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# Cardiac Vagal Tone and Quality of Parenting Show Concurrent and Time-Ordered Associations That Diverge in Abusive, Neglectful, and Non-Maltreating Mothers

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## Abstract

Concurrent and lagged maternal respiratory sinus arrhythmia (RSA) was monitored in the context of parenting. One hundred and forty-one preschooler-mother dyads—involved with child welfare as documented perpetrators of child abuse or neglect, or non-maltreating (non-CM)—were observed completing a resting baseline and joint challenge task. Parenting behaviors were coded using SASB (Benjamin, 1996) and maternal RSA was simultaneously monitored, longitudinally-nested within-person (WP), and subjected to MLM. Abusive and neglectful mothers displayed less positive parenting and more strict/hostile control, relative to non-CM mothers. Non-CM mothers displayed greater WP heterogeneity in variance over time in their RSA scores, and greater consistency over time in their parenting behaviors, relative to abusive or neglectful mothers. CM group also moderated concurrent and lagged WP associations in RSA and positive parenting. When abusive mothers displayed lower RSA in a given epoch, relative to their task average, they showed concurrent increases in positive parenting, and higher subsequent levels of hostile control in the following epoch, suggesting that it is physiologically taxing for abusive mothers to parent in positive ways. In contrast, lagged effects for non-CM mothers were observed in which RSA decreases led to subsequent WP increases in positive parenting and decreases in control. Reversed models were significant only for neglectful mothers: Increases in positive parenting led to subsequent increases in RSA levels, and increases in strict, hostile control led to subsequent RSA decreases. These results provide new evidence that concurrent and time-ordered coupling in maternal physiology and behavior during parenting vary in theoretically meaningful ways across CM and non-CM mothers. Implications for intervention and study limitations are discussed.



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**Keywords**

autonomic regulation; parenting; child abuse and neglect

Child maltreatment (CM) constitutes a violation in caregiving and lies at the extreme end of the continuum of parenting-at-risk (Cicchetti & Toth, 2005; Reid, Taplin, & Lorber, 1981; Rogosch et al., 1995). CM parents are more hostile, controlling, and dismissive toward their children than non-CM parents (Rogosch et al., 1995; Wilson, Rack, Shi, & Norris, 2008), more likely to rely on power-based discipline (Trickett & Kuczynski, 1986), and exert control in aversive, intrusive ways (e.g., Angeles Cerezo & D'Ocon, 1999; Dumas & Wahler, 1985; Skowron et al., 2011), resulting in the development of externalizing disorders, impaired regulation, and long-term persistent conduct problems in their children (e.g., Dodge, Bates, & Pettit, 1990; Eckenrode, Laird, & Doris, 1993; Patterson et al., 1989). Evidence suggests that physically abusive parents tend to engage in more aversive control than either neglecting or nonmaltreating parents (e.g., Bousha & Twentyman, 1984; Trickett & McBride-Chang, 1995). CM parents also tend to initiate fewer positive interactions, and rely more on emotional distancing and withdraw from their children, relative to their nonmal-treating peers (Burgess & Conger, 1978; Egeland et al., 1980; Kavanagh et al., 1988), though cluster analyses have documented significant within-group variation on dimensions of parent positivity and control (e.g., Haskett, Scott, & Ward, 2004).

Family systems theories have received little attention to date from researchers investigating the phenomenon of CM. Bowen theory is one of several comprehensive family systems theories of individual functioning (e.g., Nichols & Schwartz, 2002; Skowron & Woehrle, 2012; Titelman, 1998) that may provide a useful framework for conceptualizing family processes that underlie child abuse and neglect (e.g., Smith, 2001). A central construct in Bowen theory, differentiation of self, is defined as the capacity of a system and its members to manage emotional reactivity, act thoughtfully under stress, and support autonomy and connection in relationships. Individuals functioning at higher levels of differentiation of self are less emotionally reactive, better able to regulate emotion, think clearly under stress, and are better problem-solvers (Bowen, 1978; Titelman, 1998). Differentiated persons are thought to be more flexible and adaptive because they are more capable of modulating their emotional arousal under stress. In contrast, less differentiated individuals are less self-regulated, more emotionally reactive, less comfortable with both intimacy and autonomy, and find it difficult to remain calm in response to stressful experiences (Bowen, 1976; Kerr & Bowen, 1988).

The capacity for self-regulation is critically important to competent parenting (Dix, 1991), given the nature of strong emotion that is elicited in the parenting context, (e.g., Angeles Cerezo, 1997; Baker, Heller, & Henker, 2000; Chang, Schwartz, Dodge, & McBride-Chang, 2003; Denham et al., 2000). Parents who are less differentiated and challenged by robust and difficult-to-modulate emotional arousal may be less capable of engaging in positive parenting, more likely to resort to harsh, controlling parenting practices, and prone to acts of CM (Skowron & Woehrle, 2013). Research has documented that CM parents and those at heightened risk for perpetrating CM are less differentiated, more emotionally reactive, negative, and less affectionate toward their children (e.g., Skowron & Platt, 2005; Skowron, Kozlowski, & Pincus, 2010; see reviews by Cicchetti & Toth, 2005; Rogosch et al., 1995), and tend to display greater physiological reactivity to neutral and child-specific stimuli (Bugental, 2009; McCanne & Hagstrom, 1996). Likewise, research has shown that impairments in self-regulation of emotion and behavior constitute significant contributing factors for CM parenting (Cicchetti & Toth, 2005; McCanne & Hagstrom, 1996; Rogosch et al., 1995). Similar relationships between autonomic reactivity and physical child abuse

potential also are observed in samples of young adults who are not yet parents (e.g., Crowe & Zeskind, 1992; Pruitt & Erikson, 1985). To the extent that abusive and neglectful mothers experience parenting as more stressful or aversive, then efforts to engage in positive parenting may require them to exert self-control to inhibit arousal, negative emotions, and maladaptive behavior. According to the resource model of self-control (Baumeister, Heatherton, & Tice, 1994), one's capacity for self-control resembles a muscle, in the sense that it is a limited resource. Evidence shows that when we exert self-control, this reduces the amount of strength available for subsequent efforts at self-control (Muraven & Baumeister, 2000).

## Parasympathetic Regulation of Arousal, Social Functioning, and Parenting

Bowen (1978; Kerr & Bowen, 1988) proposed that autonomic reactivity and regulation underlie the capacity for differentiation of self, and leading theories (Porges, 1995, 2001; Thayer & Lane, 2000) confirm the role of the parasympathetic nervous system (PNS) in regulating physiological response, and developing and modulating social behaviors. According to Porges' (2003) polyvagal theory, the PNS exerts neural control over heart rate to regulate arousal. Patterns of heart rate variability are referred to as respiratory sinus arrhythmia (RSA), and provide a measurable index of PNS influence on heart rate (Berntson et al., 1997; Porges, 1995). Withdrawal of PNS influence (RSA decreases) results in an increase in heart rate and facilitates attention and arousal, whereas greater PNS activation (RSA increases) signifies greater change in heart rate across the inhalation—exhalation cycle, and facilitates positive, pro-social behavior by allowing an individual to rapidly modulate arousal as needed to engage with environmental demands (Porges, 2001, 2003). Porges postulates that this rapid dynamic control of arousal has important implications for regulating emotional reactivity, and allows individuals to engage appropriately in social interactions. Because of the association of RSA to general regulatory ability, this system is particularly of interest for understanding prosocial and maladaptive parenting.

