Development and Psychopathology (2020), **32**, 531–543
doi:10.1017/S0954579419000270

CAMBRIDGE UNIVERSITY PRESS

Regular Article

Differential physiological sensitivity to child compliance behaviors in abusing, neglectful, and non-maltreating mothers

Jessica Norman Wells, Elizabeth A. Skowron, Carolyn M. Scholtes and David S. DeGarmo
University of Oregon, Eugene, OR, USA

Abstract

We examined time-ordered associations between children's compliance behavior and maternal respiratory sinus arrhythmia (RSA) in a sample of 127 child-maltreating (physical abuse, physical neglect, emotional abuse) and 94 non-maltreating mothers and their preschool-aged children. Child prosocial and aversive compliance behaviors and maternal RSA were continuously collected during a joint challenge task. Child behavior and mother RSA were longitudinally nested within-person and subjected to multilevel modeling (MLM), with between-person child maltreatment subtype and level of inconsistent parenting modeled as moderators. Both child maltreatment type and inconsistent parenting moderated the effects of child compliance on maternal RSA. Increases in children's prosocial compliance behaviors led to decreasing RSA in physically abusive mothers 30s later (i.e., increasing arousal), but predicted increases in non-maltreating mothers' RSA (i.e., increasing calm). Inconsistent parenting (vacillating between autonomy-support and strict control) also moderated the effects of children's compliance behavior on maternal physiology, weakening the effects of child prosocial compliance on subsequent maternal RSA. These findings highlight variations in mothers' physiological sensitivity to their children's prosocial behavior that may play a role in the development of coercive cycles, and underscore the need to consider individual differences in parents' physiological sensitivity to their children to effectively tailor interventions across the spectrum of risk.

Keywords: child maltreatment, compliance, parenting, respiratory sinus arrhythmia

(Received 30 April 2018; revised 30 January 2019; accepted 10 February 2019)

Traditional models of the parent-child relationship conceptualize it as a hierarchical one in which parents are typically "in charge" and serve a key socializing influence on their children. In this context, the use of warm, supportive parenting results in a variety of positive developmental outcomes, whereas the use of harsh, aversive, or unpredictable parenting strategies leads to psychopathology and other negative developmental outcomes (Cicchetti & Lynch, 1993; Dodge, Bates, & Pettit, 1990; Gardner, 1989; Wilson, Rack, Shi, & Norris, 2008). However, contemporary models of parenting reflect that children also exert evocative effects on their caregivers in profound ways (e.g., Belsky, 1984; Crouter & Booth, 2003; Kerr & Bowen, 1988; Masten & Cicchetti, 2010; Paschall & Mastergeorge, 2016; Patterson, 1982; Sameroff, 1975; Serbin, Kingdon, Ruttle, & Stack, 2015; Shaw & Bell, 1993). Although many studies have examined evocative effects on parents' behavior, few have explored children's evocative effects on maternal physiology in the context of prosocial and antisocial child behaviors. Caregivers' poor emotion regulation and physiological reactivity have been implicated as critical risk factors underlying child maltreatment (CM; Bugental, 2009; McCanne & Hagstrom, 1996). However, little is known about how mothers' dynamic physiological sensitivity to their children's compliance behaviors may differ, based on maternal CM perpetration and observed parenting behavior. Thus, the goal of the current study was to examine maternal parasympathetic nervous system (PNS) responding to prosocial and aversive child compliance behaviors, in a sample of physically abusive, neglectful, emotionally maltreating, and non-maltreating mothers.

Author for Correspondence: Elizabeth A. Skowron, College of Education 1215, University of Oregon, Eugene, OR 97403-1215; E-mail: eskowron@uoregon.edu.

Cite this article: Norman Wells J, Skowron EA, Scholtes CM, DeGarmo DS (2020). Differential physiological sensitivity to child compliance behaviors in abusing, neglectful, and non-maltreating mothers. *Development and Psychopathology* **32**, 531–543. https://doi.org/10.1017/S0954579419000270

Parent-child behavioral transactions

To better understand children's evocative effects on their parents, a variety of studies has been conducted using longitudinal, experimental, and genetically informed designs (Burt, McGue, Krueger, & Iacono, 2005; Gershoff, 2002; Petit & Ariswalla, 2008; Serbin, Kingdon, Ruttle, & Stack, 2015). These studies reveal that aversive child behaviors are detrimental to parents' perceptions of and interactions with their children (e.g., Gross, Shaw, & Moilanen, 2008; Larrson, Viding, Rijsdijk, & Plomin, 2008; Pardini et al., 2008; Paschall & Mastergeorge, 2016; Stifter, Spinrad, & Braungart-Rieker, 1999). Disruptive child behavior draws for harsh parenting behaviors (Burke, Pardini, & Loeber, 2008; Hawes, Dadds, Frost, & Hasking, 2011) and drives increases in parents' negative attributions of their children over time (Larrson et al., 2008). Longitudinal research with toddler boys, for example, has shown that children's disruptive behavior leads to declines in parental support and structuring, and increasing use of controlling parenting tactics and physical punishment

across the early childhood years (Verhoeven, Junger, Van Aken, Deković, & Van Aken, 2010). In that study, structural equation modeling further demonstrated that, whereas boys' aversive behavior influenced parenting behavior over time, parenting did not drive changes in child behavior (Verhoeven et al., 2010). However, less is known about how parents respond to specific, prosocial, and aversive child behaviors during unfolding interactions and whether these dynamics may differ across CM versus lower risk parent-child dyads.

Parent physiological sensitivity, risk, and child behavior

A growing body of literature has documented how parents' physiological responding relates to the quality of parent-child relationships. Broadly speaking, biological reactivity to one's context is now widely implicated in processes linking experience to psychiatric disorders (e.g., Boyce & Ellis, 2005; Obradovic, Bush, Stamperdahl, Adler, & Boyce, 2010). Theory and empirical evidence support the notion that CM parents may have heightened physiological sensitivity to their children. Per Bugental's (2009) and Sameroff's (1975) biocognitive transactional models of child maltreatment, CM parents are more likely to perceive their child's behavior as threatening and, as a result, show a heightened physiological response to child-based stimuli. Review of empirical studies in this area (e.g., McCanne & Hagstrom, 1996) provides evidence of heightened physiological sensitivity to child behavior and reduced emotion regulation capacity in parents who have abused or are at risk to abuse their children. Recent studies have further linked evidence of physiological sensitivity to child stimuli with risk for harsh, controlling parenting behavior over time (Joosen, Mesman, Bakermans-Kranenburg, & van Ijzendoorn, 2013b).

Given its role in regulating emotion during social engagement, we focused on maternal respiratory sinus arrhythmia (RSA) as a peripheral physiological measure of measure of mothers' emotion regulation. RSA, an index of PNS-mediated cardiac control, is used frequently to assess physiological reactivity/regulation (Beauchaine, 2001; Porges, 2001). High resting RSA reflects greater PNS regulation of heart rate and is associated with better emotion regulation, executive function (Beauchaine & Thayer, 2015), and adaptive social functioning (e.g., Geisler, Kubiak, Siewert, & Weber, 2013). In the context of parenting, higher maternal resting RSA has been linked to greater sensitivity during parenting (e.g., Musser, Ablow, & Measelle, 2012). CM caregivers and parents at high risk for child maltreatment show greater emotion dysregulation, indexed by lower resting levels of RSA (Creaven, Skowron, Hughes, Howard, & Loken, 2014; Crouch et al., 2018).

