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Mapping Cardiac Physiology and Parenting Processes in Maltreating Mother–Child Dyads

Elizabeth A. Skowron,

Child Study Center, Pennsylvania State University

Eric Loke,

Human Development & Family Studies, Pennsylvania State University

Lisa M. Gatzke-Kopp,

Human Development & Family Studies, Pennsylvania State University

Elizabeth A. Cipriano-Essel,

Child Study Center, Pennsylvania State University

Petra L. Woehrle,

Child Study Center, Pennsylvania State University

John J. Van Epps,

Child Study Center, Pennsylvania State University

Anjali Gowda, and

Department of Psychology, Pennsylvania State University

Robert T. Ammerman

Cincinnati Children's Hospital Medical Center and University of Cincinnati College of Medicine

Abstract

Child maltreatment (CM) lies on an extreme end of the continuum of parenting-at-risk, and while CM has been linked with a variety of behavioral indicators of dysregulation in children, less is known about how physiological markers of regulatory capacity contribute to this association. The present study examined patterns of mother and child physiological regulation and their relations with observed differences in parenting processes during a structured interaction. Abusing, neglecting, and non-CM mothers and their 3- to 5-year-old children completed a resting baseline and moderately challenging joint task. The structural analysis of social behavior was used to code mother–child interactions while simultaneous measures of respiratory sinus arrhythmia were obtained. Results indicated that physically abusive mothers were more likely to react to children's positive bids for autonomy with strict and hostile control, than either neglecting or non-CM mothers. CM exposure and quality of maternal responding to children's autonomous bids were uniquely associated with lower parasympathetic tone in children. Results provide evidence of neurodevelopmental associations between early CM exposure, the immediate interactive context of parenting, and children's autonomic physiology.

Keywords

parenting; SASB; psychophysiology; physical abuse; neglect

Child maltreatment (CM) experienced early in childhood represents a significant stressor, challenging the child to reconcile the parent's roles as both caregiver and source of threat. Not surprisingly, CM is associated with alterations in stress physiology (e.g., Pollak, 2008; Tarullo & Gunnar, 2006; Watts-English, Fortson, Gibler, Hooper, & DeBellis, 2006), increased risks for emotional and behavioral dysregulation (Cicchetti & Toth, 2005), and consequent risk for later adverse mental health outcomes in adolescence (Kaplow & Widom, 2007). However, much remains to be clarified with regard to the specific aspects of CM children's experiences that impact neurodevelopment of affect and regulatory systems (Repetti, Taylor, & Seeman, 2002; Watts-English et al., 2006).

CM and Parenting Processes

Elucidating the effects of early CM exposure requires study that extends beyond assessment of discrete CM events, into the immediate context of parent–child interactions that unfold along the continuum of parenting-at-risk (Reid, Taplin, & Lorber, 1981). We define CM as any acts or omissions by a parent or caregiver that result in harm, or threat of harm to a child. Although parents engage in acts and omissions that define child abuse and neglect, creating a developmental context characterized by failures in the average expectable environment, children experience far more interactions with their parent outside of specific CM acts, and the nature of these are also important for understanding effects on children's developing stress reactivity and regulation (Belsky, 1993; Repetti et al., 2002). Evidence from meta-analyses confirms that abusive parents are more directive, controlling, intrusive, and hostile when interacting with their children, relative to non-CM parents (Wilson, Rack, Shi, & Norris, 2008). Parenting characterized by coercive control in turn predicts problems in the development of children's self-regulated behavior (Rothbaum & Weiss, 1994). Thus, parents characterized by their propensity to engage in acts of CM may also impart risk through day to day interactions with their children outside of specific maltreatment events.

The preschool years reflect a particularly critical time for children's efforts to define a self in the context of connection, and early experiences with caregiving characterized by warmth, involvement and support for autonomy, coalesce to promote secure self-confidence and developing capacities for self and emotion regulation (e.g., Ainsworth, Blehar, Waters, & Wall, 1978; Kopp, 1982). However, power assertive parenting characteristic of CM families frustrates development of children's autonomous self-regulated behavior and adjustment (Baumrind, 1994; Trickett & McBride-Chang, 1995), particularly when experienced in early development (Baumrind, Larzelere, & Owens, 2010; Kochanska & Knaack, 2003). Aversive parent control has been linked with physiological dysregulation in children (Calkins, Graziano, Berdan, Keane, & Degnan, 2008), and is a robust predictor of internalizing and externalizing disorders over time (e.g., Baumrind et al., 2010; Patterson, DeBaryshe, & Ramsey, 1989).

Further, CM parents' nonsynchronous aversive responding to their children's positive/prosocial behaviors reflects a hallmark of CM family functioning. Studies of sequential interactions in CM families show that parents tend to (a) ignore or respond inappropriately to their children's prosocial behaviors and (b) exert control in aversive, intrusive ways (e.g., Cerezo & D'Ocon, 1999; Dumas & Wahler, 1985). These coercive cycles escalate and become mutually reinforcing and sustaining over time, leading to externalizing disorders, impaired regulation, and long-term persistent conduct problems (e.g., Dodge, Bates, &