Several reviews have documented linkages between aggression, emotion dysregulation, and PNS functioning as indexed by RSA (e.g., Beauchaine, 2001; Lorber & O'Leary, 2005). Resting RSA levels provide a measure of parasympathetic influence on heart rate (i.e., a slowing of cardiac activity), reflecting the extent of physiological flexibility or an individual's capacity for self-regulation (Beauchaine, 2001; Porges, 1995, 2001; Thayer & Lane, 2000). Low resting RSA is observed in negative emotional states and reflects a nonspecific marker of dysregulated emotion in both children and adults (e.g., Beauchaine, 2001; Porges, 1995), and is linked to depression (Carney et al., 2000), anxiety (Thayer, Friedman, & Borkovec, 1996), and CM status (Creaven et al., in press). Alternately, higher resting RSA in adults is associated with socioemotional competence (Beauchaine, 2001), marital quality (Smith et al., 2012), positive emotionality (Oveis, Cohen, Gruber, Shiota, Haidt et al., 2009), and spontaneous regulation of negative emotional states (Pu, Schmeichel, & Demaree, 2010). With regard to parenting, higher resting RSA has been observed in mothers who display greater sensitivity with their infant (Musser, Ablow, & Measelle, 2012), who self-report use of positive emotional socialization practices with their 4- to 5-year-old children (Perlman, Camras, & Pelphrey, 2008), and who show greater emotional flexibility (i.e., exhibited a wider range of emotions) and mutual positivity during mother-adolescent laboratory interactions (Connell, Hughes-Scalise, Kostermann, & Azem, 2011).

In comparison with resting measures, short-term RSA decreases in response to a challenge reflect parasympathetic withdrawal, are commonly observed during exposure to psychological stress (e.g., Berntson, Cacioppo, Quigley, & Fabro, 1994), and accompany negative emotional states (Beauchaine, 2001). For example, Ham and Tronick (2006) observed RSA decreases (i.e., lower parasympathetic tone) in a sample of 12 mothers of

infants during recovery from the Still Face procedure, a challenging parent-infant interaction task. Findings drawn from Mills-Koonce and colleagues' Durham Child Health and Development Study have documented decreases in maternal RSA associated with more sensitive (Moore et al., 2009) and less intrusive parenting (Mills-Koonce et al., 2009) of infants exhibiting distress or other negative affect. Another Durham study (Mills-Koonce et al., 2007) documented that smaller maternal RSA decreases in response to high levels of infant negativity were linked to lower maternal sensitivity, a finding observed only among mothers of avoidantly attached children, and not in mothers of securely attached children. However, a handful of other studies suggest that RSA decreases can be detrimental to good parenting and other aspects of relational functioning. For example, Lorber and O'Leary (2005) have documented that mothers who display harsh overreactive discipline with their preschool children also show corresponding decreases in RSA, and Moore (2009) reported that mothers in the Durham study who were exposed to anger showed RSA decreases across all episodes of the Still Face paradigm. With respect to adult social functioning, greater RSA decreases have been observed during married couples' conflict discussions (Nealey-Moore et al., 2007), and result from social bond disruptions in prairie voles (Grippo, Lamb, Carter, & Porges, 2007). Older women who show larger RSA decreases in response to stress exposure also report greater impairments in social functioning (Egizio et al., 2008).

In contrast, short-term RSA increases reflect greater parasympathetic activation, and appear to signal social self-regulation (e.g., Butler et al., 2006; Skowron et al., 2011; Smith et al., 2012). For example, experimentally induced RSA increases (i.e., greater parasympathetic tone) have been observed during successful efforts to suppress negative emotion in social interactions with a stranger (Butler, Wilhelm, & Gross, 2006). A few studies of RSA in the context of parenting also support the notion that RSA increases signal social self-regulation. For example, Skowron and colleagues (2011) documented that mothers of preschool children displayed RSA increases from resting baseline when engaged with their child to complete a joint-challenge task. Hill-Soderlund et al. (2008) monitored episode-by-episode RSA responding of mothers and their avoidant or securely attached infants during the Strange Situation procedure, and found that mothers of both secure- and avoidant infants posted significant *decreases in RSA* during both separations and the stranger-alone-with-child conditions, and *RSA increases* when interacting with the stranger, and during the final mother-child reunion, signaling positive social engagement and greater regulation. In sum, published studies of RSA response during social interactions suggest that positive social engagement and self-regulation occur in the context of RSA increases, whereas sensitive parenting-under-stress appears with decreases in RSA. However, more work is needed to clarify the nature of associations between maternal RSA and quality of parenting, and to explore these relations in a sample characterized by severe disruptions in parenting, such as in a sample of maltreating mothers.

## The Current Study

The purpose of this study was to investigate maternal physiology and parenting behavior in CM and nonmaltreating mothers during a laboratory-based joint challenge with their pre-school children. We reasoned that a mother's ability to engage in positive parenting (warm, support for autonomy and warm guidance) and refrain from aversive parenting (strict/harsh, critical control) would rely in part on her physiological capacity to inhibit arousal and self-regulate in the act of parenting. The broad goal of this person-centered approach was to document the concurrent and time-lagged associations between maternal physiology and parenting behavior, and to determine whether the strength of physiology and quality of parenting associations varied across physically abusive, neglectful, or nonmaltreating mothers. We focused on child physical abuse, comprising care-giver-inflicted physical injury to a child by other than accidental means, and physical neglect, defined as caregiver

failure to meet a child's minimum physical needs for food, clothing, shelter, supervision, a safe environment, or adequate substitute care (Barnett, Manly, & Cichetti, 1993), and contrasted these groups with non-CM mothers for whom we confirmed no history of CPS involvement.

This study is grounded in a larger project focused on understanding parenting processes and children's self-regulation development in physically abusive, neglectful, and non-CM families, and includes 53% of mothers who also were examined in Skowron et al., 2011. We used an intensive repeated measures design and multilevel modeling to assess maternal RSA at rest and over the course of a 5-min joint challenge task with her preschool child. Mothers' positive and aversive parenting behaviors were observationally coded at the speaking turn level using the Structural Analysis of Social Behavior (Benjamin, 1996, 2011; see Figure 1).

### Maternal RSA and Parenting: Level and Stability

First, we examined levels of maternal RSA and positive or harsh control parenting by CM group. In line with published research, we predicted that physically abusive and neglecting mothers would display less positive and more harsh, controlling parenting behaviors (Wilson et al., 2008), and lower resting RSA, and as compared with non-CM mothers. We also examined the extent of over time variability in maternal RSA and positive- or aversive-parenting, and tested whether within person (WP) variability over time in physiology or parenting was associated with CM group status. With regard to our predictions about variation in mothers' RSA scores, biological models (Friedman, 2007; Thayer & Lane, 2000) posit that high levels of variability in physiological systems reflect healthy processes, whereas low variation over time tends to be characteristic of more pathological states. Therefore we hypothesized that greater fluctuation in mother RSA scores over time (i.e., greater WP variation) would be observed in non-CM mothers while parenting, as compared with the abusive and neglectful mothers. With regard to predictions of parenting, we referenced findings from studies of CM parent–child interactions showing less reciprocity and predictability, and more indiscriminant parent responding to their child's immediate cues among CM mothers (e.g., Dumas & Wahler, 1985; Knutson, DeGarmo, & Reid, 2004; Knutson, DeGarmo, Koeppl, & Reid, 2005; Lorber & Smith Slep, 2005; Wahler & Dumas, 1986). Therefore, we predicted that greater over time variation in positive and aversive parenting would be observed among physically abusive and neglectful mothers, relative to non-CM mothers.

### Maternal RSA and Parenting Over Time

Second, we examined WP associations in maternal RSA and parenting over time, and tested for CM group moderation effects, in light of few research findings to date regarding quality of parenting and RSA responding, and because relatively little is known about how CM parents' autonomic physiology in the act of parenting maps onto their use of positive versus aversive parenting practices. Concurrent and cross-lagged associations between maternal RSA and quality of parenting were tested. With respect to concurrent effects, we asked whether, if a mother displayed higher RSA at Time X, relative to her usual level (i.e., task average), does she also show increased positive parenting at Time X, again relative to her usual level? In line with a growing number of studies documenting that RSA increases in adults are indicative of successful self-regulation in social contexts, we hypothesized WP associations in concurrent RSA increases and positive parenting, and concurrent RSA decreases and aversive parenting (i.e., harsh control), across CM groups.

