–259. Point biserial correlations are reported for race and attachment disorganization. SCL, Skin conductance level; RSA, respiratory sinus arrhythmia.
a The percentage White is reported instead of mean. Race 1 = White, 0 = non-White.
b The percentage disorganized is reported instead of mean.
*$p < .05$. **$p < .01$.

The parenting tasks yielded the anticipated pattern of change in maternal physiology from baseline. Maternal SCL during each task were significantly higher than at baseline (all $p < .001$), whereas maternal RSA during each task was significantly lower than at baseline (all $p < .05$). Most (95.7%) mothers demonstrated SCL augmentation (average SCL change scores > 0), and 72.1% of mothers demonstrated RSA withdrawal (average RSA change scores > 0).

Hypothesis testing

Hypotheses were evaluated by conducting path analysis with Mplus version 7 (Muthén & Muthén, 1998–2012). Two path models were conducted separately, one for each infant outcome. In the path models, mothers' SCL augmentation and RSA withdrawal while parenting were specified as exogenous variables that predicted maternal sensitivity and infant outcomes, as was the product term representing the interaction between SCL augmentation and RSA withdrawal. Maternal sensitivity was also included as a predictor of infant outcomes. Maternal attachment coherence of mind, emotional risk, education, and race were specified as exogenous control variables linked to maternal sensitivity and infant outcomes. Hypotheses related to indirect

associations and interaction effects were evaluated using bias-corrected bootstrapped 95% confidence intervals (95% CI; Esarey & Summer, 2015; MacKinnon, Lockwood, & Williams, 2004). The results of the path models are described below. Confidence intervals for unstandardized betas that do not span zero indicate such effects are significant.

Path model predicting attachment disorganization. Path coefficients predicting attachment disorganization are presented in Figure 1. Contrary to hypotheses, mothers' SCL augmentation and RSA withdrawal were not significantly associated with maternal sensitivity as main effects or in interaction with each other. Maternal sensitivity, SCL augmentation, and RSA withdrawal were not significantly associated with infant attachment disorganization. Consistent with prediction, the interaction between SCL augmentation and RSA withdrawal was significantly related to attachment disorganization. Maternal SCL augmentation was linked with higher likelihood of the infants being classified as disorganized when maternal vagal withdrawal was low (−1 *SD, B* = 0.30, *p* = .014, 95% CI = 0.05, 0.28) but was not linked with disorganization when vagal withdrawal was high (+1 *SD*, *B* = −0.08, *p* = .71; 95% CI = −0.15, 0.08), as illustrated in Figure 2. No indirect effects via maternal sensitivity were apparent.