In terms of RSA responding during social interactions, mothers who engage in more warm and less harsh parenting behavior display higher average RSA scores during interactions with their children (Lorber & O'Leary, 2005; Smith, Woodhouse, Clarke, & Skowron, 2016; Weisman, Zagoory-Sharon, & Feldman, 2012). Researchers are also beginning to model parent dynamic RSA responding over time in the context of parent-child interactions. For example, Hill-Soderlund and colleagues (2008) found that parents who displayed RSA increases from a resting baseline to the reunion phase of the Strange Situation task were more likely to have securely attached infants. Others have studied parents while they interact in stress-inducing or challenging tasks with their infant (i.e., the still-face paradigm), and have found that maternal RSA decreases are associated with more sensitive parenting behavior under these conditions (Leerkes, Su, Calkins, O'Brien, & Supple, 2016; Mills-Koonce et al., 2009; Moore et al., 2009).

Parasympathetic responding has been shown to differ among high-risk and maltreating parents. Parents at high risk for child abuse have displayed less flexible RSA responding during an individual, cognitive challenge (Crouch et al., 2018) and parents with a CM history have shown lower heart rate variability while watching videos of parent-child conflicts (Disbrow, Doerr, & Caulfield, 1977). At least one other study reported no differences in RSA responding between CM and non-CM parents when exposed to recordings of infant cries (e.g., Reijman et al., 2014). The authors reasoned that the lack of significant differences may have been due to their use of a high-risk, non–CM-exposed comparison group of children (i.e., all children diagnosed with a mental health disorder; Reijman et al., 2014).

Distinct patterns of PNS responding in concordance with parenting behavior have also been observed among mothers with a history of perpetrating CM. For example, one study documented divergent patterns of RSA and behavioral responding among physically abusive, neglecting, and non-maltreating mothers while they completed a joint challenge task with their preschooler (Skowron, Cipriano-Essel, Benjamin, Pincus, & Van Ryzin, 2013). In this study, physically abusive mothers showed time-ordered links between their parenting behavior and their own RSA, such that within-person increases in positive parenting were associated with concurrent declines in RSA, but led to increases in harsh controlling parenting a short time later. In contrast, for non-CM mothers, RSA decreases were followed by increases in positive parenting. For neglecting mothers, their parenting behavior seemed to drive their physiology: increases in positive parenting led to subsequent increases in RSA and decreases in harsh control led to decreasing RSA shortly thereafter. These findings may suggest that positive parenting was experienced as physically taxing for the highest risk mothers, namely those with a history of physical abuse (Skowron et al., 2013). Taken together, this body of literature suggests that critical differences in CM parents' autonomic sensitivity to child stimuli may underlie their harsh parenting behavior. More research is needed using fine-grained, behavioral observation measurement tools and time-ordered analytic techniques to disentangle how a mother's physiological sensitivity to her child may unfold in the context of specific, behavioral interchanges between mother and child.

Parental physiological sensitivity to child compliance

Whereas much research to date has focused on the evocative effects of child externalizing behavior, to our knowledge few studies have examined the effect of children's compliance behaviors on their parents. Thus, the focus of this study was to examine the evocative effects of child compliance behaviors on maternal autonomic physiology (i.e., RSA). Additionally, we were interested in determining whether contextual risk factors (i.e., CM status and observed parenting) would moderate associations between child compliance behaviors and maternal RSA. Just as defiant, noncompliant children learn functional behaviors that pay off in their environment (i.e., noncompliance leads parents to backing down or withdrawing; Kalb & Loerber, 2003; Reid & Patterson, 1989), we wondered whether compliant children also learn to behave in ways that shape and influence their parents and the quality of their relationship outcomes.

https://doi.org/10.1017/S0954579419000270 Published online by Cambridge University Press

Children's compliance with parental directives is broadly considered prosocial and desirable (Chamberlain & Patterson, 1995; Kochanska & Aksan, 1995; Stifter et al., 1999). Compliance during the toddler years is viewed as an early indicator of a child's ability to internalize rules and independently self-regulate (Kochanska, 1991; Kopp, 1982; Lytton, 1980) and is associated with lower rates of later externalizing behavior problems throughout childhood and adolescence (Keenan, Shaw, Delliquadri, Giovannelli, & Walsh, 1998; Kimonis, Frick, & McMahon, 2014; Kochanska & Aksan, 1995). Furthermore, according to family systems theory (Bowen, 1978; Kerr & Bowen, 1988; Skowron, 2015), child compliance may serve a function of calming down an anxious or aroused parent, particularly if the parent is more emotionally reactive or less differentiated.

Scant evidence exists to suggest that child compliance dynamics may differ among parent-child dyads with a history of CM, wherein caregivers may show higher emotional reactivity. For example, Crittenden and DiLalla (1988) videotaped interactions between maltreated children and their mothers and found that by age 1 year, toddlers exposed to physical abuse learn to inhibit behavior that upset their mothers and display higher rates of compliance with maternal demands than children who had not been maltreated or who were exposed to neglect only. Further, the quality of compliance displayed by abused children was deemed "compulsive," characterized by affective flatness, withdrawal, and devoid of complaints or assertions of independence that would be considered developmentally typical in the early years (Crittenden & DiLalla, 1988). The authors argued that elevated compliance may be adaptive for abused children in the short run to reduce the probability of more abuse, but may have maladaptive implications in the long term. Thus, in line with Bugental and Sameroff's biocognitive transactional models, we wondered whether CM parents, who tend to hold more 'threat-sensitive' attributions of their children's behavior (Bugental, 2009), would show greater physiological sensitivity to their child's compliance behaviors than non-maltreating mothers.

We also examined the moderating effect of another proximal risk factor: inconsistent parenting. CM parents not only engage in harsh, aversive control, and less support for age-appropriate child autonomy (Lyons-Ruth, Connell, Zoll, & Stahl, 1987; Reid & Patterson, 1989), but also behave less predictably with their children than do non-CM parents (Skowron et al., 2013; Skowron, Kozlowski, & Pincus, 2010; Trickett & Kuczynski, 1986; Trickett & Susman, 1988). Parental inconsistency plays a critical role in maintaining coercive cycles of parent-child interaction (e.g., Wahler & Dumas, 1986). Benjamin and other interpersonal researchers have investigated a powerful form of parental inconsistency originally conceptualized in early studies of schizophrenia, in which two incompatible messages about autonomy and submission are communicated in quick succession, making it difficult to respond to either message (Bateson, Jackson, Haley, & Weakland, 1963; Humphrey & Benjamin, 1986). In the current study, we used the Structural Analysis of Social Behavior (SASB; Benjamin, 1996; Benjamin & Cushing, 2000) a microsocial coding system, to observationally code a form of inconsistent parenting characterized by display of diametrically opposed behaviors of granting autonomy and then asserting control, in quick succession over the course of a parent's moment-by-moment interactions with their child. Thus, we operationalized parental inconsistency in terms of these vacillations between a mother's controlling (i.e., "Do as I say") and autonomy-granting ("You can do it your own way") behavior. We tested whether observations of parent inconsistency would moderate the effects of children's compliance behavior on maternal parasympathetic physiology.