Next, we examined the time-ordered (i.e., cross-lagged) effects of maternal RSA on subsequent parenting. Here, we asked whether, if a mother displays higher RSA at Time X relative to her usual level, does she show an increase in subsequent positive parenting at

Time Y, again relative to her usual level, and does CM group status moderate those lagged associations? We reasoned that physiological arousal experienced by CM mothers would have a disruptive effect on parenting and would interfere with their capacity to engage in positive parenting. Therefore, we hypothesized that decreases in maternal RSA would subsequently lead to more strict/hostile control and less positive parenting, whereas increases in CM mothers' RSA might allow for more positive parenting to follow. We further tested whether the pattern of lagged effects would hold across CM subtypes, or would be present only in abusive or neglectful mothers. In the case of non-CM mothers, we advanced two possible hypotheses. First, in line with evidence of the positive attentional and mobilization effects of RSA decreases in normative samples (e.g., Mills-Koonce et al., 2009), we theorized that RSA decreases would lead to more positive parenting in non-CM mothers. Alternately, we considered that any physiological arousal experienced by non-CM mothers might occur independently of the quality of parenting they display (i.e., non-CM mothers would evidence positive parenting, regardless of their physiological response). To assess the directionality of effects, we also tested a series of reversed cross-lagged models in which parenting effects on subsequent changes in maternal RSA were examined.

## Method

### Participants

Participants were 141 mothers and their pre-school children. Mother's average age was 29.5 years (*SD* = 5.7). The majority of the mothers were Caucasian (94.2%), 54.0% had a high school degree or less, and 69.0% reported incomes at or below $30,000 per year. Children ranged in age from 3 to 5 years (*M* = 3.7, *SD* = 0.72), 52.5% were female, and a majority were Caucasian (83.9%). A subsample of *n* = 62 CM mothers in the study were documented perpetrators of CM, based on Maltreatment Classification System coding (MCS; Barnett et al., 1993) of CPS case records. *Physical abuse* (14 cases) was coded when there was evidence of a caregiver-inflicted physical injury to the child by other than accidental means and *Physical neglect* that the caregiver failed to meet the child's minimum physical needs in the form of *Failure to Provide* (50 cases) and/or *Lack of Supervision* (29 cases). CM subtypes were then classified hierarchically so that neglected children may have experienced emotional maltreatment but did not have records indicating physical abuse, and physically abused children may have also experienced neglect and/or emotional abuse (e.g., Pollak, Cicchetti, Hornung, & Reed, 2000). Comorbidity of CM subtypes was observed in 51.2% of the CM group, consistent with other published findings (e.g., Belsky, 1993; Kaufman & Ziegler, 1989).

Recruitment of non-CM dyads (*n* = 79) sought a sociodemographically comparable sample from department of public welfare agencies and a database maintained on birth announcements published in local newspapers. Non-CM mother-child dyads were drawn from a sociodemographically comparable sample from department of public welfare agencies and a database maintained on birth announcements published in local newspapers, and non-CM mothers consented to verification that their family was free of CPS preventive or protective service records.

CM group differences were observed on mother's educational attainment, $F(2, 138) = 13.14$, $p < .001$, and age, $F(2, 140) = 3.03$, $p = .05$, with non-CM mothers (*M* = 14.2 years; *SD* = 2.6) reporting higher education than did either abusive (*M* = 11.9 years; *SD* = 1.6) or neglectful mothers (*M* = 12.3 years; *SD* = 1.8). Less than half (38.5%) of non-CM mothers reported a high school degree or less, compared with 64.3% of abusive and 76.6% of neglectful mothers. Neglectful mothers were significantly younger in age than non-CM mothers (*M* = 28.8; *SD* = 5.8 vs. *M* = 30.5; *SD* = 5.5, respectively). Across CM groups,

participating children did not differ on dimensions of age, $F(2, 140) = .03$, $p = .97$, or gender, $\chi^2(2, n = 141) = 1.29$, $p = .53$.

## Procedure

All procedures used in this study were approved and monitored by the Office for Research Protections. Mother–child dyads were invited to participate if mothers were 18 years of age or older, fluent in English, and living with her preschool child. Mother–child dyads completed a 3-visit protocol over a 2–3 week period, comprising two home visits for psychosocial and cognitive assessments and a subsequent 2.5-hour laboratory visit to assess physiological function and parent–child interaction and conducted by a team of two trained experimenters. Only the lab procedures related to the current report are summarized. During the lab visit, mother–child dyads first participated in a 5-min resting baseline period seated on a comfortable couch, with lights dimmed while viewing a "bedtime" video showing slow-moving animal characters with soothing music, during which physiology was monitored. Maternal physiology and parenting behavior was assessed during the subsequent joint puzzle task. Mother and child were seated together at a small table and the child was provided a Model 3-dimensional duplo figurine and 12 disassembled blocks to construct a replica. Mothers were asked to assist their children to build a model as they might typically, but not to handle any of the blocks. Families were paid $150 to complete the protocol, provided transportation, snacks, and children's small toys/gifts.

## Measures

**Physiological assessment—**To monitor cardiac physiology, disposable pregelled Ag/AgCl electrodes were placed in a modified Lead II placement on the distal end of the right clavicle, lower left rib cage chest, and the lower abdomen. Data were acquired via Mindware Technologies (Gahanna, OH) ambulatory electrocardiograph MW1000A, transmitted via wireless signal to a computer, and monitored by a research assistant. Heart rate data were quantified by taking the ECG signals and passing them through an A/D converter with ECG sampled at a rate of 500 ms. Electrocardiograph data were processed offline using Mindware Technologies HRV 3.0.10 analysis program, and epochs were visually inspected by trained research assistants. Erroneously identified, or missing heartbeats were manually deleted or inserted as appropriate. The resulting interbeat interval time series was subjected to a fast-Fourier transformation, and power in the respiratory frequency band was derived from the spectral density function (e.g., Berntson et al., 1997; Berntson, Cacioppo, & Quigley, 1993). The RSA frequency band was set between 0.12 and 0.40, and maternal RSA was calculated in 30-s epochs across the 5-min joint puzzle task.

**Assessment of parenting behaviors—**The *Structural Analysis of Social Behavior* (SASB; Benjamin, 1996, 2011; Benjamin & Cushing, 2000, see Figure 1) was used to observationally code mothers' parenting behavior during the joint teaching task. The SASB is a circumplex model of interpersonal behavior described by Pinsof (1981) as one of the best integrated and coordinated approaches to family process analysis. The SASB coding system is widely used to study psychotherapy interventions (e.g., Constantino, 2000; Henry, 1996), adult personality, and parent–child interactions (e.g., Florsheim, Tolan, & Gorman-Smith, 1996; Skowron, Kozlowski, & Pincus, 2010). Mother and her child were seated together at a small table for the task, and the child was given colored duplo blocks and instructed to build a figure identical to the model provided. Mothers were told they could help their child as they normally would at home, but were instructed not to handle the blocks. Upon completion, the child was allowed to choose a sticker for his or her efforts. Verbatim transcripts of video-recorded interactions during the task were prepared and then unitized to indicate each "speaking" turn, comprising verbal, nonverbal, and other

paralinguistic behaviors (i.e., smiling at child, moving child's hand away, warm vs. critical tone of voice).