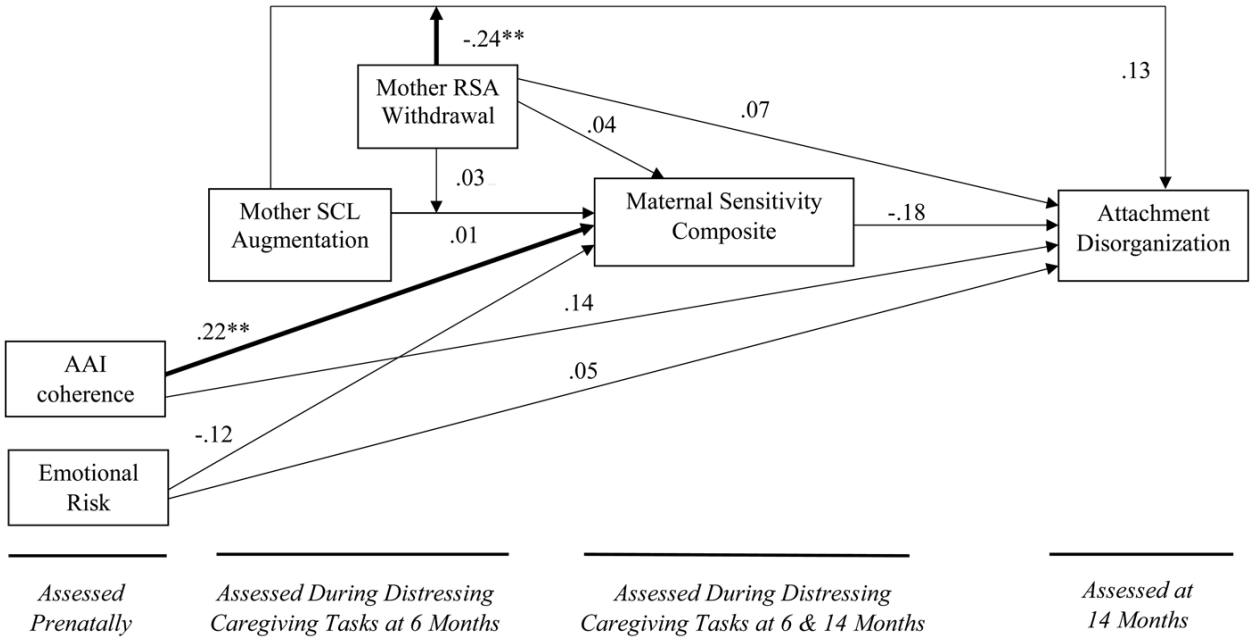

Figure 1. Path model predicting attachment disorganization from maternal physiology and maternal sensitivity to distress. Values are standardized coefficients. Statistically significant paths are bold. *$p < .05$, **$p < .01$. Maternal education and race were included as covariates for maternal sensitivity and behavior problems in the path model, but coefficients are not displayed to simplify presentation of the path model.

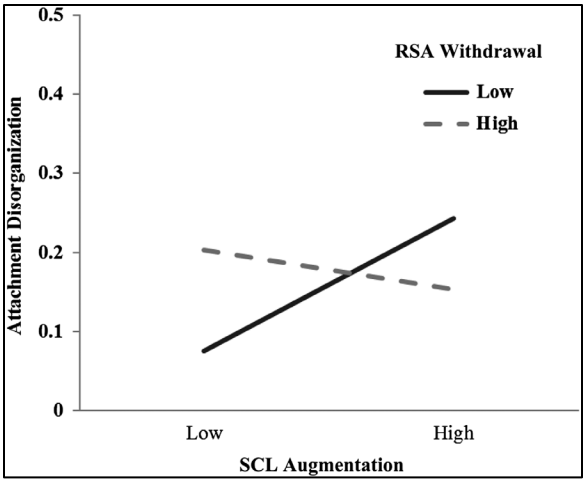

Figure 2. Interaction effect between physiological arousal and regulation in relation to attachment disorganization.