Pettit, 1990; Eckenrode, Laird, & Doris, 1993; Patterson et al., 1989). Physically abusive parents engage in the highest levels of aversive control relative to neglecting and nonmaltreating parents (e.g., Bousha & Twentyman, 1984; Trickett & McBride-Chang, 1995), though cluster analyses have documented significant within-group variation on dimensions of positivity and control (e.g., Haskett, Scott, & Ward, 2004). Further, significant improvements in parenting quality and declines in CM recidivism have been achieved through randomized controlled interventions (e.g., Chaffin et al., 2004, 2010; Patterson, 1982), and mediated in part through increases in parents' positive responding and reductions in nonsynchronous aversive responding to their children's positive behaviors (Hakman, Chaffin, Funderburk, & Silovsky, 2009; Patterson, Forgatch, & DeGarmo, 2010). In this study we characterized sequential patterns of mother-child interaction in physically abusing, neglecting, and non-CM dyads using the Structural Analysis of Social Behavior (SASB; Benjamin, 1996, see Figure 1). Use of SASB technology enabled us to map the extent of warmth, autonomy-support, and control in sequentially ordered individual mother and child "speaking" turns. The SASB circumplex consists of blends of warm affiliation and autonomy (i.e., Friendly Autonomy) in the upper right quadrant with aversive control (i.e., Criticism) appearing as its antithesis. SASB enables researchers to distinguish between parental control that is strict, from that which is affiliative (Nurture/Protect), or hostile (Criticize). Likewise, children's affiliative autonomous behavior (Friendly Autonomy) can be distinguished from hostile autonomy (Walling Off) or complex self-assertion (e.g., Florsheim et al., 1996).

CM and Psychophysiological Indices of Regulation

CM children show deficits across the spectrum of neuro-biological function, including problems with neuroendocrine regulation (Cicchetti, Rogosch, Gunnar, & Toth, 2010; Tarullo & Gunnar, 2006), enhanced ERP responding to caregiver negative emotion (Shackman, Shackman, & Pollak, 2007), and heightened autonomic responding to interpersonal hostility (Pollak, Vardi, Bechner, & Curtin, 2005; see Watts-English et al., 2006, for a review). Biological research suggests variation in stress physiology and selective attention to negative emotion cues may serve adaptive functions for individuals in high threat environments. However, the entrainment of these physiological response styles over time likely underlies the regulatory dysfunction that contributes to increased rates of psychopathology in children exposed to CM. One physiological marker of regulatory capacity, respiratory sinus arrhythmia (RSA), appears to represent a general correlate of psychopathology across both the internalizing and externalizing spectra (Beauchaine, 2001). According to Porges' (2001) polyvagal theory, the parasympathetic nervous system (PNS) exerts neural control over cardiac output to regulate arousal in response to environmental cues. Withdrawal of PNS influence (decrease in RSA) results in an increase in heart rate and facilitates arousal and engagement in the environment. Unlike the sympathetic nervous system (SNS), which can also contribute to a rapid increase in arousal, the PNS is better able to rapidly reengage cardiac control to reduce arousal when needed. Porges postulates that this rapid dynamic control of arousal has important implications for regulating emotionality associated with heightened and prolonged arousal (typically experienced as anger, fear, or agitation), 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 in understanding the relationship between early parenting experiences and the ability to regulate arousal during normal developmental tasks, which likely has important implications for risk for pathological outcomes as children age.

Baseline levels of RSA represent the extent of an individual's regulatory capacity, by reflecting the degree to which arousal can be increased through PNS withdrawal before SNS activation needs to be used (Porges, 1998, 2001). Low baseline RSA is a common correlate

of psychopathology generally, and is thought to reflect reduced flexibility in responding to social and cognitive challenge (Beauchaine, Gatzke-Kopp, & Mead, 2007). In addition to baseline conditions of challenge, RSA withdrawal, or suppression, is generally considered to reflect an adaptive response by increasing task engagement without compromising control (e.g., El-Sheikh et al., 2009), though findings are also emerging that link greater vagal suppression to psychopathology (Calkins, Graziano, & Keane, 2007) and early exposure to adversity (e.g., Obradovi, Bush, Stamperdahl, Adler, & Boyce, 2010). Further, RSA augmentation (i.e., increased parasympathetic activation) has been observed among adults in conditions specific to emotion regulation in social interactions (Butler, Wilhelm, & Gross, 2006).

In considering the role parenting interactions may play in helping children's self regulatory development, it may also be useful to understand mothers' regulatory style in the immediate relational context of parenting-at-risk, to provide clues about why CM is particularly resistant to intervention (Skowron & Reinneman, 2005), and insight into the mechanisms of change within effective CM interventions (e.g., Hakman et al., 2009). Parasympathetic physiology is a useful indicator of regulatory ability, and may provide insight into maternal states. Mothers who are themselves challenged by robust and difficult-to-modulate emotional arousal may be especially prone to acts of CM when faced with frustration. Research indicates that parents at increased risk for perpetrating CM tend to show more emotional reactivity, negativity, and less affection toward their children (e.g., Cicchetti & Toth, 2005), greater threat-sensitivity, negative affect, and sympathetic activation at rest and in response to children's distress and other child-related stimuli (e.g., Bugental, 2009). Though studies of PNS functioning in CM mothers have not been published to date, researchers studying normative samples have documented higher resting RSA in parents who self-report use of positive emotional socialization practices (Perlman, Camras, & Pelphey, 2008). Greater maternal vagal suppression in response to infant distress has been linked to less sensitive parenting, though only among mothers of avoidantly attached children (Mills-Koonce et al., 2007). A mother's own regulatory ability may not only reflect her propensity for CM and overreliance on aversive control to manage her child, but also may present challenges to her ability to support her child's age-appropriate independent behaviors.

Joint Contributions of CM and Parenting Transactions on Children's Physiology

Parenting quality is known to play an important role in shaping developing stress response systems, and capacities for biological regulation in offspring (e.g., Francis, Diorio, Liu, & Meaney, 1999; Meaney, 2001). For example, higher quality parenting has been shown to predict greater vagal suppression during a series of solo and collaborative lab tasks (e.g., Calkins et al., 2008; Kennedy, Rubin, Hastings, & Maisel, 2004). Human and primate research has documented the powerful modulating effect of social affiliation, control, and subordination on the stress response (Sapolsky, 2004). For example, relational experiences characterized by low positivity, low control, or subordinate status have been linked to elevations in sympathetic tone, heightened anxiety, vigilance (Repetti et al., 2002; Sapolsky, 2004), and abnormal cortisol profiles (Abbott et al., 2003; Flinn & England, 1997).