The process of SASB coding each transaction involves three steps to determine (a) focus (Other or Self), (b) degree of Affiliation (ranging from loving to hostile), and (c) interdependence [ranging from low (i.e., autonomous) to high (i.e., control-submit)] (Humphrey & Benjamin, 1986) to arrive at one of eight prototypical parenting behaviors distributed across the circumplex and shown in bold type in Figure 1. SASB cluster codes scores reflect the proportion of speaking turns that mother was engaged in each parenting behavior of interest, divided by the total number of mother speaking turns during the epoch(s) of interest.

Two variables were derived from SASB cluster codes: positive parenting and strict/hostile control. *Positive parenting* was characterized by mother's transitive Weighted Affiliation score, in which each of the 8 transitive cluster scores are weighted to reflect their distance from the affiliation pole (Benjamin & Cushing, 2000). Highly warm, affiliative codes are reflected on the right, for example, with warm autonomy-granting in Cluster 1–2 *Affirming/ Understanding* (e.g., Mother asks, "Where do you think the green block should go?"); warm loving in SASB Cluster 1–3 *Loving/Approaching* (e.g., Mother exclaims, "You're wonderful at this!); and warm helping and teaching behaviors in SASB Cluster 1–4 *Nurturing/ Protecting* (e.g., "Try to put a green block on your red one.").

*Strict/Hostile Control* comprised SASB Cluster 1–5 (*Controlling*; i.e., strict control) and Cluster 1–6 (*Blaming/Criticizing*; i.e., hostile control) parenting behaviors, because of their theoretical-grounded associations to coercive parenting (i.e., Dishion, Andrews, & Crosby, 1995; Patterson, 1982). Scores from Clusters 1–5 or 1–6 (e.g., Mother grabs child's hand and states, "Put the green block down." or "You're doing it all wrong!" or "Don't do it like that.") were summed to create a composite Strict/Hostile Control code for each mother. Values for the Positive Parenting and Strict/Hostile Control Parenting scores were also calculated in 30-s epochs across the 5-min joint puzzle task.

SASB coding was conducted by successive teams of three trained coders working with the unitized transcripts and videotapes and who were blind to family CM status. Coders completed more than 75 hours of training and coded using practice videos in order to achieve sufficient reliability (weighted $\kappa > .70$) before coding. In the present study, weighted kappas were calculated on 15% of the sample and ranged from .53 to 1.0 ($M = .74$), on par with those reported in other studies of SASB-coded parent–child interactions (e.g., Florsheim et al., 1996; Skowron et al., 2010).

*Child Behavior Questionnaire* (CBQ-Short Form; Rothbart et al., 2001) is a child temperament questionnaire with adequate validity and good internal consistency (e.g., Rothbart et al., 2001). Mothers rated their child on a 7-point scale for each statement (1 = *extremely unlike your child* to 7 = *extremely true of your child*). Research has shown that the CBQ has good internal consistency and adequate validity (e.g., Rothbart et al., 2001). Child ratings on the Negativity factor (comprising Anger, Discomfort, Fear, Sadness, and Soothability (reverse-scored) scales) were used in this study, because of observed linkages with emotion dysregulation and externalizing disorders (Morris et al., 2002; Santucci et al., 2008). Overall Negativity scores were computed by summing and averaging the subscale scores, with higher scores reflecting greater children's temperamental negativity.

## Analytic Plan

Mothers' resting RSA was computed as the average across the 5-minute baseline condition. During the joint puzzle task, mother RSA and parenting behavior were collected

simultaneously and longitudinally nested within person. Across 141 mothers, RSA data were collected for a total of $n$ = 1,266 epochs, and coded parenting data were available for all epochs. We used multilevel modeling (MLM) estimated in SAS PROC MIXED 9.3, to test within-person (WP) associations in maternal RSA and parenting (i.e., Positive Parenting and Strict/Hostile Control Parenting) over the course of the joint task, and between-person (BP) differences in those effects (e.g., Hoffman, 2007). MLM techniques are particularly useful for simultaneously modeling WP and BP effects and determining whether person-level WP covariation in mother physiology and parenting behavior is a function of Level 2 (BP) differences in CM group status. Our analyses were guided by three questions: Do level and stability [that is, within-person (WP) variation] of simultaneously assessed maternal RSA and parenting over the course of a joint challenge task with child differ by CM group? Do maternal RSA and parenting covary between- and within-mothers? Does between- and within-mother covariation in maternal RSA and parenting differ by CM group?

The data were organized into a two-level hierarchy, where Level 1 (time in epochs) consisted of repeated measures of RSA and parenting (positive, strict/hostile control), nested within mothers. Maternal RSA and parenting scores were calculated in 30-s epochs across the 5-min joint task. Person-mean-centered RSA and parenting values were calculated at each epoch across the 10 30-s epochs to model concurrent associations, and centered lagged RSA and lagged parenting values were calculated to model *cross-epoch* or lead-lag associations. To test the moderating role of CM group status on these associations, the dummy-coded CM group variable was added at Level 2 and interacted with parenting and RSA measures. Mothers were assigned to the CM group based on documented perpetration of physical abuse, neglect, or to the non-CM group which served as the reference group. We used an extension of the multilevel model for heterogeneous variances, also referred to as dispersion models on clustered or nested data (e.g., Hoffman, 2007), to examine CM group differences in short-term, within-person (WP) variation in parenting and maternal RSA. Second, models were specified to test concurrent associations between maternal RSA and Positive Parenting, and then respecified to test concurrent effects with Strict/Hostile Parenting. Then cross-lagged effects of maternal RSA on subsequent parenting variable were examined. Finally, we reversed the cross-lagged models to clarify the directionality of effects.

## Results

### CM Group Differences in Maternal RSA and Parenting

Table 1 shows the means, standard deviations for maternal resting and task RSA, positive parenting, and strict/hostile control parenting by CM status. We conducted an ANOVA to test for CM group differences (i.e., PA vs. PN vs. non-CM) on the two parenting variables: Positive Parenting and Strict/Harsh Control. In both cases, the omnibus test was significant: $F(2, 138) = 5.38$, and $F(2, 138) = 6.06$, $p$s $< .001$, respectively (see Table 1). Pairwise tests revealed that non-CM mothers displayed more positive parenting than either the physically abusive or neglectful mothers (who did not vary from each other) and less strict/hostile control than either the abusive or neglectful mothers, who again did not vary from each other. In contrast, no CM group differences were observed in mothers' mean resting or task RSA scores. Zero-order correlations between task level RSA and parenting scores are shown in Table 3, for the full sample and by CM group. Across the full sample, significant negative associations were observed between positive and hostile control parenting. When examined within group, neglectful and non-CM mothers' resting RSA was significantly, positively correlated with her joint task RSA, and RSA levels were unrelated to mean parenting scores. However, physically abusive mothers displayed a markedly different pattern of associations. Among abusive mothers, higher resting RSA was correlated with less positive parenting and

greater strict/hostile control parenting during the joint task. Figure 2 illustrates CM group differences in positive and strict/hostile control parenting at ±1 *SD* mean RSA scores during the joint mother–child challenge task.

### CM Group Differences in Person-Level Variation in Parenting and Maternal RSA

First, we tested for CM group differences (i.e., PA vs. PN vs. non-CM) in the magnitude of WP variation over time in mothers' Positive Parenting, Strict/Hostile Control Parenting, and joint task RSA. Nested models with and without separate estimates of variance for each CM group were compared using the difference in −2 log-likelihood values as a function of the difference in the number of parameters estimated in each. This likelihood difference was then evaluated for significance using a chi-square distribution and the associated differences in number of parameters. As shown in Table 2, tests of the level 1 heterogeneity of variance over time (i.e., dispersion) in maternal parenting scores and RSA scores all were significant. Pairwise comparisons using a Bonferroni correction set at .05/3 ≈ .017 were conducted to isolate group differences. Results indicated non-CM mothers displayed greater variability in their physiology over time, and less variation in their parenting over time, as compared with the abusive and neglectful mothers. Specifically in regard to parenting, physically abusive mothers displayed significantly more within-person (WP) variability over time in their levels of Positive Parenting than the non-CM mothers, and more WP variation over time in levels of Strict/Hostile Control, relative to non-CM mothers. Neglectful mothers showed greater variability in Positive Parenting as compared with non-CM mothers. In contrast, physically abusive and neglectful mothers displayed significantly less WP variability over time in their joint task RSA scores, as compared to non-CM mothers.