The current study

Our objective was to investigate child evocative effects on caregiver parasympathetic physiology by investigating time-ordered associations between children's compliance behavior and maternal RSA. We considered two types of child compliance: warm, prosocial compliance versus aversive, hostile compliance. Prosocial child compliance was characterized by trusting and relying behaviors, whereas aversive child compliance was marked by whining, protesting, and sulking as a child submits. Research to date has not examined the differential evocative effects of prosocial versus aversive child compliance behaviors on maternal physiology, thus making this a key contribution of the current study. Next, we sought to identify risk factors that may moderate associations between child compliance and maternal RSA in an effort to better characterize mother-child dyads in which parents were more or less physiologically sensitive to their child's compliance behavior. Key moderators of theoretical interest were CM perpetration by mother (i.e., physical abuse, physical neglect, emotional abuse, or non-maltreating) as a time-invariant risk factor and maternal inconsistent parenting as a time-varying, proximal risk factor.

The conceptual model integrating developmental and family systems theories of dyad transactions is presented in Figure 1. The model summarizes hypothesized relationships based on the literature reviewed previously, with main effects paths shown as bold, and moderating paths shown as dashed lines. Within-dyad levels of child prosocial compliance behavior were hypothesized to "drive" increases in maternal RSA (i.e., PNS activation, greater calm), and child aversive compliance was expected to drive decreases in maternal RSA (i.e., PNS withdrawal, greater arousal). Based on theory (i.e., Bugental, 2009; Skowron, 2015) and previous findings that support heightened physiological arousal among maltreating and high-risk parents (e.g., McCanne & Hagstrom, 1996), CM perpetration was hypothesized to moderate or amplify effects of child compliance behaviors in predicting maternal RSA. Specifically, we predicted that CM mothers would show greater RSA increases to child prosocial compliance and greater RSA decreases to child aversive compliance. In a similar manner, inconsistent parenting, coded using the SASB system (Benjamin & Cushing, 2000) was expected to moderate the effect of child compliance behaviors on maternal RSA. Although this aim was somewhat exploratory, we reasoned that high levels of inconsistent parenting—vacillation between maternal autonomy granting and control—may predict a mother's greater parasympathetic responding to her child's prosocial and aversive compliance behavior.

Method

Participants

Participants were 221 mothers and their 3- to 5-year-old children (mean [*M*] = 3.76, standard deviation [*SD*] = .74). Children were 50.7% female and white (76.9%), African-American (2.7%), Hispanic/Latino (0.5%), and multiracial (15.8%). Mothers were, on average, 30 years old (*SD* = 6.06) and white (88.2%), Hispanic/Latino (1.8%), multiracial (3.2%), African-American

https://doi.org/10.1017/S0954579419000270 Published online by Cambridge University Press

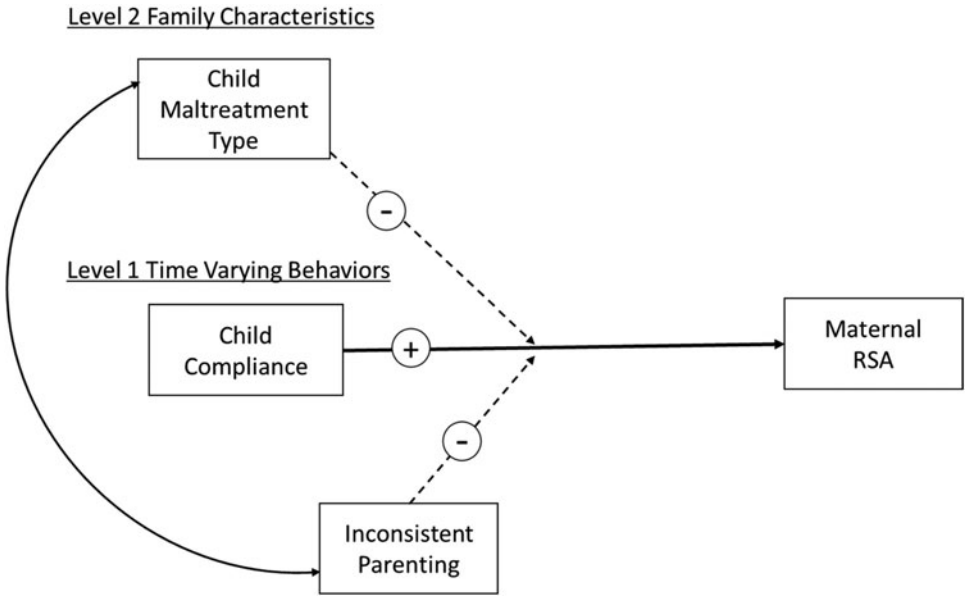

Figure 1. Conceptual model of hypothesized family systems relationships among family level characteristics and repeated measures mother and child behaviors predicting maternal RSA.

(3.6%), or Asian-American (0.5%). A majority (72.3%) of mothers reported an annual income of $30,000 or less and 74.2% had obtained a high school degree or less. Among mothers in the total sample, $n = 127$ mothers were classified as CM and $n = 94$ were classified as non-maltreating.

Procedure

Mothers and children completed three assessments over a 2- to 3-week period consisting of two home visits and a laboratory visit lasting approximately 2.5 hours. During the home visits, mothers provided demographic information and completed psychosocial assessments. Both mothers and children completed a cognitive assessment during the home visits. During the laboratory assessment, mothers and children participated in joint interaction tasks, mothers completed additional questionnaires, and children participated in a variety of individual tasks. Electrocardiograph (ECG) recordings were taken from mothers and children throughout the laboratory visit. Of particular interest to this study, mother-child dyads completed a Joint Duplo task (3–5 minutes in length), which was subjected to SASB observational coding. In the Joint Duplo task, children were given a three-dimensional model figure and instructed to construct an identical model from a set of deconstructed pieces provided. Mothers were instructed to help as they would at home without physically touching the pieces. Families received $150 for their participation in the full study, were compensated for the cost of transportation, and received snacks and small gifts for the participating child.

Measures

Maternal RSA

Disposable pregelled silver/silver chloride electrodes were applied in a modified lead II placement on the right clavicle, lower left rib cage, and lower right ribcage to monitor cardiac physiology throughout the laboratory tasks. Data were acquired via Mindware Technologies (Gahanna, OH) ambulatory ECG MW1000A, transmitted wirelessly to a computer, and monitored by a research assistant. Heart rate data were computed by passing ECG signals through an A/D converter with ECG sampled at a rate of 500 ms. Trained research assistants visually inspected ECG data offline using Mindware Technologies HRV 3.0.10 analysis program. Incorrectly identified heartbeats were deleted and missing beats were inserted as needed. 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, 1994). The RSA frequency band was set between 0.12 and 0.40, and maternal RSA was calculated in 30-second epochs across the joint Duplo problem-solving task for a total of up to 10 time-sampling epochs. The Duplo task was no longer than 5 minutes but may have been as brief as 3 minutes depending on how quickly the dyad completed the puzzle. Of the total sample, 66% had 10 epochs, 76% had at least 8 epochs, 90% had at least 6 epochs.