Overview of Study

This study sought to clarify the relationships between CM status, patterns of dyadic interaction along a continuum of autonomy– control, and parasympathetic physiology. We hypothesized that CM children, relative to nonmaltreated children, would show lower resting RSA, lower task RSA, and greater RSA suppression in the context of a joint

challenge. We explored differences in children's vagal tone as a function of CM subtype, and theorized that physically abused children's greater threat sensitivity (Pollak, 2008) may lead them to show lower resting RSA and greater RSA suppression relative to neglected children. Next, we hypothesized that CM mothers would show lower resting and task RSA, and greater RSA suppression during a moderately challenging teaching task, suggesting a weakened regulatory capacity and predisposition to heightened arousal in the parenting context.

Next, we mapped CM group differences in sequential patterns of maternal–child interactions in the context of the joint challenge task. In line with previously published research, we expected to observe less affirming and more controlling behaviors in physically abusive and neglecting mothers, relative to nonmaltreating mothers. We reasoned that CM mother–child dyads would engage in more nonsynchronous aversive interactions in which mothers react to children's positive autonomous behaviors with hostile control, and more synchronous aversive transactions characterized by a controlling–submit pattern. We also hypothesized that CM mothers, relative to nonmaltreating mothers, would engage in less affirming of their children's autonomous actions. In contrast, we predicted that non-CM mothers would remain more affiliative and less controlling in their transactions, and specifically engage in more affirmation of child autonomy. In line with published findings, we further posited that physically abusive mothers would engage in (a) highest mean levels of hostile control, and (b) more mother–child transactions characterized by nonsynchronous aversive control behavior, relative to neglecting or nonmaltreating mothers.

Finally, we tested a hierarchical model that examined the independent contributions of CM status and mother–child sequential exchanges on children's parasympathetic regulation. We also tested moderation models to determine whether quality of parenting transactions reflect a source of developmental risk or resilience specific to CM, or alternately, signify an additional source of risk. We reasoned that dynamic parenting processes high in support for children's positive autonomous action would facilitate healthy parasympathetic regulation (i.e., high vagal tone and greater vagal suppression in response to challenge), over and above contributions of socio-economic status (SES) and CM status. In contrast, experience with nonsynchronous parenting characterized by maternal aversive control in response to child positive autonomy was expected to show associations with lower parasympathetic tone. Lag 1 patterns of nonsynchronous aversive maternal responding to child friendly autonomy were expected to predict lower task RSA and greater RSA suppression, beyond CM status.

Method

Participants

Participants were 43 CM and 33 non-CM preschool children and their mothers. Children ranged in age from 3 to 5 years ($M = 3.70$, $SD = .73$), 48.7% were male, and a majority were White (77.3%), followed by multiracial (18.7%), African American (4.0%), and 1 unreported. Mothers ranged in age from 20 to 45 years ($M = 28.7$; $SD = 5.7$), a third (36.8%) were married (44.8% single; 17.1% separated or divorced), and over half (51.3%) were employed outside the home. Among the subsample of CM children, 17 were identified as physically abused and 26 as physically neglected, based on documentation from Child Protective Services (CPS) of mother's perpetration toward the target child, and using the Maltreatment Classification System (MCS; Barnett et al., 1993).¹ *Physical abuse* was coded when there was evidence of a caregiver-inflicted physical injury to the child by other than accidental means. *Physical neglect* was coded based on documentation that the caregiver failed to meet the child's minimum physical needs. CM subtypes were 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 et al., 2000). Comorbidity of subtypes (i.e., physical abuse with neglect and/or emotional abuse; physical neglect with emotional abuse) was observed in 51.2% of the CM group, consistent with other published findings (e.g., Belsky, 1993; Kaufman & Ziegler, 1989). Sampling from CPS has its limitations, in that formal reports of CM disproportionately occur among low SES and ethnic minority families (e.g., Chaffin, Kelleher, & Hollenberg, 1996), and are more likely when children come into greater contact with child protective or law enforcement agencies (e.g., Heller, Larrieu, D'Imperio, & Boris, 1999). Recruitment of non-CM dyads sought a sociodemographically comparable sample from department of public welfare agencies and a database maintained on birth announcements published in local newspapers. Non-CM mothers consented to verification that their family was free of CPS preventive or protective service records.

Physically abused, neglected, and nonmaltreated children did not differ on dimensions of child age, $F(2, 75) = .98, p = .38$; sex, $F(2, 75) = 1.45, p = .24$; race, $\chi^2(4, N = 75) = .91, p = .92$; or child IQ (Stanford Binet-5), $F(2, 68) = .72, p = .49$. Likewise, no CM group differences were observed on mothers' age, $F(2, 75) = .71, p = .49$, or relationship status, $\chi^2(4, N = 75) = 6.76, p = .15$. Despite efforts to match on Participant SES, mothers from the CM groups reported fewer total years of education, $F(2, 75) = 13.90, p < .0001$ ($M_s = 12.4, 12.0$, and 14.6 years for physical abuse, neglect, and non-CM, respectively), and lower household income, $F(2, 74) = 11.09, p < .0001$, than non-CM mothers. Forty-two percent of CM families reported incomes below \$30,000 per year, and 92.9% reported incomes below \$50,000 per year, as contrasted with 48.5% of non-CM families reporting income below \$30,000 per year, and 78.8% reporting income below \$50,000 per year.