### WP Associations in Maternal RSA & Positive Parenting Vary by CM Group

CM group moderation of within-person (WP) associations in maternal RSA and parenting over time was analyzed using MLM procedures. In Model 1a reflecting concurrent effects of RSA on positive parenting (see Table 4), the Level 1 (WP) predictor was mother's person-mean-centered RSA during each of the 30-s epochs (i.e., mother's RSA at each epoch, centered around her task mean, or average RSA over the 10 epochs), and the Level 2 (BD) predictors were mothers' overall mean RSA (i.e., average RSA over the 10 epochs), and CM group status. For Model 1b testing lagged effects of maternal RSA on parenting, additional Level 1 predictors were mother's lagged RSA and positive parenting scores.

**Concurrent effects—**CM group status was found to significantly moderate concurrent WP associations in maternal RSA and positive parenting during the joint challenge task. Specifically, physically abusive mothers showed significant WP associations in their positive parenting and RSA scores over time in the 5-min joint challenge with their child, such that increases in abusive mothers' positive parenting were linked with concurrent decreases in their RSA scores ($\beta = -6.10$, $p < .05$). WP effects of concurrent maternal RSA levels on the extent of positive parenting were not observed in neglectful ($\beta = 1.26$, *ns*), or non-CM mothers ($\beta = 1.01$, *ns*). Thus, when an abusive mother engaged in more positive parenting, relative to her task average, her vagal tone decreased in the moment, relative to her task average, suggesting that abusive mothers experienced positive parenting as physiologically challenging, whereas neglectful and non-CM mothers did not.

**Lagged effects—**Next, we respecified the models to test for a moderating effect of CM group on time-ordered associations between mothers' lagged RSA scores and their subsequent parenting scores (controlling for concurrent RSA scores and lagged parenting). The concurrent effects of RSA on positive parenting for physically abusive mothers remained significant ($\beta = -5.87$, $p < .05$), and we observed a significant lagged effect of RSA on subsequent positive parenting for the non-CM mothers ($\beta = -1.63$, $p < .05$; see

Table 4, Model 1b). Interpretation of the effect indicates that declines in non-CM mother's RSA levels, relative to their task averages, predicted subsequent increases in the extent of positive parenting they displayed, again relative to their own task average. Planned contrasts showed the effect for non-CM mothers was significantly different from abusive mothers (β = 6.04, $p < .05$), who themselves showed a nonsignificant trend of decreases in RSA leading to subsequent decreases in positive parenting (β = 4.40, $p = .11$).

### WP Associations in Maternal RSA & Strict/Hostile Control Vary by CM Group

Turning to prediction of strict, hostile control, no significant main effects or CM group-moderated effects were observed for mothers' concurrent RSA and extent of their hostile, control parenting, as shown in Table 4, Model 2a. When we respecified the model to include lagged RSA scores (accounting for concurrent RSA and parenting autocorrelations), we found significant time-ordered associations in RSA and subsequent strict/hostile control parenting for physically abusive and non-CM mothers that diverged from one another (see Table 4, Model 2b). RSA declines predicted subsequent increases in strict, hostile control in abusive mothers' (β = −.10, $p = .01$), but decreases in the extent of non-CM mothers' control (β = .02, $p < .05$). No effects of time-ordered RSA changes on parent control were observed in the neglectful mothers. The findings indicate that decreases in a physically abusive mother's parasympathetic tone (RSA), relative to her average, lead to subsequent increases in her use of strict/hostile control with her child at the next measurement point (i.e., next 30-s epoch), whereas among non-CM mothers, RSA declines led to subsequent reductions in already low levels of parent control. Planned contrasts showed that the time-ordered effect observed in abusive mothers was significantly different from both non-CM and neglectful mothers. Random effects of person-level RSA scores on parenting were tested in all of the models, but did not improve their fit significantly.

### Reversal of Lagged Models

Next we reversed the lagged models to test the directionality of these effects, and used positive or aversive control parenting to predict maternal RSA. No concurrent effects of positive parenting or aversive control parenting on RSA were observed in any of the sample. Further, no WP effects of lagged positive parenting on maternal RSA levels were observed in abusive (β = .003, $SE = .003$, $p = .23$), or non-CM mothers (β = .001, $SE = .005$, $p = .79$). However for neglectful mothers, we observed a significant lagged effect of positive parenting on subsequent RSA scores (β = .008, $SE = .003$, $p = .004$), such that increases in a neglectful mother's positive parenting behaviors, relative to her task average, predicted subsequent increases in her parasympathetic tone, again relative to her task average.

We also examined the WP effects of lagged strict/hostile control parenting for predicting maternal RSA, and again, significant effects emerged for the neglectful mothers only (β = −.48, $SE = .20$, $p = .02$). Specifically, a significant lagged effect of strict/hostile controlling parenting on subsequent RSA scores, such that increases in neglectful mother's strict/hostile control of their child predicted subsequent decreases in parasympathetic tone. WP effects of lagged strict/hostile control parenting on maternal RSA levels were not observed in abusive (β = −.03, $SE = .38$, $p = .94$) or non-CM mothers (β = −.28, $SE = .19$, $p = .14$). As noted above, we reran all models while including measures of parent education and child temperament; however, the results did not vary beyond what would be expected because of a loss in power. Thus, in the interest of conserving power for our small sample, we reported results without these covariates.

## Discussion

The purpose of this study was to examine CM group differences in within-person (WP) associations in parenting and maternal parasympathetic tone in the context of parenting a pre-school child. Viewed through the lens of family systems theory (Bowen, 1978; Kerr, 1983), maladaptive parenting processes are thought to be fueled by parent emotional reactivity and reflect limited capacities for emotion regulation in the context of parenting. Although CM parents' harsh, aversive control may be harmful to a developing child, use of these strategies may reflect parent attempts to cope with emotion dysregulation and serve a maladaptive stabilizing function in the system (Campos, Campos, & Barrett, 1989; Skowron & Woehrle, 2012). In line with existing research (e.g., Angeles-Cerezo, 1997; Wilson et al., 2008), both physically abusive and neglectful mothers in the current study displayed less positive parenting and more strict/hostile control parenting during a joint challenge with their preschool child, relative to non-CM mothers, who displayed more positive parenting and less aversive control. Further, non-CM mothers showed more over time consistency in their parenting scores, whereas abusive and neglectful mothers displayed greater variation in the levels of positive parenting and aversive control while engaged with their child to complete the challenge task. These findings build on earlier microanalytic observational studies of CM family interactions that have documented inconsistency and unpredictability in parenting during adolescence (e.g., Reid et al., 1981; Dumas & Wahler, 1985; Wahler et al., 1990).