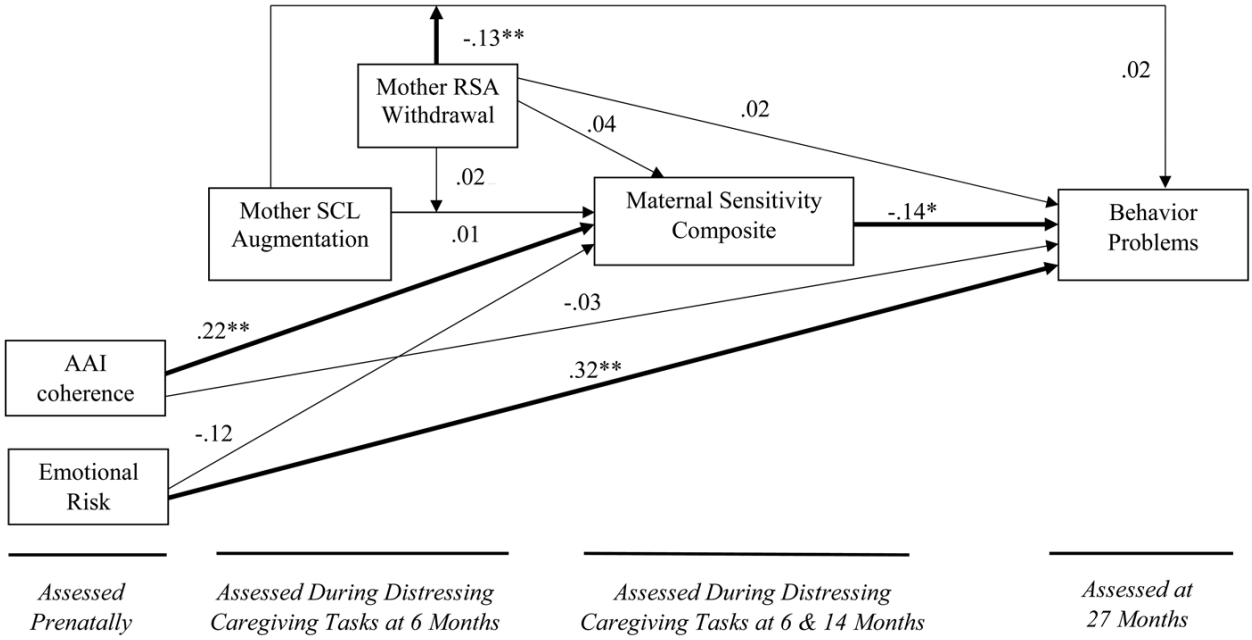

Figure 3. Path model predicting behavior problems from maternal physiology and maternal sensitivity to distress. Values are standardized coefficients. Statistically significant paths are bold. *$p < .05$, **$p < .01$. Maternal education and race were included as covariates for maternal sensitivity and behavior problems in the path model, but coefficients are not displayed to simplify presentation of the path model.

Path model predicting behavior problems. Path coefficients predicting infant behavior problems are presented in Figure 3. Independent of covariates, maternal sensitivity was associated with lower reported infant behavior problems. Neither SCL augmentation nor RSA withdrawal were significantly associated with behavior problems directly. Mothers' SCL augmentation and RSA withdrawal interacted to predict infant behavior problems, such that SCL augmentation while parenting was associated with higher behavior problems when maternal vagal withdrawal was

very low (−1 *SD, B* = 0.35, *p* = .11; −2 *SD, B* = 0.65, *B* = 0.25, *p* = .047; 95% CI = 0.18, 1.37) but was unrelated to behavior problems when vagal withdrawal was high or very high (+1 *SD, B* = −0.26, *ns*; +2 *SD, B* = −0.57, *ns*; see Figure 4). Contrary to prediction, mothers' SCL augmentation, RSA withdrawal, and their interaction were not significantly associated with maternal sensitivity, and no indirect effects via maternal sensitivity were apparent.

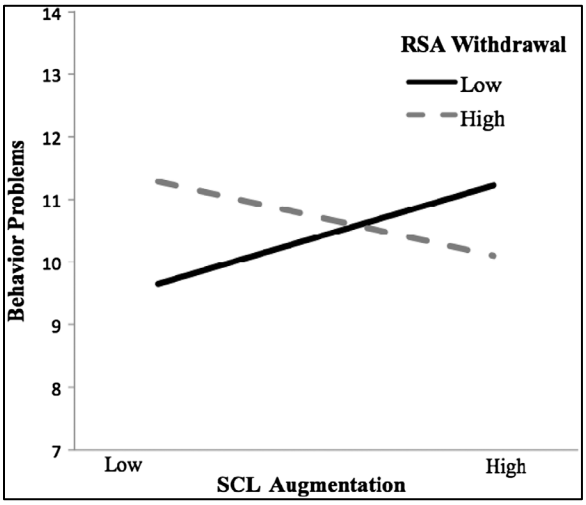

Figure 4. Interaction effect between physiological arousal and regulation in relation to behavior problems.