Procedures

All procedures used in this study were approved and monitored by the Office for Research Protections. Mother-child dyads were invited to participate if the mother was 18 years of age or older, spoke fluent English, and was living with her preschool child. Ninety-four dyads each completed a three-visit protocol over a 2–3 week period conducted by a team of two trained interviewers, comprised of two home visits for psychosocial and cognitive assessments, and a 2.5-hr laboratory session. Families were paid \$150 to complete the three interviews, provided transportation, snacks, and children's small toys/gifts. During the lab visit, behavioral and physiology recordings were collected and monitored through a one-way mirror. Dyads participated in a 5 min resting baseline period seated together on a comfortable couch, while viewing a relaxing video segment, followed by the 3–5 min moderately challenging teaching task (i.e., duplo puzzle; Hoffman, Crnic, & Baker, 2007). During the joint task, mother and child were seated together at a small table and the child was provided a model 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.

Physiological monitoring—Disposable pregelled Ag/AgCl electrodes were placed on mothers' and children's chests 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 and sampled at 500

¹Families in which the child had been sexually abused were excluded from study participation because such cases more often involve perpetrators other than the child's mother and are more likely to result in the child's removal from the home (Berliner & Elliott, 2002). In the present sample, physical abuse included bruises, abrasions, or welts to the child's body; excessive physical punishment; and severe injuries requiring hospital treatment. Physical neglect consisted of failure to meet children's minimum physical needs for food, clothing, shelter, to provide appropriate supervision, a safe environment, or adequate substitute care. Four physically abused and three neglected children had been placed in foster care previously, though were living with their mothers at the time of study participation.

HZ, and transmitted via wireless signal to a computer monitored by a research assistant. RSA data were missing for 6 children and 5 mothers during the baseline period, and 5 children and 8 mothers during the joint task, a rate common in research that uses physiological recording procedures with young children. Four children refused electrode placement, and remaining RSA data was missing because of excessive movement artifacts or technical problems (i.e., dropped signals, loosened leads, or child pulling on electrode). Data were not missing systematically by CM status, children's age or sex, mother's age, or SES.

Electrocardiograph data were processed offline using Mindware Technologies HRV 2.6 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. The RSA frequency band was set between 0.24 and 1.04 for children, and 0.12 to 0.40 for mothers. RSA values were averaged across the 30 second epochs present to create a single score for the baseline period (RSA_{base}) and another for the joint teaching task (RSA_{task}). Mean RSA_{Δ} scores for mother and child were calculated by subtracting task RSA from baseline RSA scores. Positive RSA_{Δ} scores reflected vagal suppression, whereas negative scores reflected vagal augmentation. Physiological analyses were based on the number of individuals for which there were data. Thus, RSA data were available for 68 children and 69 mothers in the baseline episode, and 65 children and mothers in the joint challenge/teaching task. Joint patterns of maternal and child RSA were calculated based on the number of dyads in which data were available for both mother and child.

Coding mother– child interactions—Observational data obtained during the mother–child joint task were coded using the Structural Analysis of Social Behavior (SASB; Benjamin, 1996; Benjamin & Cushing, 2000), which has been used elsewhere to code brief parent– child interactions (e.g., Florsheim et al., 1996; Skowron, Kozlowski, & Pincus, 2010). Sixteen possible cluster codes are distributed across two circumplex surfaces (see Figure 1). Videotapes are transcribed and unitized into “speaking” turns defined as a single transactional turn bound on either side by one's partner. Coders work from videotapes and verbatim transcripts to assign a code to each individual transaction by determining (a) focus, (b) degree to warmth/affiliation, and (c) degree of interdependence (ranging from autonomy to control/submission).

Four SASB cluster codes characterizing mother's parenting behavior were extracted (Affirm Autonomy, Nurture/Protect, and two hostile control codes: Strict Control & Criticize), and five child SASB codes were extracted (two friendly autonomy codes: Separate & Disclose and (note reference to the 1st two codes as friendly autonomous, while the last 2 are not) Trust/Rely; Submit; and Sulk) and reported; the remaining codes were not a focus of this report. Next, three mother– child interaction sequences of interest were used, and indexed by lag-1 conditional probabilities of mother response to an antecedent child behavior: (a) *positive contingent responding* defined as the proportion of mother Affirm responses to child Friendly Autonomous behavior [$P(1-2 \mid 2-1 \text{ \& } 2-2)$]; (b) *nonsynchronous aversive responding* reflected proportion of mother aversive Control in response to child Autonomy [$P(1-5 \text{ \& } 1-6 \mid 2-1 \text{ \& } 2-2)$]; and (c) *negative contingent responding* was the proportion of maternal aversive Control conditioned on child Submitting & Sulking [$P(1-5 \text{ \& } 1-6 \mid 2-5 \text{ \& } 2-6)$]. SASB coding was conducted by a team of three trained raters who were blind to family status. Coders completed over 75 hr of training and achieved sufficient reliability on practice tapes before coding (weighted $\kappa > .70$). Interrater reliabilities were assessed on 15% of tapes coded, yielding weighted kappas ranging from .64 to .84 ($M = .74$), on par with

those reported in other studies of SASB-coded parent–child interactions (e.g., Florsheim et al., 1996; Skowron et al., 2010).

Results

Preliminary Analyses

Across all CM dyads, no differences by history of child foster care placement were observed in mother or child SASB cluster codes, sequential patterns, or RSA scores (all *ts ns*). Within the full sample, neither child age ($r_s = -.01$ to $.01$) nor sex ($r_s = .02$ to $.07$) predicted children's RSA scores. Given the sample stratification by CM status, sociodemographic indicators (maternal education and household income) were included in the hierarchical regressions on CM status, parent–child transactions, and children's parasympathetic physiology.