Findings from this study further clarify the role of parasympathetic function in parenting-at-risk. Although we observed no differences in abusive, neglectful, or non-CM mothers' resting RSA (i.e., vagal tone), we found different patterns of concurrent and time-ordered associations between mother's vagal tone and quality of parenting, based on CM group status. Specifically, higher resting vagal tone was associated with more positive parenting in neglectful and non-CM mothers, but more hostile control parenting in abusive mothers. In line with biological models (e.g., Friedman, 2007; Porges, 2011; Thayer & Lane, 2000), dispersion tests on maternal RSA scores across the ten 30-s joint task epochs revealed significantly greater epoch-to-epoch variability in non-CM mothers' RSA scores and less variability, or greater consistency, in the RSA scores of physically abusive and neglectful mothers. These findings support the notion that healthy adaptive physiology tends to be expressed in terms of high levels of variability, whereas pathological states are often characterized by low variability or predictability in cardiac vagal tone (Appel et al., 1989; Goldberger, 1992, 1996). Further, the pattern of CM effects on variability observed in maternal RSA and quality of parenting showed greater over time *consistency* in non-CM mothers' positive parenting but *more flexibility* in their parasympathetic responding. This set of findings can be further understood as evidence of 'heterostasis,' in which stability in one variable (i.e., behavior) within an organism is maintained by variability in another (i.e., autonomic states; Friedman, 2007). Further research is needed to understand whether the high degree of unpredictability in quality of parenting observed in abusive mothers is the result of efforts to maintain consistency over time in parasympathetic tone or a steady physiological state. When a mother is stressed, is she more concerned about how she feels or how she relates to her child?

Our central question concerned CM group differences in concurrent and time-ordered associations in maternal physiology and quality of parenting. Here we modeled vagal augmentation and withdrawal in terms of changes from a mother's person-level RSA task average, rather than changes from resting baseline to challenge. Patterns of significant coupling in the extent of positive and aversive parenting and maternal physiology during the act of parenting varied, depending on whether mothers were involved with Child Protective Services for physical child abuse, physical neglect, or they were non-maltreating. First, we

observed that RSA declines in non-CM mothers while parenting predicted subsequent shifts toward use of more positive parenting and less aversive control, relative to their own typical or average during the interaction. These findings replicate other studies that have reported the benefits of modest short term decreases in RSA (i.e., vagal tone) for mobilizing adaptive parenting in non-CM populations (e.g., Ham & Tronick, 2006; Mills-Koonce et al., 2007, 2009; Moore et al., 2009), and are consistent with a biological model that RSA decreases are instigated in response to attentional engagement and challenge (Beauchaine, 2001; Porges, 1995, 2001).

Second, we found concurrent and lagged associations between physiology and parenting in physically abusive mothers. Among abusive mothers, decreases in person-level RSA (i.e., vagal withdrawal) were associated with simultaneous increases in positive parenting, but led to subsequent increases in use of strict/harsh control. No significant effects were observed when we reversed the models (i.e., tested parenting's effect on RSA scores), supporting the time-ordered effect of maternal physiology on subsequent parenting and not the reverse. The concurrent association suggests that a physically abusive mother's efforts to provide warm support to her child while he or she completes a challenging task may be taxing her limited resources for self-control, and that increased arousal and depleted self-control leads her to subsequently shift toward controlling her child in strict and hostile ways. From a family systems perspective, although CM parents' use of aversive control may be harmful to a developing child, it may serve a maladaptive stabilizing function in the system, in terms of reflecting a parent's attempts to cope with emotion dysregulation.

This pattern of significant coupling in physiology and behavior observed among the abusive mothers while parenting provides support for both Porges' (2011) polyvagal theory and Baumeister's resource model of self-control (Muraven & Baumeister, 2000). Consistent with polyvagal theory, the concurrent effects suggest that abusive mothers' impaired social engagement skills may derive from experiencing the parenting context as more threatening on an autonomic level than their lower-risk peers. Porges' (2011) concept of "neuroception" describes a process that operates outside of our awareness through which we evaluate risk in the environment, which in turn shapes our autonomic responding. These findings highlight the challenges that abusive mothers face in providing adequate caregiving, given the heightened arousal they experience in particular while engaged in positive parenting, and suggest that the parenting capacities of abusive mothers are uniquely challenged by deficits in physiological regulation. Further work is needed to determine whether abusive parents who display patterns of concurrent and lagged parasympathetic withdrawal and positive/aversive parenting, are also predisposed toward threat-biased attributions of their child and greater vigilance in the context of parenting (e.g., Bugental, 2009). Do abusive parents exert strict, hostile control of their child in an effort to manage their experience of the parenting context as threatening?

If it is more physiological taxing for abusive mothers to parent in positive ways, then according to self-control theory (e.g., Baumeister & Heatherton, 1996), the efforts of abusive parents to engage in positive parenting represent active efforts to self-control in the context of caregiving. It follows that engaging in positive parenting then depletes an abusive parent's self-control resources, which leads to increased harsh parenting that follows. CM parents are known to engage in more aversive, controlling parenting (Rogosch et al., 1995; Wilson et al., 2008). These study results indicate that abusive mothers show the greatest variation over time in their levels of positive parenting and harsh control. Taken together, these findings suggest that the emergence of aversive control parenting in abusive parents may be physiologically-driven, and result from threat-biased perceptions, vigilance in the parenting context, and/or depletion in self-control resources following efforts to engage in positive parenting. These findings suggest that physiological function may reflect a direct

liability for the perpetration of physical abuse, and help to explain why abusive parenting is so resistant to many interventions.

With respect to neglectful mothers, RSA levels were not found to predict quality of subsequent parenting, whereas the reversed models in which parenting predicted subsequent changes in mothers' physiology response were significant. Specifically, when neglectful mothers increased their positive parenting, this led to subsequent increases in vagal tone. Conversely, increases in harsh control in neglectful mothers led to subsequent decreases in vagal tone. Thus, in sum, the pathways linking maternal physiology and quality of parenting were different for maltreating mothers who were abusive versus those who solely engaged in physical neglect of their child. Maternal physiological states were found to affect quality of parenting in abusive mothers, whereas in neglectful mothers the reverse was observed, whereby the quality of parenting led to changes in maternal physiology. Further work is needed to learn whether parenting interventions that teach, reinforce, and support greater use of positive parenting strategies to neglectful mothers' not only strengthen their positive parenting skills, but also lead to secondary benefits in the form of improvements in physiological regulation.

## Limitations, Implications, and Future Directions

Several limitations must be considered in the interpretation of these findings. Most important is the sampling of physiological measures and parenting behavior, which were gathered from an intensive repeated-measures design during a single research session. Replication of these findings is necessary to confirm and/or clarify the pattern of associations observed here. Subsequent studies are needed with larger sample sizes that include observations of parenting extended across a longer time-frame and into naturalistic contexts. It is possible that mothers attempted to display their "best behavior" in the lab, and this would only serve to weaken associations observed between maternal physiology and parenting. Likewise, on average, non-CM mothers had completed two more years of education than both abusive and neglectful mothers. Among the lower risk mothers, more education was associated with better quality parenting as would be expected. In contrast, quality of parenting and level of education were unrelated in the sample of physically abusive mothers, while the measures of autonomic reactivity showed both concurrent and predictive associations with parenting behavior. Further study of this phenomenon is needed to learn whether mothers' physiological capacities for regulation play a greater role in shaping parenting in the moment than do educational background or other contextual resources. In line with others (e.g., Bornstein & Suess, 2000; Pine et al., 1998; Obradović et al., 2010), we did not control for respiration rate when measuring RSA, which may be considered a physiological confound particularly in cases where measurement occurs in contexts that vary widely in the extent of activity. However, our measure of RSA is not highly susceptible to respiration artifacts (Denver, Reed, & Porges, 2007), and some suggest that respiration may be a coordinated physiological parameter that underlies parasympathetic influence on heart rate, which if statistically controlled, may undercut the goal of understanding how RSA relates to psychological processes (Allen, Chambers, & Towers, 2007). Further, measures of sympathetic activation were not considered in this study and are needed to gain a fuller picture of the autonomic response of high-risk mothers in the act of parenting. In spite of the study limits, these results document critical temporal associations between maternal physiology and parenting in abusive, neglectful, and nonmaltreating mothers that suggest the capacity for self-regulation is inextricably linked to quality of parenting across the spectrum of risk. The current findings are particularly valuable in highlighting how cardiovascular regulation shapes and is affected by parenting across risk groups, and thus offers significant insights into neurobiology of parenting-at-risk.