SASB coding

The SASB (Benjamin, 1974, 1996; Benjamin & Cushing, 2000), a microsocial coding system, was used to code parent and child interactions during the Joint Duplo problem-solving task. The SASB model is designed to describe behavior across three interpersonal domains: (1) focus, (2) affiliation (i.e., the degree of warmth or hostility in any interpersonal message, from attack to love), and (3) interdependence (i.e., the degree of enmeshment (control or submit) to differentiation (autonomy-giving or autonomy-taking) observed in a behavior. As shown in Figure 2, SASB behavioral codes are thus distributed across two circumplex surfaces into 16 behavioral codes reflected in 8 clusters on the circumplex. Videotaped interactions during the Duplo task were transcribed, unitized into individual speech acts, and coded by a trained team of observational coders who received over 80 hours of training. Coding began with the first speaking utterance by the mother or child and ended with the last utterance during the task. Coders used both the unitized transcripts and digital video recordings to SASB code each speech act during the mother-child interaction. Inter-rater reliability of SASB coders

https://doi.org/10.1017/S0954579419000270 Published online by Cambridge University Press

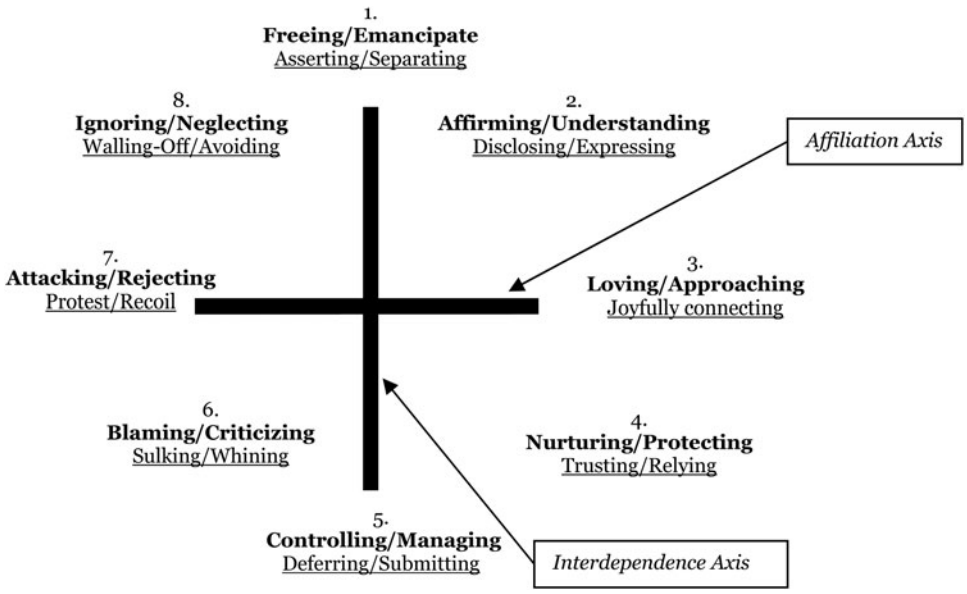

Figure 2. SASB simplified cluster model. The affiliation axis is the x-axis and the interdependence axis is the y-axis. Labels in **bold print** describe proto-typical parenting behaviors directed toward another person (i.e., child) and are the focus in the present study. Labels in underline print describe proto-typically child-like actions in response to the other (intransitive).

was based on weighted kappa coefficients, which ranged from .73 to .84. The coding teams were not informed of family's group membership or which families were examined for reliability.

Child prosocial compliance and aversive compliance behavior

For the current study, child prosocial compliance was operationalized as the proportion of child behaviors coded in SASB clusters 2–4 (Trust/Rely). Child aversive compliance scores were created by summing the proportion of child behaviors coded in SASB clusters 2–5 (Defer/Submit) and 2–6 (Sulk/Whine). Next, children's prosocial compliance scores and aversive compliance scores were summed separately into consecutive 30-second epochs during the Duplo task (i.e., corresponding with maternal RSA scores described previously), resulting in up to 10 time-ordered child prosocial compliance and aversive compliance scores. Task averages also were calculated for children's prosocial compliance and aversive compliance scores.

Inconsistent parenting

Mothers' behaviors during the Joint Duplo task also were subjected to SASB coding as described previously. Maternal inconsistent parenting scores were generated using Benjamin's SASB conflict pattern coefficient, which reflects a single nonlinear polynomial curve denoting elevated behavioral cluster scores on opposing points of the horizontal axis of the interpersonal circumplex (e.g., maternal controlling vs. letting go), described as denoting an enmeshment–differentiation conflict (Benjamin & Cushing, 2000). In SASB terms, high positive conflict coefficients describe significant conflict along the vertical axis of the SASB model, namely the differentiation axis (i.e., maternal behaviors characterized by freeing/letting go on the one hand and strict control on the other). Thus, higher inconsistent parenting scores indicate greater inconsistency in mothers' behaviors along the dimension of autonomy-granting versus control (e.g., mothers try to control their child one moment and let their child do their own thing in the next moment).

Child maltreatment

The Maltreatment Classification System (MCS; Barnett, Manly & Cicchetti, 1993) was used to code child welfare records for subtypes of child maltreatment perpetrated by mothers. The MCS differentiates CM subtypes (i.e., physical abuse, physical neglect, sexual abuse, and emotional or moral/legal maltreatment) and severity of each subtype on a 0 (none) to 5 (highest) scale (Barnett et al., 1993). Further, CM subtypes were classified hierarchically, so that mothers who had engaged in physical abuse and any other subtype of CM were categorized as physically abusive, mothers who engaged in neglect and any other subtype except physical abuse were categorized as neglecting, and mother who engaged in emotional abuse but not physical abuse or neglect were classified as emotionally maltreating (e.g., Belsky, 1993; Kauffman & Ziegler, 1989; Pollak, Cicchetti, Hornung, & Reed, 2000). MCS coding of participating families' child welfare records determined that, of the CM families, 17.3% of mothers had engaged in physical abuse, 48.0% engaged in physical neglect, and 8.7% had engaged in emotional maltreatment. An additional 26.0% of families were involved in child welfare services, but with no MCS codable instance of abuse or neglect recorded in their files, these families were considered in a distinct category (i.e., child welfare-involved, but no specific CM type identified). Comorbidity of CM subtypes was observed in 74% of cases, consistent with other published findings (e.g., Belsky, 1993; Kaufman & Ziegler, 1989). Non-maltreating families consented to review of child welfare records to confirm there was no documented history of child maltreatment.

Analytic strategy

The time varying research questions were tested using MLM, specified as linear growth models in the HLM7 program (Raudenbush, Bryk, Cheong, Congdon, & du Toit, 2013). MLM is a regression framework also known as mixed modeling and linear mixed effects models. Analyses are multilevel because time-

https://doi.org/10.1017/S0954579419000270 Published online by Cambridge University Press

varying repeated measures at level 1 are nested or clustered within individuals at level 2. The repeated measure design for the present study is 10 30-second time samplings of child compliance behavior, mother physiology data, and inconsistent parenting collected during the problem-solving interaction task. The time series data were specified using methods outlined by Singer and Willett (2003) for entering time-ordered and time-varying covariates. That is, to better establish causal assumptions, time-varying predictors were tested concurrently over epochs and using temporally specified lagged effects and person-centered level 1 predictors (Singer & Willett, 2003; Skowron et al., 2013).