CM differences in parent–child transactions—During the joint challenge task, mothers engaged in a high proportion of SASB Nurture/Protect (i.e., warm guidance) behaviors ($M = .56$, $SD = .17$) cluster codes, followed by Strict Control ($M = .19$, $SD = .15$), Affirm (i.e., autonomy-support; $M = .18$, $SD = .17$), and Hostile Control ($M = .03$, $SD = .06$). Next, descriptive statistics for mother and child SASB cluster and sequential codes by physical abuse, neglect, and non-CM groups are shown in Table 1. *T* tests were conducted to assess differences in mother and child cluster codes, and mother–child Lag 1 transitional probabilities by CM status, and then probed for CM subtype differences. As shown in Table 1, physically abusive and neglecting mothers displayed more strict Controlling behavior than did non-CM mothers ($p_s < .006$). Physically abusive mothers also engaged in fewer Affirming Autonomy behaviors than non-CM mothers ($p = .03$). Though mother Nurture/Protect behavior was the most prevalent behavior across groups, accounting for roughly one half of mothers' speaking turns (i.e., 53% of neglecting to 59% of non-CM mothers' behaviors), this maternal behavior did not distinguish between CM subtypes nor did it predict children's RSA scores or successful task completion. In terms of children's observed behaviors, physically abused children engaged in more Sulking (i.e., hostile submission), relative to neglected ($p = .009$) and non-CM children ($p = .001$). Neglected children showed the lowest levels of Autonomous behavior, relative to physically abused children.

Differences were also observed by CM status in the Lag 1 probabilities of positive contingent responding (i.e., mother Affirm–child Autonomy), $t(74) = 2.31$, $p = .02$; aversive nonsynchronous responding (i.e., maternal Control conditioned on child Autonomy), $t(74) = -2.18$, $p = .03$; and negative contingent responding (i.e., mother Control–child Submit), $t(74) = -2.00$, $p = .05$. Mother–child dyads in the physical abuse group engaged in more nonsynchronous ($p = .02$) and negative contingent ($p = .04$) transactions, and fewer positive contingent transactions ($p = .02$) during the joint challenge task, as compared to non-CM dyads, with neglect dyads falling roughly in between the two.

Mother and child physiology patterns by CM subtype—Two CM group (Physical Abuse vs. Neglect vs. Non-CM) $\times$ task (baseline vs. joint challenge) repeated measures ANOVAs were conducted with child and mother RSA scores entered as the dependent variable. Main effects were observed for children on Task $F(1, 59) = 31.73$, $p < .0001$, indicating a significant reduction in children's RSA scores from baseline to the joint challenge task. Analyses conducted on mothers' RSA scores also revealed significant Task effects, $F(1, 58) = 10.78$, $p = .002$, demonstrating RSA increases from baseline to joint challenge task (see Figure 2). Neither CM subtype main effects nor CM $\times$ Task interactions were significant for children or mothers in terms of predicting the slope of RSA changes.

To represent the mother– child differences in RSA change, we defined vagal suppression as RSA_{Δ} scores >0 , and RSA_{Δ} scores >0 as indicating vagal augmentation.

Inspection of individual differences in children's RSA_{Δ} scores showed that 75.9% children displayed vagal suppression from baseline to the joint task, while 24.1% of children showed vagal augmentation. In contrast, most mothers' RSA_{Δ} scores revealed a pattern of vagal augmentation (70.4%) while interacting with their child, while the remaining (29.6%) demonstrated vagal suppression. Rates of suppression and augmentation significantly differed between mothers and children (McNemar's exact test $p = .001$), though no CM group differences emerged for direction of children or mothers' individual change scores. Exam of dyadic patterns of RSA_{Δ} indicated over half of the dyads (51.9%) engaged in a mother RSA augmenting– child RSA suppressing pattern from resting baseline to the joint challenge task. Only three dyads (5.6%) showed the opposite pattern (i.e., mother RSA suppression– children RSA augmentation), all of whom were in the CM-Neglect group.

CM, Parenting Processes, and Children's Physiology

To test the incremental prediction of CM status and mother– child Lag 1 transitions on children's parasympathetic regulation, hierarchical regression models were fit to the data. Given the sample stratification, sociodemographic indicators (income and maternal education) were included as covariates. As shown in Table 2, three models were examined each for children's task RSA and RSA_{Δ} : (a) *positive contingent responding*, that is, maternal Affirm given child Autonomy [$P(1-2 \mid 2-1 \text{ \& } 2-2)$]; (b) *aversive nonsynchrony*, that is, maternal Control given child Autonomy [$P(1-5 \text{ \& } 1-6 \mid 2-1 \text{ \& } 2-2)$]; and (c) *negative contingent responding*, that is, maternal Control given child Submit/Sulk [$P(1-5 \text{ \& } 1-6 \mid 2-5 \text{ \& } 2-6)$]. Dependent variables were children's joint task RSA or children's RSA_{Δ} (i.e., baseline to task) and covariates identified above were included in the models. Baseline RSA scores were also covaried in the models predicting child RSA_{Δ} .

Hierarchical regression of children's joint task RSA scores onto maternal *positive contingent responding*, controlling for effects of maternal education, income, and CM status, was not significant, $\Delta F(1, 58) = 1.06$, $p = .31$, $\Delta R^2 = .02$. As shown in Table 2, step 2 entry of physical abuse and neglect was significant, $F(2, 59) = 4.20$, $p = .02$, $\Delta R^2 = .12$, indicating that both uniquely predicted lower task RSA. Regression of child RSA_{Δ} scores onto mother's positive contingent responding was significant, $\Delta F(1, 54) = 4.78$, $p = .03$, $\Delta R^2 = .06$, after covarying education, income, CM status, and children's baseline RSA scores. Interpretation of regression coefficients showed that mother affirming– child friendly autonomy transitions predicted less RSA suppression (i.e., higher parasympathetic tone) while the child was engaged in the moderately challenging task with mother, relative to children whose mothers were less affirming of their autonomous behavior. Baseline RSA scores and maternal education also uniquely predicted children's RSA_{Δ} scores.