Historically few interventions for CM have been shown to be effective for reducing CM parenting (Skowron & Reinneman, 2005), though evidence is growing with respect to the efficacy of a handful of intensive interventions (e.g., Chaffin et al., 2004, 2011). Evidence-based parenting interventions such as Parent–Child Interaction Therapy (Eyberg et al., 2001) have been adapted for use with child welfare populations (Urquiza & McNeil, 1996) and shown to be effective in reducing aversive parenting and lower rates of CM recidivism (Chaffin et al., 2004, 2011). Through its live-coached, intensive mom-by-moment scaffolding of positive parenting, and gentle interruption of aversive control in the moment, PCIT may be particularly effective at building regulatory strength in parents that supports positive engagement between mother and child, and lasting behavior change. The current findings suggest that interventions such as PCIT that are effective in reducing CM parenting, may achieve positive outcomes through different mechanisms of change for abusive versus neglectful mothers. Interventions that aim to increase positive parenting in abusive mothers may first need to successfully strengthen their physiological regulatory capacities in the context of caring for their child. Does PCIT exert its effects on abusive parenting via early improvements in parents' capacities for autonomic regulation during parenting, which then facilitates use of more positive parenting and less harsh control? It is possible that effective parenting interventions for abusive mothers need to first enhance parents' regulatory strength, decouple the linkage between negative arousal and positive parenting, and facilitate the experience of positive parenting as less physiologically taxing. Research is needed to learn whether use of relaxation training, systematic desensitization, or meditation in the context of parenting interventions may help abusive mothers to calm and dampen their aversive experience of engaging in warm, positive parenting. In contrast, given the time-ordered effects of parenting on subsequent changes in neglectful mothers' physiology, would PCIT or other parenting interventions first improve neglectful mothers' repertoire of positive parenting skills, and then lead to subsequent improvements in physiological regulation? Can parenting interventions that are effective in reducing CM recidivism also strengthen dimensions of mothers' autonomic regulation in the context parenting? Further investigations are needed to elucidate the neurobehavioral mechanisms of change in effective CM parenting interventions to better optimize and tailor parenting interventions for this challenging public health concern.

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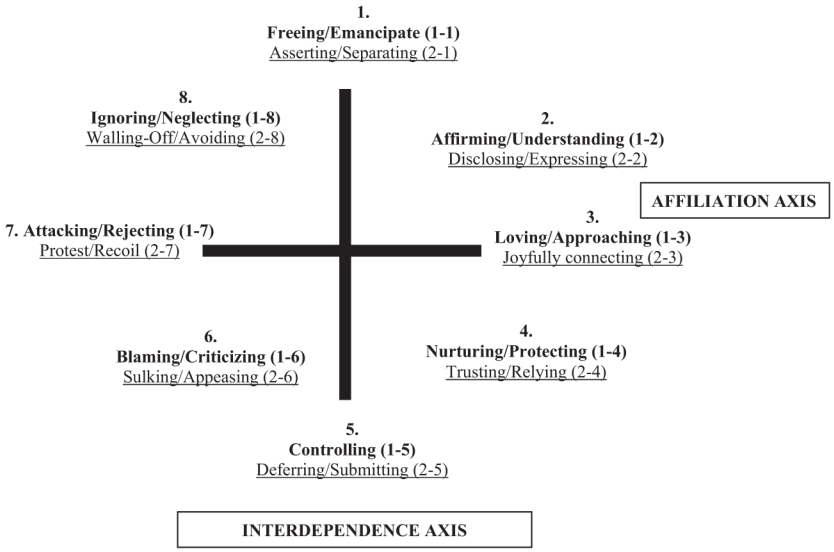


**Figure 1.**

SASB simplified cluster model. Labels in bold print describe actions directed toward another person. Labels in underline print describe actions in response to the other. Adapted from *Interpersonal Diagnosis and Treatment of Personality Disorders* (2nd ed.), by L. S. Benjamin, 1996, New York, NY: Guilford Press. Copyright © 1996 by Guilford Press. Reprinted with permission.

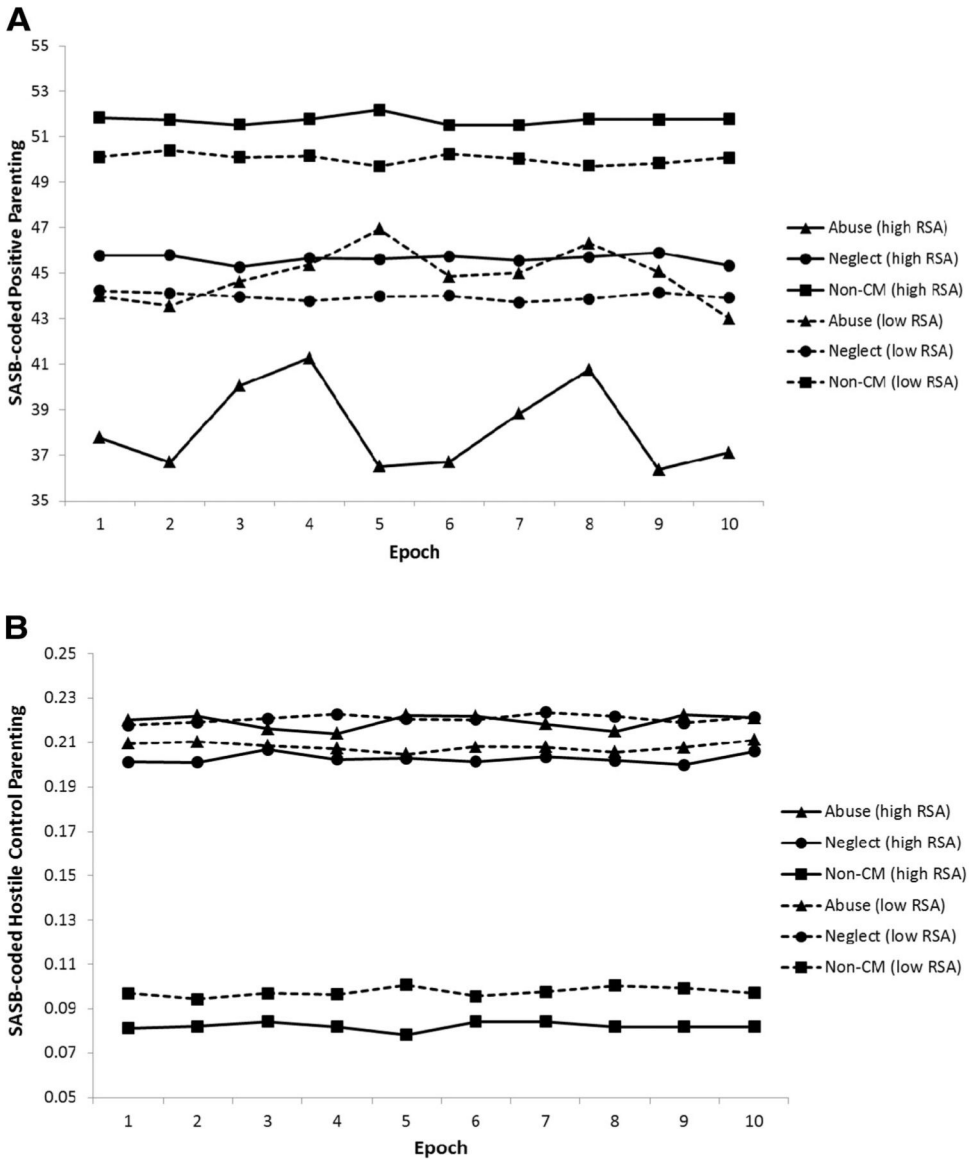


**Figure 2.**

A, Positive parenting as a function of maternal RSA and time. B, Strict/hostile control parenting as a function of maternal RSA level and time. Low and high RSA values are graphed at 1 SD below and above the mean, respectively. RSA = respiratory sinus arrhythmia.