Analyses were conducted in three stages. First, we evaluated an unconditional model of a given dependent variable (e.g., RSA) to best establish the pattern of change over the 10 epochs. Next, we tested within family level 1 main effects and interactions, controlling for family level characteristics. In the final stage of analyses, we tested for level 2 moderators of level 1 effects. More specifically, in addressing the research question, testing hypothesized effects of child compliance behaviors as predictors of maternal RSA, the level 1 model was:

$$\text{RSA}_{ti} = \pi_{0i} + \pi_{1i}(\text{Time}) + \pi_{2i}(\text{Compliance}) + e_{ti}$$

where RSA for mother i at time t is a function of a time-varying random intercept π_0, a function of a person-centered linear growth rate π_1, and the person-centered time-varying effect of child compliance π_2, plus a residual error term e_{ti}. As an initial step, the unconditional growth pattern of RSA is tested in a series of sequential models evaluating the fit of a random intercept model, a linear growth rate, and a quadratic or accelerated growth rate (Biesanz, Deeb-Sossa, Papadakis, Bollen, & Curran, 2004). We had no theoretical reasons for evaluating cubic and higher order polynomial time functions.

After estimation of level 1 time-varying parameters, the intercept, growth rate, and slope effect of child compliance behaviors are summarized at the family system level in the level 2 model. These coefficients represent the mean level intercept, mean growth rate, and mean compliance effect for the study sample. Child maltreatment types are time-invariant family-level characteristics entered as between family-level predictors of maternal RSA, and as moderators of RSA growth or child compliance effects. The level 2 model is specified as:

$$\pi_{0i} = \beta_{00} + r_{0i}$$

$$\pi_{1i} = \beta_{10} + \beta_{11}(\text{Physical Abuse}) + \beta_{12}(\text{Neglect}) \ldots . + r_{1i}$$

$$\pi_{2i} = \beta_{20} + \beta_{21}(\text{Physical Abuse}) + \beta_{22}(\text{Neglect}) \ldots . + r_{2i}$$

where β_{00} is the sample average RSA across time and across mothers, β_{01} is the effect of physical abuse on average RSA, and β_{02} is the effect of neglect. The level 2 β_1 and β_2 effects are the respective moderators of growth in RSA and moderator of child compliance, respectively. Summarized in the full mixed model as:

$$\begin{aligned}\text{RSA}_{ti} = {} & \beta_{00} + \beta_{01}(\text{Physical Abuse}) + \beta_{02}(\text{Neglect}) + \beta_{10}(\text{Time}) \\ & + \beta_{11}(\text{Abuse} \times \text{Time}) + \beta_{12}(\text{Neglect} \times \text{Time}) \\ & + \beta_{20}(\text{Compliance}) + \beta_{21}(\text{Abuset} \times \text{Compliance}) \\ & + \beta_{22}(\text{Neglect} \times \text{Compliance}) + r_{0i} + r_{1i}(\text{Time}) \\ & + r_{2i}(\text{Compliance}) + e_{ti}\end{aligned}$$

Results

Preliminary analyses

Sample *M*, *SD*, and *n* for the key study variables are provided in Table 1 for the key between-dyad and within-dyad variables. Frequency scores are also reported for categorical variables. Mean proportions in the level 2 characteristics represent the sample demographics described previously. The time-varying means represent the average levels of child and maternal behavior and maternal RSA. The sample was characterized by higher proportions of prosocial compliance behavior ($M = .35$) relative to aversive compliance ($M = .25$); still, one-quarter of all child behaviors were aversive. More than one-third (i.e., $M = .38$) of the maternal behaviors in this at-risk sample were characterized by inconsistent parenting.

We next examined potential mean differences by family CM types using analysis of variance *F* tests and post hoc pairwise comparisons. *M*, *SD*, and comparisons are shown in Table 2. There were no significant differences between the family types for maternal RSA or child compliance variables. Maternal inconsistent parenting differed by family types (F (4,216) = 2.75, $p < .05$), with physically abusive mothers being more erratic than non-maltreating mothers.

Predicting maternal RSA: main effects and dyad-level moderators

The first step of the maternal RSA analyses was to evaluate an unconditional growth model to best describe the patterns of maternal RSA over the 10 epochs of the joint mother-child interaction. Nested model comparisons of the χ^2 deviance test showed that a random intercept model was optimal. First, in comparison of adding a growth parameter over and above a random intercept, the change in χ^2 deviance significantly worsened the model for adding a linear growth rate ($\Delta\chi^2$ (2) = 8.32, $p < .05$) and a quadratic term ($\Delta\chi^2$ (2) = 13.62, $p < .01$). Second, although there was a marginal trend for a linear growth rate ($\beta_{10} = -.06$, $p < .10$), the variance component was nonsignificant ($\sigma^2 = .18$, $p = .15$), and only the random intercept mean and variance components were significantly different from zero ($\beta_{00} = 5.92$, $p < .001$, and $\sigma^2 = 1.83$, $p < .001$, respectively). Therefore, we eliminated time as a parameter in the level 1 model and proceeded with tests of dyad-level and time-varying and lagged main effects, plus the hypothesized moderators.

We next tested the hypothesized relationships shown in Figure 1. To specify this model, the level 1 main effects paths of child compliance were entered in the model as well as the main effect of inconsistent parenting. The paths for child maltreatment moderators of child compliance were entered as level 2 CM types predicting level 1 compliance effects, also known as cross-level interactions. Finally, the level 1 inconsistent parenting moderator was entered as a time-varying level 1 interaction term (inconsistent parenting × child compliance). Results of the MLM are presented in Table 3 in the form of unstandardized multilevel regression coefficients.

Focusing on level 1 lagged child compliance scores, main effects supported hypotheses for child prosocial compliance but were not supported for child aversive compliance. That is, controlling for CM type, greater lagged child prosocial compliance behavior was associated with higher subsequent maternal RSA ($\beta_{10} = .60$, $p < .05$). Lagged inconsistent parenting did not obtain a significant main effect on RSA.

https://doi.org/10.1017/S0954579419000270 Published online by Cambridge University Press

Table 1. M and SD of within-family level 1 repeated measure variables and between-family level 2 predictors, with frequency of categorical variables

Level 2 between family	*M*	*SD*	Frequency, %	*n*
Boy	.48	.50	49.3	221
Child age	3.76	.74	–	220
Mother education, y	13.20	2.37	–	221
Physical abuse	.10	.30	10.0	221
Neglect	.28	.45	27.6	221
Emotional abuse	.05	.22	5.0	221
Child welfare: no codable instance of maltreatment	.15	.36	14.9	221
No child maltreatment	.43	.50	42.5	221
Level 1 within family				
Child prosocial comply	.35	.33	–	1852
Child aversive comply	.25	.30	–	1852
Inconsistent parenting	.38	.18	–	1926
Maternal respiratory sinus arrhythmia	5.93	1.59	–	1430

Note: *M* = mean; SD = standard deviation.

Focusing on CM types as a cross-level moderator of child compliance, the beneficial effect of children's lagged prosocial compliance on maternal RSA was moderated by the presence of physical abuse. That is, the effect of prosocial compliance was more positive in the non-maltreating families, compared to the effect of child compliance in dyads headed by physically abusive mothers (Physical Abuse × Prosocial Compliance $\beta_{13} = -.71$, $p < .05$). No CM moderation effects were observed for aversive compliance. Physical abuse as a moderator of child prosocial compliance is plotted in Figure 3 as the model based simple slopes. Figure 3 shows the lagged effect of child prosocial compliance on maternal RSA scores was positive for non-maltreating mothers but was negative for physically abuse mothers.