Regression of child task RSA scores onto mother aversive nonsynchronous responding was also significant, $\Delta F(1, 58) = 8.14$, $p = .006$, $\Delta R^2 = .10$. Children who experienced higher proportions of maternal controlling & criticizing in response to their friendly autonomous behavior showed lower task RSA and greater RSA suppression. Physical abuse and maternal education also significantly predicted task RSA scores. Nonsynchronous responding also emerged as a significant unique predictor of children's RSA_{Δ} scores, $\Delta F(1, 55) = 4.60$, $p = .04$, $\Delta R^2 = .07$. However, aversive contingent responding (maternal control/criticize– child submit/sulk) was neither a significant predictor of children's task RSA, $\Delta F(1, 58) = .96$, $p = .33$, nor RSA_{Δ} scores, $\Delta F(1, 55) = .20$, $p = .65$.

Follow-up tests were conducted to determine whether positive contingent responding and aversive nonsynchrony would each continue to predict children's RSA scores, after

controlling for base rates of mother Affirm or Control/Criticize codes. After covarying base rates of SASB Affirming (along with SES, CM status, & baseline RSA), the effects of positive contingent responding on children's RSA $_{\Delta}$ scores were attenuated to the null, $\Delta F(1, 54) = 2.03, p = .16$. Conversely, after partialing out base rates of SASB Control/Criticize, the effects of mother–child aversive non-synchrony (control child autonomy) on children's task RSA and RSA $_{\Delta}$ scores remained significant, $\Delta F(1, 55) = 4.49, p = .04, \Delta R^2 = .06$, and $\Delta F(1, 53) = 9.68, p = .003, \Delta R^2 = .10$, respectively. Mean levels of maternal Control varied by CM status, but the negative effects of Control on child parasympathetic tone were only observed when it immediately followed children's friendly autonomous bids. In contrast, higher mean levels of maternal Affirming Autonomy predicted higher RSA, regardless of children's antecedent responses. Finally, two sets of three hierarchical multiple regressions were conducted to examine whether CM status moderated relations between parenting transactions and children's parasympathetic physiology, however, no significant interactions were observed.

Discussion

In this study of parenting-at-risk in CM families, we tested associations between CM group status, parenting transactions, and autonomic physiology in a sample of mother–preschooler dyads. Our findings offer evidence that both exposure to CM, and the quality of maternal responding to children's positive autonomy, were independently associated with parasympathetic tone in children.

CM and Physiological Characteristics

Focusing first on observed patterns of children's physiology across risk groups, we found that the majority displayed a pattern of RSA suppression, as they transitioned from resting baseline to joint challenge. These findings are consistent with the biological model that RSA withdrawal is instigated in contexts presenting a challenge and requiring attentional and effortful engagement (Beauchaine, 2001; Porges, 2001). Children across physical abuse, neglect, and non-CM groups were equally likely to demonstrate this profile. However, relative to the comparison group, both abused and neglected children displayed lower RSA levels while interacting with mothers to complete the challenging task. Greater vagal suppression in response to challenge also contributed to the lower RSA values during the task, but only in the physically abused subgroup. These findings are consistent with a growing literature documenting deficits across the spectrum of neurobiological function among maltreated children in general, and physically abused children in particular (Pollak, 2008; Tarullo & Gunnar, 2006; Watts-English et al., 2006).

Mothers predominantly displayed a pattern of RSA augmentation from baseline to interactive task, in contrast to the RSA suppression observed in children. The divergent physiological response patterns observed in mothers and children suggest they are engaging in different processes to complete the joint challenge. The joint task is far more cognitively challenging for children than for an adult, requiring greater effortful and attentional engagement. Mothers, on the other hand, are asked to serve in a facilitative role, and so may suppress their impulses to complete the task or frustration in response to the child's struggles. In other words, mothers may be tending more to emotional and relational aspects of the situation while their children attended to the challenge of completing the puzzle. By augmenting RSA, mothers may be actively controlling arousal tendencies to remain calm, positive, relationally engaged, and thus supportive of their child. Thus although vagal suppression is often considered characteristic of appropriate engagement, augmentation may be both normative and functional when individuals are required to suppress arousal in the service of relational engagement (e.g., Butler et al., 2006; Porges, 1998, 2001). The reverse pattern, in which mother suppressed and child augmented, was rare and observed only

among neglecting mother–child dyads. We can only speculate from this physiological pattern that some neglecting mothers may find engagement with their children to be taxing and thus reflect a significant cognitive and emotional challenge, similar to Dozier and Kobak's (1992) observations of heightened physiological arousal in avoidantly attached adults. Neglecting mothers who suppress vagal tone in the context of engaging with their child may be working hard to establish and maintain positive contact.

Mother–Child Interactions

All mothers, regardless of CM status, spent at least half their time engaged in nurture/protect behaviors, a form of affiliative control. This finding is not surprising given that the joint task required mothers to teach or coach their child to facilitate its successful completion. One possible reason for the lack of associations with children's physiology is that the laboratory setting's demand characteristics may have led mothers to alter their normative behavior in light of the observational context, toward more socially desirable guidance behaviors. Instead, what distinguished physically abusive, neglecting, and non-CM mothers was the extent of autonomy support and harsh control they displayed during the teaching task. In line with existing research (e.g., Cerezo, 1997; Wilson et al., 2008), mothers in the physical abuse group engaged in less affirming and more strictly controlling and hostile controlling behaviors during task interactions, than nonmaltreating mothers. Neglecting mothers also used greater amounts of strict control than did non-CM mothers.