## Table 1

Mean Levels of and Within-Person Variation in Maternal RSA and Parenting Differ by CM Group Status: Mean Comparisons

| | PA | PN | Non-CM | ANOVA |
|---|---|---|---|---|
| Positive parenting | $32.98_{a}$ | $35.28_{b}$ | $42.52_{a,b}$ | $F(2, 138) = 5.38^{**}$ |
| Strict/hostile control parenting | $.34_{a}$ | $.32_{b}$ | $.20_{a,b}$ | $F(2, 138) = 6.06^{**}$ |
| Baseline RSA | 5.79 | 5.62 | 6.03 | $F(2, 127) = 1.59$ |
| Joint task RSA | 6.05 | 5.73 | 6.08 | $F(2, 138) = 1.05$ |

*Note*. Subscripts denote significant pairwise differences with a standard Bonferroni correction $p < .05/3 \approx .017$.

** $p < .01$.

## Table 2

Mean Levels of and Within-Person Variation in Maternal RSA and Parenting Differ by CM Group Status: Comparisons of Group-Level Variance

| | PA | PN | Non-CM | Omnibus test |
|---|---|---|---|---|
| Affiliation/positive parenting | $280.00_{a}$ | $254.82_{a,b}$ | $207.12_{a,b}$ | $\chi^2(2) = 7.3^{*}$ |
| Harsh controlling parenting | $.06_{a}$ | .05 | $.03_{a}$ | $\chi^2(2) = 36.9^{***}$ |
| Joint task RSA | $.35_{a,b}$ | $.48_{a}$ | $.80_{b}$ | $\chi^2(2) = 46.9^{***}$ |

*Note*. Subscripts denote significant pairwise differences with a standard Bonferroni correction $p < .05/3 \approx .017$.

* $p < .05$.

*** $p < .001$.

**Table 3**

Zero-Order Correlations Among Task Level Maternal Respiratory Sinus Arrhythmia (RSA) and Parenting in the Full Sample and by CM Status

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Total sample | | | | | |
| 1. Maternal education | — | | | | |
| 2. Resting RSA | .004 | — | | | |
| 3. Joint task RSA | −.10 | .81* | — | | |
| 4. Positive parenting | .35* | −.10 | −.03 | — | |
| 5. Strict/hostile control | −.34* | .07 | −.004 | −.96* | — |
| Non-maltreating group | | | | | |
| 1. Maternal education | — | | | | |
| 2. Resting RSA | .007 | — | | | |
| 3. Joint task RSA | −.13 | .82* | — | | |
| 4. Positive parenting | .30* | −.09 | .03 | — | |
| 5. Strict/hostile control | −.30* | .08 | −.04 | −94* | — |
| Physical abuse group | | | | | |
| 1. Maternal education | — | | | | |
| 2. Resting RSA | −.30 | — | | | |
| 3. Joint task RSA | −.13 | .29 | — | | |
| 4. Positive parenting | .17 | −.55* | −.17 | — | |
| 5. Strict/hostile control | −.22 | .62* | .24 | −.98* | — |
| Physical neglect group | | | | | |
| 1. Maternal education | — | | | | |
| 2. Resting RSA | −.18 | — | | | |
| 3. Joint task RSA | −.27 | .88* | — | | |
| 4. Positive parenting | .29* | −.13 | −.14 | — | |
| 5. Strict/hostile control | −.25 | .08 | −.06 | −96* | — |

*Note.* Mean values reflect average taken across all 30-sec epochs.

* $p < .05$.

**Table 4**

Multilevel Model Estimates: Effects of Maternal RSA on Parenting Quality Vary by CM Group

| | Model 1: Positive parenting | | | | Model 2: Strict/hostile control | | | |
|---|---|---|---|---|---|---|---|---|
| | a. Concurrent model | | b. Lagged model | | a. Concurrent model | | b. Lagged model | |
| **Variable** | **Estimate** | ***SE*** | **Estimate** | ***SE*** | **Estimate** | ***SE*** | **Estimate** | ***SE*** |
| | | | | Fixed effects | | | | |
| Intercept | | | | | | | | |
| Abuse | 41.63*** | 7.08 | 42.45*** | 7.36 | .21* | .10 | .23* | .10 |
| Neglect | 44.82*** | 5.88 | 45.62*** | 6.08 | .21** | .08 | .20* | .13 |
| Non-CM | 50.92*** | 6.02 | 51.58*** | 6.22 | .09 | .08 | .08 | .08 |
| RSA (WP) | | | | | | | | |
| Abuse | −6.10* | 2.58 | −5.87* | 2.74 | .01 | .03 | .01 | .04 |
| Neglect | 1.26 | 1.10 | 1.11 | 1.19 | −.01 | .01 | −.01 | .02 |
| Non-CM | 1.01 | .67 | .71 | .74 | −.01 | .01 | −.004 | .01 |
| Abuse vs. Neglect | −7.34** | 2.80 | −6.98* | 2.99 | .02 | .04 | .02 | .04 |
| Abuse vs. Non-CM | −7.10** | 2.66 | −6.58* | 2.84 | .02 | .03 | .02 | .04 |
| Non-CM vs. Neglect | −.25 | 1.29 | −.41 | 1.40 | .004 | .02 | .01 | .02 |
| RSA (BP) | −1.52 | .95 | −1.67 | .99 | .01 | .01 | .02 | .01 |
| Lagged RSA (WP) | | | | | | | | |
| Abuse | | | 4.40 | 2.78 | | | −.10* | .04 |
| Neglect | | | .77 | 1.17 | | | −.01 | .02 |
| Non-CM | | | −1.63* | .73 | | | .02* | .01 |
| Abuse vs. Neglect | | | 3.64 | 3.02 | | | −.09* | .04 |
| Abuse vs. Non-CM | | | 6.04* | 2.88 | | | −.11** | .04 |
| Neglect vs. Non-CM | | | −2.40 | 1.38 | | | .02 | .02 |
| Lagged parenting (autocorrelation) | | | .11** | .03 | | | .10** | .03 |
| | | | | Variance components | | | | |
| Between person | | | | | | | | |
| Intercept | 198.90*** | 27.34 | 210.10*** | 29.35 | .04*** | .01 | .04*** | .01 |

| | Model 1: Positive parenting | | | | Model 2: Strict/hostile control | | | |
|---|---|---|---|---|---|---|---|---|
| | a. Concurrent model | | b. Lagged model | | a. Concurrent model | | b. Lagged model | |
| **Variable** | **Estimate** | ***SE*** | **Estimate** | ***SE*** | **Estimate** | ***SE*** | **Estimate** | ***SE*** |
| Within person | | | | | | | | |
| Residual | 229.85*** | 9.71 | 221.74*** | 10.15 | .04*** | .01 | .04*** | .002 |
| *−2LL* | 10753.0 | | 9331.2 | | −82.9 | | −63.3 | |
| *AIC* | 10757.0 | | 935.2 | | −78.9 | | −59.3 | |

*Note*. Unstandardized estimates and standard errors. Mother's intercept is centered at 0. Slopes or rates of RSA change are scaled in 30-sec epochs. Model is based on 10 occasions nested within 141 mothers. AIC = Akaike Information Criterion; −2LL = −2 Log Likelihood, relative model fit statistics.

* $p < .05$.

** $p < .01$.

*** $p < .001$.