Finally, among the level 1 time-varying moderating hypotheses, inconsistent parenting moderated the effect of prosocial compliance but not aversive compliance. That is, inconsistent parenting was a further risk factor that attenuated the positive effect of child prosocial compliance on maternal RSA (Inconsistent Parenting × Child Prosocial Compliance $\beta_{40} = -1.08$, $p < .05$). In other words, children's prosocial compliance was more influential in increasing their mother's RSA in the presence of less inconsistent parenting. This two-way level 1 interaction is plotted in Figure 4 and shows how maternal inconsistency moderated the effects of children's compliance behavior on maternal arousal. Specifically, the weakest associations between children's prosocial compliance and maternal RSA levels were observed in dyads characterized by greater inconsistent parenting (i.e., vacillating between supporting child autonomy and controlling one's child).

We also considered an alternative hypothesis that maternal physiology predicted maternal inconsistent parenting behaviors (models not shown). We specified time-ordered lag models to test whether maternal physiology predicted her parenting behaviors, controlling for evocative effects of child compliance. In these models, epoch lagged RSA was entered as a predictor of inconsistent parenting. Maternal RSA did not predict subsequent parenting behaviors. Taken together, the data support that notion that child compliance behavior and inconsistent parenting are affecting subsequent mother RSA levels, whereas maternal RSA did not predict parenting behaviors, controlling for child behaviors. The proportion of variance explained in maternal RSA was 0.25, a large effect, computed as the change in the RSA variance component between the unconditional and prediction model [(τ_{00} unconditional – τ_{00} prediction model)/τ_{00} unconditional].

Finally, to illustrate the time-varying nature of child compliance behaviors and maternal RSA, the unconditional means for mother RSA and child behaviors were plotted across the 10 30-second epochs in Figure 5. The plotted means suggest that there was greater variation over time in the proportion of child prosocial compliance behaviors relative to aversive compliance behaviors, and early epochs support the notion that children's prosocial compliance covaried positively with maternal RSA, whereas aversive compliance was unrelated.

Discussion

The current study reflects a novel effort to examine time-ordered associations in the behavioral and physiological systems of mothers and their preschool children. Using microsocial behavioral coding and dynamic measures of PNS responding, we tested the evocative effects of children's prosocial and aversive compliance behavior on maternal PNS responding (i.e., RSA). The pattern of findings observed provides new evidence of the critically different evocative effects that children's prosocial behaviors have on a caregiver physiological system implicated in bond formation and emotion regulation, based on maternal risk factors.

Child maltreatment status moderates effects of prosocial compliance

In the context of a relatively challenging laboratory task, children's prosocial behavior showed time-ordered effects on their mothers' RSA responding during joint interactions that were moderated by CM type. Although no differences across the various CM and non-maltreating dyads were observed in levels of children's prosocial compliance behaviors, nor in mothers' dynamic RSA responses, we found that mothers in the study were differentially physiologically responsive to their children's prosocial compliance (i.e., trusting and relying behavior) depending on whether they were physically abusive, neglecting, or non-maltreating mothers. In response to increasing prosocial compliance in their preschool-aged child, physically abusive mothers displayed patterns of RSA decreases (i.e., increasing arousal) in the next 30-second epoch, whereas non-maltreating mothers displayed patterns of RSA increases (i.e., decreasing arousal or greater calm) 30 seconds later, and neglected children's behavior showed no discernable effects on the PNS physiology of their neglectful mothers.

Thus, in non-maltreating dyads, mothers responded to their children's bids for protection and warm guidance with subsequent increasing parasympathetic influence on heart rate, promoting physiological calm that enables and supports social coordination and engagement, which may be experienced by both interactive partners as mutually reinforcing. These findings are consistent with existing literature documenting patterns of parent RSA increases during positive interactions with their preschool children. For example, previous studies show that dynamic increases in RSA (i.e., vagal activation) are generally associated with greater

https://doi.org/10.1017/S0954579419000270 Published online by Cambridge University Press

Table 2. M, SD, and mean comparisons across epochs for key study variables by maltreatment type

	Normative (*n* = 94) (1)		Physical Abuse (*n* = 22) (2)		Neglect (*n* = 61) (3)		Emotional Abuse (*n* = 11) (4)		Child Welfare No CM (*n* = 33) (5)			
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F* (4,216)	Significant Contrasts
Maternal RSA	6.05	1.27	6.05	.70	5.73	1.60	6.04	1.92	5.76	1.38	.50	
Prosocial compliance	.38	.24	.31	.19	.39	.19	.36	.25	.28	.21	1.74	
Aversive compliance	.23	.19	.26	.20	.24	.18	.25	.20	.26	.22	.19	
Inconsistent parenting	.34	.13	.41	.09	.39	.12	.36	.09	.35	.14	2.75*	2 > 1

Note: CM = child maltreatment; *M* = mean; RSA = respiratory sinus arrhythmia; SD = standard deviation. *p < .05.

Table 3. Unstandardized Estimates, SE, and t Ratio for lagged Predictors of Mother RSA

Model 1	Estimate	*SE*	*t*
L1 Random Intercept, β_{00}	5.91	.11	55.03***
L1 Lag Child Prosocial Compliance β_{10}	.60	.29	2.06*
L2 Physical Abuse β_{11}	−.71	.34	−2.07*
L2 Neglect β_{12}	−.38	.23	−1.66
L2 Emotional Abuse β_{13}	−.39	.27	−1.50
L2 Child Welfare No Maltreatment β_{14}	−.41	.28	−1.46
L1 Lag Child Aversive Compliance β_{20}	.32	.26	1.19
L2 Physical Abuse β_{21}	.22	.37	.59
L2 Neglect β_{22}	−.31	.29	−1.07
L2 Emotional Abuse β_{23}	.09	.31	.31
L2 Child Welfare No Maltreatment β_{24}	−.56	.30	−1.85
L1 Lag Inconsistent Parenting β_{30}	.09	.38	.70
Model 2 Level 1 Time-Varying Interactions			
L1 Inconsistent Parenting × Child Prosocial β_{40}	−1.08	.53	−2.07*
L1 Inconsistent Parenting × Child Aversive β_{50}	−.56	.50	−1.12

Note: L1 = level 1; L2 = level 2; L = level; RSA = respiratory sinus arrhythmia; SE = standard error. ***p < .001; **p < .01; *p < .05.

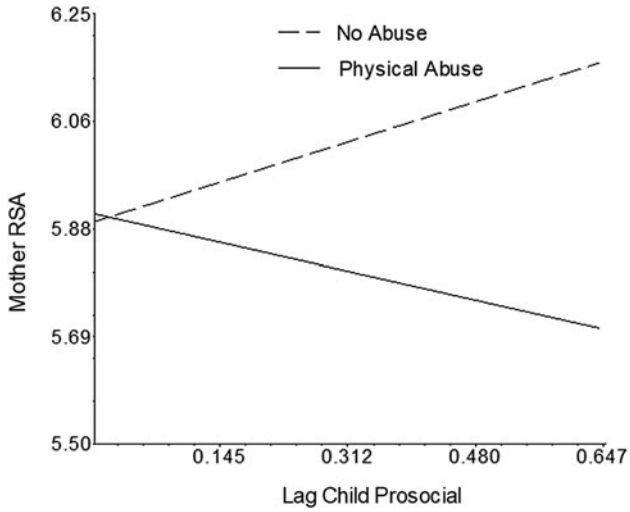

Figure 3. Detrimental moderating effect of physical abuse on relation between child prosocial compliance and maternal RSA, a Level 2 moderator on Level 1 effect.

warmth and positive affect during parent-adolescent conversations (Connell, Dawson, Danzo, & McKillop, 2017; Cui, Morris, Harrist, Larzelere, & Criss, 2015). Other studies have found higher RSA levels linked to positive mood states (Kreibig, 2010) and positive adult social interaction (Butler, Wilhelm, & Gross, 2006; Ingjaldsson, Laberg, & Thayer, 2003). These young children's prosocial compliance behaviors can be considered evolutionarily adaptive because they entail following their caregiver's lead, maintaining proximity, and seeking parent guidance. Based on our findings, these prosocial child behaviors may also serve to support caregiver homeostasis, by down-regulating and soothing mothers' physiology in the context of connection.