Further, sequential analyses indicated that physically abusive mothers were more likely to react to their children's positive bids for autonomy by controlling them (i.e., non-synchrony), than were neglecting and nonmaltreating mothers. Physically abused children also experienced significantly more contingent control-submit exchanges. In other words, physically abused children's autonomous and submissive behaviors were each more likely to elicit a strict controlling and/or critical response from mothers, than was the case for neglected or nonmaltreated children. Such indiscriminate, rigid control has been observed elsewhere among physically abusive parents (e.g., Cerezo & D'Ocon, 1999). Although there were no observed effects of CM status on maternal measures of resting and task physiology, suggesting that physiological function may not be a direct liability for the perpetration of CM, variations in mothers' resting or context-specific parasympathetic tone may interact with other factors such as low power attributions (e.g., Bugental, 2009) to precipitate an overreliance on aversive control strategies. Naturalistic observations of compliance episodes in the home along with CM severity and chronicity documentation are needed to illuminate patterns of maternal physiology that underlie episodes of abuse or neglect.

CM, Parenting, and Parasympathetic Physiology

The final study aim was to examine linkages between child physiology and parent–child sequential transactions. Beyond the impact of maternal education and CM status on children's physiology, parenting transactions were also observed to have significant direct associations with children's physiology. Although CM children showed lower RSA during the challenge task than did non-CM children, the effects of parenting transactions on children's parasympathetic functioning did not vary as a function of CM status (i.e., broad social address effects); rather, the effects held for children across the spectrum of risk. Findings indicated that children whose autonomous ideas and actions were more often thwarted by maternal control or criticism while interacting to complete the challenge task, showed lower parasympathetic activity. Notably, the effects of the Lag 1 control–autonomy sequences on children's RSA remained after partialing out base rates of maternal control and criticism. In summary, while findings indicated that physically abusive parents engaged in more maladaptive parenting practices, all children exposed to such practices showed physiological sensitivity to those effects. Beyond the threat sensitivity observed in CM

samples (e.g., Pollak, 2008), these findings suggest that parenting which stifles preschoolers' friendly autonomous actions may have adverse physiological implications in the form of underdeveloped regulatory capacity. Children's heightened physiology during aversive, nonsynchronous mother–child exchanges may be what underlies the “predictability” phenomenon observed by Wahler and colleagues, in which children respond to inconsistent, aversive parenting by escalating negative, aversive behavior to obtain more predictable, albeit negative, responses from parents (Dumas & Wahler, 1985; Wahler et al., 1990). These data suggest that children's experiences of parent aversive intrusion and demands for compliance that characterize the onset of coercive cycles and lead to problems of underregulation (e.g., externalizing disorders, substance abuse, and antisocial behavior; Patterson et al., 1989; Reid et al., 1981), may be linked to parental failures to support children's friendly individuation, and at-risk adolescents' tendencies to assert autonomy in hostile or complex ways (e.g., Florsheim et al., 1996).

Second, our findings indicate that children whose efforts to assert autonomy were more often met with maternal affirmation (i.e., warm support for their independent ideas and actions), showed stronger parasympathetic tone in the context of a joint challenge. The attenuation of these affects to the null after controlling for base rates of maternal affirming behavior suggests that unconditioned support for friendly autonomy in the context of a challenge is a more important predictor of children's physiology. Taken together, these findings support Porges' (2001) assertion that the experience of safe environment as essential for development of optimal vagal functioning, and highlights how early parent–child dynamics may entrain physiological response styles that are adaptive or maladaptive to the goals of regulation and affiliation.

Because CM children showed higher parasympathetic activity when their mothers parented in ways which affirmed their autonomous bids, a plausible interpretation for physically abused, neglected, and non-CM children alike is that positive parenting that includes blends of warm affiliation and autonomy-support in one-on-one moments with their child may facilitate the development of appropriate autonomic regulation, and serve a protective function for abused and neglected children. Examined inversely, the amount of *positive* parenting experiences, or the ratio of positive to negative parenting experiences, may be as important for understanding how children develop emotional and behavioral regulation as is documenting the presence of poor parenting. These findings highlight the possibility that interventions for physical abuse such as parent–child interaction therapy (Chaffin et al., 2004) and parent management training (Patterson et al., 2010) which achieve significant reductions in parents' nonsynchronous aversive control and increase positive parenting, may also be positively impacting CM children's autonomic physiology.

However, several caveats must be considered. Most important is that the causal direction of the associations between children's physiology in the context of parenting exchanges is not clear from this study. Beyond the links observed between children's physiology and CM subtype, children's vagal activity also appears sensitive to variations in parenting transactions. Conversely, it is equally plausible that children's physiological reactivity and regulation impacted variations in the quality of maternal responding. This is an especially difficult distinction to make, given that even as young as age 3, children have experienced countless caregiver interactions that contribute to the canalization of a physiological response tendency. Furthermore, the historical context of the relationship may allow children to respond physiologically in anticipation of a parental action, leading to an appearance of a child-led shift in the interaction that may be based on historical experiences of parent-initiated actions. Clarification of these issues awaits longitudinal follow-up.