Tests of race as a moderator. To examine possible differences in path coefficients between European American and African American mothers, multigroup analyses (conducted separately for path models predicting each infant outcome) were conducted in Mplus by comparing a model with all paths (paths involving race were removed first) constrained to equality with one that had all paths freely estimated across African American and European American women using a Wald test. The change in chi-square across these two models was nonsignificant, $\Delta\chi^2 = 13.48$, $\Delta df = 10$, $p = .20$, and $\Delta\chi^2 = 10.27$, $\Delta df = 10$, $p = .42$, for models predicting attachment disorganization and behavior problems, respectively. These findings indicate that path coefficients in the path models did not differ significantly across racial groups.

Discussion

The purpose of this study was to examine the possibility that maternal physiological dysregulation while parenting is linked with infant maladjustment. Consistent with prediction, infants were more likely to be classified as having a disorganized attachment and to be rated as higher on behavior problems by their mothers if their mothers were both highly aroused and poorly regulated while parenting but not if mothers were highly aroused and well regulated. The link between maternal dysregulation and infant outcomes was direct, with no evidence that maternal sensitivity explained these associations. Moreover, the pattern of findings did not vary significantly for dyads in which the mothers were African American versus European American.

That mothers' physiological arousal while parenting was associated with higher subsequent infant maladjustment only when physiological regulation was low is consistent with the view that maternal arousal while parenting, in and of itself, does not place infants at risk. Rather, a

dysregulated maternal state characterized by high SCL augmentation and low vagal withdrawal is a condition that places infants at risk for subsequent attachment disorganization and behavior problems (albeit only for very low regulation, −2 *SD*, for the latter). Maternal arousal was not significantly related to attachment disorganization and behavior problems when regulation was high. This pattern of results supports our view that RSA withdrawal and not augmentation (Hastings et al., 2008) is adaptive in parenting contexts designed to elicit infant distress, at least among mothers who do become highly aroused. Inspection of Figure 4 suggests that infants whose mothers were low on SCL augmentation and high on RSA withdrawal, a state that may reflect overregulation, were as likely to have elevated behavior problems as those whose mothers were high on SCL augmentation and low on RSA withdrawal, reflecting underregulation. Mothers in an overregulated state may be unaware of and nonresponsive to their infants' needs (Sturge-Apple et al., 2011), which may promote behavior problems more so than attachment disorganization, which tends to be predicted by overtly negative maternal behaviors (Lyons-Ruth & Jacobvitz, 2008). However, the interaction was generally weaker in relation to behavior problems than in relation to attachment disorganization as evidenced by the nonsignificant simple slopes at ±1 *SD*; thus, it is premature to make much of the implications for maternal "overregulation" across outcomes in the absence of replication.

Interactive rather than main effects of arousal and regulation on infant outcomes is consistent with the perspective of Berntson et al. (1991, 2008) that joint patterns of SNS and PNS activation may yield greater or different prediction to outcomes than focusing on just one system or on the two systems independent of each other because it yields more precise information about the underlying physiological state of the individual. Moreover, that the joint effect of maternal arousal and regulation while parenting is apparent over and above mother's broad emotional risk increases confidence that the results are a function of maternal affective processes while caregiving and not global maternal affect. These results support the continued use of intervention efforts designed to enhance maternal awareness and regulation of her affective state while parenting such as Attachment and Biobehavioral Catch-Up (Bick & Dozier, 2013) and the Circle of Security (Cassidy et al., 2010) in an effort to promote infant well-being.

Of note, the link between maternal physiological dysregulation and infant maladjustment is not explained by observed insensitive maternal behavior; thus, the underlying mechanism of transmission remains to be identified. It is possible that specific patterns of physiological arousal and regulation predict unique types of insensitive behavior (Sturge-Apple et al., 2011), which may in turn have different implications depending on the child outcome under consideration. For example, underregulation may predict more anomalous, frightened and frightening maternal behavior, which has been demonstrated to be a stronger predictor of disorganization than is maternal sensitivity (Lyons-Ruth & Jacobvitz, 2008). In addition to considering specific type of insensitive behavior, three alternative mechanisms should be considered in future research. First, there is a genetic transmission of traits related to psychopathology. In this study, the relationship between maternal dysregulation and infant maladjustment was apparent over and above global maternal emotional risk, making genetic transmission unlikely. Second, the results may be explained by emotion contagion whereby physiologically dysregulated mothers communicate greater negative affect to their infants, which exacerbates infant arousal and undermines infant emotion regulation (Moore, 2009). Third, given evidence of synchronization between mother and infant biorhythms, such as heart rate (Feldman, Magori-Cohen, Galili, Singer, &

Louzoun, 2011), it may be the case that maternal physiological dysregulation contributes to infant physiological dysregulation, which places infants at risk for maladjustment (Feldman, 2007).