In contrast, this same type of prosocial compliance behavior in children appeared to heighten arousal in their physically abusive mothers (i.e., leading to decreases in RSA in the following 30-second epoch). Thus, the highest risk mothers—those who perpetrated child physical abuse—responded to their children's prosocial bids for warm guidance with a physiological response suggestive of arousal, effortful exertion, or distress. One explanation is that abusive mothers may experience more strain in response to their children's prosocial bids for protection and guidance, relative to non-maltreating parents. Other studies have documented patterns of decreasing RSA in parents while they are interacting sensitively with their distressed infant or toddler (e.g., Leerkes et al., 2016; Moore et al., 2009) or when exposed to negative child-based stimuli (e.g., Frodi & Lamb, 1980; Joosen et al., 2013a), but also in parents who engage in harsh, overreactive discipline (Lorber & O'Leary, 2005). Extending this finding to CM parents, Skowron and colleagues (2013) observed that physically abusive mothers became more physiologically aroused (i.e., declining RSA) while engaged in positive parenting, but shortly thereafter displayed increasingly harsh and controlling behavior toward their child. Taken together, the current findings indicate that physically abusive mothers may experience their children's age-appropriate, prosocial behavior as physiologically taxing. One critical next step is for researchers to determine whether these patterns of dynamic decreases in abusive mothers' RSA scores lead to increased harsh, aversive controlling behaviors, as Skowron et al. (2013) observed, or whether these parasympathetic declines function to increase attention and engagement that might facilitate adaptive parental responding.

https://doi.org/10.1017/S0954579419000270 Published online by Cambridge University Press

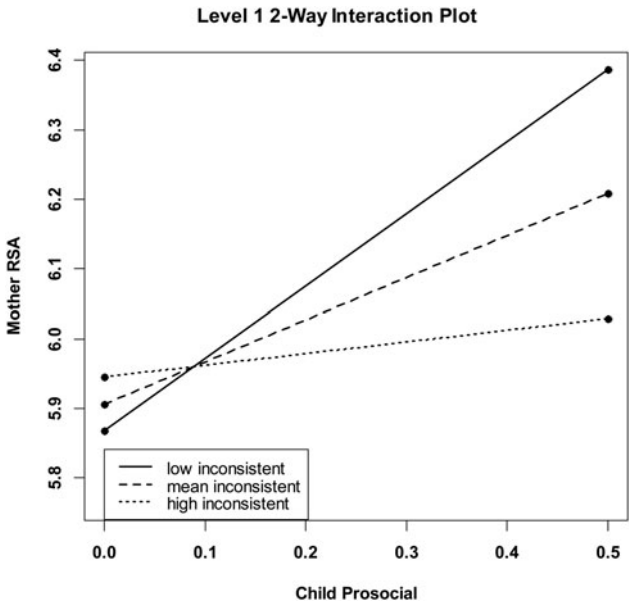

Figure 4. Two-way time-varying Level 1 interaction of inconsistent parenting with child prosocial compliance. Simple slopes estimates of child prosocial compliance were plotted at -1, 0, and 1 standard deviations of inconsistent parenting. High inconsistent parenting erodes beneficial effect of child compliance.

Although researchers have long recognized that children are active contributors to the parent-child relationship, most work to date has documented a variety of individual child factors known to heighten risk for CM (i.e., low birthweight, prematurity, temperament, developmental disabilities), by compromising the quality of children's social interactional skills (e.g., Black, Heyman, & Smith Slep, 2001; Rogosch, Cicchetti, & Aber, 1995). We are not aware of studies that have documented patterns of parents' negative physiological responding to children's initiations of prosocial (i.e., socially appropriate) behavior. Of note, our findings indicate that children's developmentally appropriate, prosocial trusting and relying behavior elicits significant RSA declines 30s later in mothers who are documented perpetrators of child physical abuse. Social learning principles suggest that if children's prosocial bids are not reinforced, children are likely to use other, less positive behavioral strategies to gain parents' attention and approval (Patterson, 1992; Reid & Patterson, 1989; Wahler & Dumas, 1986). If children of abusive mothers discern that their prosocial behavior causes arousal or distress in their parent, they may learn to adopt an alternative repertoire, potentially one that involves use of more aversive behaviors. This transaction could represent a central mechanistic process that contributes over time to elevated conduct problems in maltreated children (Kim & Cicchetti, 2010). In line with this notion, Hakman and colleagues (2009) reported patterns of parental indiscriminate responding to children's positive and neutral behaviors, and positive parent responding to negative child behaviors in physically abusive families. Other unpublished findings from the current sample suggest that physically abused preschoolers' aversive compliance behavior during mother-child interactions appears to drive increases in the preschooler RSA levels, indicating that physically abused children may experience their own aversive behavior in ways that are physiologically calming (Norman Wells, Degarmo, Schweer-Collins, & Skowron, in preparation).

Finally, in dyads headed by physically neglectful mothers, children's prosocial compliance behaviors were unrelated to maternal RSA, indicating that physically neglectful mothers appear unaffected physiologically by their child's positive compliance behavior. It is possible that neglecting mothers' lack of autonomic response to their child's prosocial compliance reflects a lack of attention to and attunement with their child (e.g., Wilson et al., 2008), or a blunted physiological sensitivity to their child, or perhaps both. This finding may provide evidence of a biologically based vulnerability for neglectful behaviors. That is, a neglectful parents' lack of PNS response to their child's positive bids for attention could indicate individual differences in mothers' stress physiology that may drive the failure to engage with and provide for their child. Conversely, a lack of physiological response to child prosocial behavior may be the result of neglectful parents' broader, effortful strategy to withdrawal or distance from their child, as has been documented in other studies (Egeland, Breitenbucher, & Rosenberg, 1980; Kavanagh, Youngblade, Reid, & Fagot. 1988).

In sum, these findings contribute to the growing evidence of children's evocative effects on parent physiology and indicate that children's prosocial behavior evokes heightened arousal in abusive mothers and a physiologically calming response in non-maltreating parents, but no discernable pattern of responding in neglectful mothers. Whereas previous research has documented heightened physiological arousal among CM parents primarily to aversive or emotionally evocative child stimuli (e.g., infant cries; McCanne & Hagstrom, 1996), our findings indicate that physically abusive mothers also show time-ordered declines in parasympathetically mediated control of heart rate (i.e., arousal) when their children behave in positive, prosocial ways.

Inconsistent parenting moderates effects of prosocial compliance

Inconsistent parenting was also found to moderate time-ordered relations between child prosocial compliance and mother's RSA responding. In dyads headed by mothers who vacillated more often between supporting autonomy and controlling their child, variations in children's prosocial compliance behavior exerted less impact on maternal RSA levels in the subsequent epoch, regardless of CM status. Mothers who behaved more consistently, in contrast, showed a stronger PNS calming response (i.e., larger RSA increases 30s later) when their child warmly complied.