Use of CPS-involved participants likely constrained representation of higher SES families among the CM subgroups in this sample, given that CPS-involved samples are disproportionately lower SES, women, and ethnic minorities (Chaffin et al., 1996). Replications within a probabilistic community sample of non-CPS involved maltreating families are necessary to determine generalizability of these findings. The relatively brief period of observation and small sample size further necessitate caution with interpreting these findings. For example, the small CM subgroup sizes reduced statistical power, thus limiting our ability to explore other individual difference variables including the severity, onset, and chronicity of CM (e.g., Kim, Cicchetti, Rogosch, & Manly, 2009). Further work is needed to determine if these findings observed in the lab would generalize to home settings. Our thinking is that mothers might make efforts to display their “best behavior” in the lab, and this would only serve to weaken associations observed between CM and parenting. To the extent that the relatively brief, standardized lab task is not an accurate situation in which to observe unfolding transactions, the magnitude of effects observed may actually reflect underestimates.

In conclusion, this study examined physiology in the immediate context of well characterized parent–child interactions during a standardized laboratory task. Findings provide evidence of the neuro-developmental impact of CM and quality of parenting vis-à-vis children’s autonomy. Physically abusive mothers differed substantially from neglecting and non-CM mothers in their interactive styles, and these variations in parenting were associated with children’s regulatory ability. These findings suggest that interventions with CM parents that focus on increasing positive interactions as well as decreasing specific acts of maltreatment may be beneficial. Yet, temperamental and genetic variations likely contribute to the influence of parenting processes’ on children’s physiological development. Models that consider children’s individual differences in the context of parenting and CM risk are needed to understand the interactive dynamics between parents and children that precipitate CM, and further clarify heterogeneity in children’s outcomes.

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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. *Note:* From *Interpersonal Diagnosis and Treatment of Personality Disorders* (2nd ed., p. 55), by L. S. Benjamin, 1996, New York: Guilford Press. Copyright 1996 by Guilford Press. Reprinted with permission.

Figure 2.

Child and mother RSA values during resting baseline and joint challenge task by CM subtype. *Note.* RSA values in milliseconds square (msec^2).

Table 1

Descriptive Statistics for SASB Mother and Child Codes by CM Subtype

	Physical abuse (<i>n</i> = 17)			Physical neglect (<i>n</i> = 26)			Non-CM (<i>n</i> = 33)		
	<i>M</i>	<i>SD</i>	Range	<i>M</i>	<i>SD</i>	Range	<i>M</i>	<i>SD</i>	Range
Mother codes									
Affirm Autonomy (1–2)	.12 ^a	(.09)	0 to .32	.17	(.19)	0 to .71	.22 ^a	(.13)	0 to .57
Nurture/Protect (1–4)	.54	(.19)	.19 to .71	.53	(.16)	.29 to .93	.59	(.16)	.28 to .88
Strict Control (1–5)	.24 ^a	(.15)	0 to .59	.23 ^b	(.16)	0 to .51	.13 ^{ab}	(.13)	0 to .42
Hostile Control (1–6)	.06	(.08)	0 to .27	.03	(.05)	0 to .21	.03	(.06)	0 to .29
Child codes									
Autonomous/Disclose (2–2)	.27 ^a	(.18)	0 to .60	.17 ^a	(.16)	0 to .64	.24	(.16)	0 to .64
Rely/Trust (2–4)	.32	(.22)	.03 to .79	.43	(.22)	.03 to .81	.43	(.22)	0 to .95
Submit (2–5)	.07	(.08)	0 to .26	.11	(.10)	0 to .30	.08	(.09)	0 to .30
Sulk (2–6)	.23 ^{ab}	(.22)	0 to .60	.11 ^a	(.13)	0 to .51	.08 ^b	(.10)	0 to .35
Mother–Child Lag 1 transitions									
Affirm–Autonomy P(1–2 2–1,2–2)	.14 ^a	(.13)	0 to .50	.16	(.20)	0 to .67	.25 ^a	(.18)	0 to .65
Control–Autonomy P(1–5,1–6 2–1,2–2)	.13 ^a	(.11)	0 to .40	.09	(.10)	0 to .38	.06 ^a	(.08)	0 to .33
Control–Submit P(1–5,1–6 2–5,2–6)	.20 ^a	(.16)	0 to .46	.15	(.13)	0 to .50	.10 ^a	(.14)	0 to .43

Note. Means in the same row that share subscripts differ at $p < .05$.

Table 2

Hierarchical Regressions Testing the Effects of CM Status and Mother–Child Autonomy–Control Sequences on Children’s Vagal Tone

	<i>B</i>	<i>SE</i>	β	<i>R</i> ²	ΔR^2
I. Children’s joint task RSA					
Step 1				.06	
Income	.13	.19	.3.03		
Maternal education	3.14	.07	3.27		
Step 2					.12*
Physical abuse	31.17	.42	3.42*		
Neglect	3.78	.38	3.31*		
Step 3					
(a) Mother Affirm–Child Autonomy	.87	.84	.13	.02	
(b) Mother Control–Child Submit/Sulk	31.06	1.08	3.13	.01	
(c) Mother Control–Child Autonomy	34.17	1.46	3.34*	.10*	
II. Children’s RSA _A					
Step 1				.25*	
Income	.01	.10	.02		
Maternal education	.08	.04	.27*		
Baseline RSA	.24	.06	.44*		
Step 2					.06*
Physical abuse	.53	.24	.31*		
Neglect	.30	.22	.20		
Step 3					
(a) Mother Affirm–Child Autonomy	31.00	.46	3.26*	.06*	
(b) Mother Control–Child Autonomy	.02	.61	.003	.00	
(c) Mother Control–Child Submit/Sulk	2.84	.80	.39*	.13*	

Note. In Step 3, the letters indicate separate regressions for each measure of the parent–child interaction. Steps 1 and 2 were identical across all regressions.

* $p < .05$.