That mothers' SCL augmentation and RSA withdrawal, as main effects and in interaction with one another, while parenting were not significantly directly associated with maternal sensitivity is inconsistent with prior research in other samples (Lorber & O'Leary, 2005; Miller et al., 2015; Mills-Koonce et al., 2009; Moore, 2009; Sturge-Apple et al., 2011). However, in this sample, we have found indirect links between physiology and sensitivity via mothers' self-reported emotions and cognitions while parenting (Leerkes et al., 2015, in press). For example, mothers who were highly aroused and well regulated reported more empathy and more accurate interpretations of their infants' affect, which in turn predicted higher sensitivity. Thus, despite the lack of direct association between maternal physiology and sensitivity in the current report, there is accumulating evidence that maternal physiology while parenting is linked to important individual differences in parenting behavior.

Strengths of the current investigation include the prospective design, the simultaneous measurement of indices of arousal and regulation while parenting, and the careful observation of maternal sensitivity and attachment disorganization. Our interactive tasks were designed to elicit infant distress, and were quite effective at eliciting a stress response from mothers. It seems somewhat unlikely that similar effects would be observed during more benign or positive interactive tasks. In tasks that are challenging and social in nature, but not emotionally arousing (e.g., joint problem-solving tasks), a different pattern of physiological responding may be adaptive (Miller et al., 2015). The moderately large, ethnically diverse sample with a fairly high rate of attachment disorganization is a notable strength. This allowed for a formal comparison of the path model between European American and African American dyads. Although mean differences in key constructs were apparent between these groups, the paths did not vary significantly, adding to accumulating evidence that links between parenting, and in this case parenting-related physiological arousal and regulation, and infant outcomes are similar across ethnic groups (Bakermans-Kranenburg, van IJzendoorn, & Kroonenberg, 2004; Mesman et al., 2012).

Limitations of the current research include the use of maternal report on the BITSEA as the only measure of early behavioral problems. However, that the joint effect of maternal arousal and regulation while parenting was found for both an observed outcome (attachment disorganization) and maternal report reduces this concern somewhat. Our inability to control for mothers' unresolved attachment status given low base rates in our sample is also a limitation. In addition, we took a fairly simple approach to quantifying mothers' physiological responses by focusing on mean change from baseline. Others have demonstrated that more dynamic measures of physiology reflecting patterns of change across a task (Brooker & Buss, 2009) or across multiple trials (Joosen, Mesman, Bakermans-Kranenburg, Pieper, et al., 2013; Joosen, Mesman, Bakermans-Kranenburg, & van IJzendoorn, 2013) predicts behavior. Finally, we were unable to identify the mechanisms that explain the association between maternal dysregulation and infant maladjustment; identifying these mechanisms is an important avenue for future research. Likewise, the possibility that the effects of maternal physiological dysregulation on these outcomes are exacerbated by infant characteristics, such as temperamental reactivity, or by other

contextual risk factors is warranted given that psychopathology typically emerges as the result of multiple risk factors (Calkins, 1994; Cicchetti & Rogosch, 1996; Sroufe & Rutter, 1984).

In sum, our results demonstrate that infants whose mothers are physiologically dysregulated, as evidenced by high arousal accompanied by poor regulation, while interacting with them are at greater risk for developing disorganized attachments to their mothers and behavior problems. These findings extend recent literature demonstrating effects of maternal physiological arousal and regulation on parenting by demonstrating direct effects on infants' early emerging psychopathology.

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