Inconsistent parenting has been linked with elevated rates of child oppositional and aggressive behavior (Chamberlain & Patterson, 1995; Reid & Patterson, 1989; Wahler & Dumas, 1986). Wahler and Dumas suggested that children, when faced with unpredictable and inconsistent parenting, are at greater risk for engaging in oppositional and defiant behaviors, and that they do so to elicit a more predictable, albeit aversive response from their parent. The current findings suggest that such coercive patterns may be maintained partially through the parent's physiological responsiveness to children's prosocial behaviors. Parents who engage in highly inconsistent parenting appear to be less physiologically reinforced by their children's positive behavior and may instead be responding more to their own physiological needs (e.g., Skowron et al., 2013).

Aversive compliance

In contrast to effects observed for children's prosocial compliance, results indicated that during mother-child interactions, children's aversive compliance (i.e., sulking, whining, and hostile

https://doi.org/10.1017/S0954579419000270 Published online by Cambridge University Press

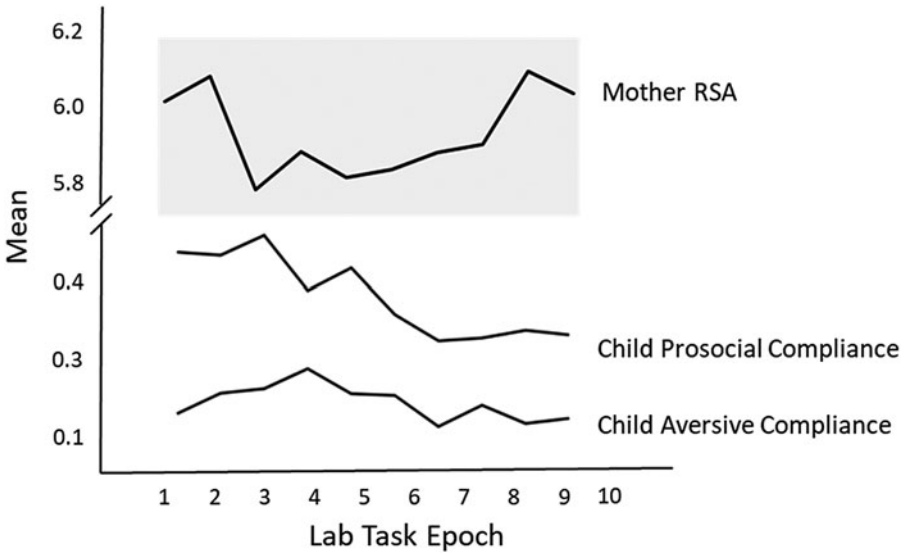

Figure 5. Plot of mother RSA, child prosocial and child aversive compliance across 10 30-second epochs.

submission) did not predict their mothers' RSA responses, in contrast to our predictions. It is well-documented that aversive child stimuli (e.g., negative affect, infant cries) tend to produce heightened physiological responding in parents (i.e., elevated heart rate, skin conductance, declines in RSA; Frodi & Lamb, 1980; Joosen et al., 2013a; Reijman et al., 2014), particularly in caregivers who engage in harsh parenting or CM (Joosen et al., 2013b; Lorber & O'Leary, 2005). One explanation for the current null findings may be that children's aversive compliance behavior produced a small effect on maternal RSA that was not discernable with our moderate sample size. It is likely that our study paradigm did not trigger significant levels of negative child behavior (i.e., crying and other forms of higher intensity negative affect displays) on par with other published studies. In this study, parent physiology was assessed during live interactions with their own child, whereas other published studies tend to assess parental autonomic responding in laboratory-based audio or video simulations of negative child behavior. Future research should continue to examine patterns of parents' physiological responding to children's aversive behavior, including a wider range of child aversive behaviors, using larger sample sizes, and diverse experimental paradigms.

Limitations

It is important to note that a number of other personal and environmental risk factors, such as low socioeconomic status, large family size, unemployment, parent stress, parent depression, and parental history of CM victimization, are also associated with risk for CM perpetration (see Diaz & Peterson, 2014, and Stith et al., 2009, for reviews). The current findings documenting the moderating effects of CM on maternal physiological response to child compliance behaviors represent only one facet of a much broader context of biopsychosocial risk linked to CM that may have contributed to the effects observed here.

We measured physiological effects of child behavior on their mothers using a single index of PNS responding: maternal RSA during a joint interaction task. Future studies will benefit from the inclusion of measures of sympathetic and neuroendocrine response systems to understand further how child compliance behavior influences parents' physiological response systems and to better characterize variation across risk groups. To ascertain the directionality of findings observed here, there is a need go beyond use of longitudinal designs and use experimental intervention designs to enable stronger causal inference testing. Further, the current sample included mothers only, and so these findings may not generalize to fathers or other types of caregivers. Replication of these evocative child effects should be conducted in samples of at-risk father-child dyads, especially given evidence that fathers' coercive parenting exchanges are particularly salient for child noncompliance (DeGarmo, 2010).

Finally, given the significant comorbidity in children's CM exposures and our decision to hierarchically classify physical abuse, neglect, and emotional maltreatment, conclusions regarding the effect of pure types of CM were not possible to derive (Toth, Maughan, Manly, Spagnolo & Cicchetti, 2002). Additionally, some families in our sample were known to have CM backgrounds and child welfare involvement, but did not have a specific, substantiated instance of abuse in their record that could be categorized via the MCS coding system. Consistent with past studies (Belsky, 1993; Kaufman & Ziegler, 1989; Pollak et al., 2000), we observed comorbidity across CM subtypes in 74% of sample cases. Researchers studying CM should work to use innovative methodological approaches, including open science approaches for high-powered meta-analyses, that will allow for a more nuanced examination of how maternal physiological responding to their children may vary based on the constellation of CM perpetrated by parents.

Future directions

Although findings here suggest that prosocial child behavior elicits an aversive autonomic response in physically abusive mothers, it is unknown whether and how these transactions affect children's distal behavioral and health outcomes. Future research should examine child physical health outcomes, including biomarkers of stress-related illness, to investigate whether these dyadic exchanges exact a biological cost for abused children. Further research is needed to clarify the mechanisms through which prosocial child compliance affects decreasing RSA among the physically abusive mothers, an autonomic response pattern that characterizes physiological arousal consistent with defensive

https://doi.org/10.1017/S0954579419000270 Published online by Cambridge University Press

responding in a social context. The increased risk for aversive parenting fueled by elevated physiological arousal has been documented elsewhere (Skowron et al., 2013). Further investigations are needed to better understand how parental physiological responding may underlie and maintain commonly observed patterns of dysfunctional interactions in high-risk parent-child transactions, including inconsistent use of controlling parenting.

It seems plausible that abusive mothers' patterns of decreasing RSA in response to their children's prosocial, age-appropriate behavior may serve to shape children's subsequent response repertoires in maladaptive ways. In the short term, this might involve children using increasingly aversive behavior to elicit a predictable response from their mother (i.e., Hakman et al., 2009); over time, children may show more significant adjustment difficulties related to these coercive transactions, such as oppositional behavior problems. In this way, abusive mothers' physiological responding to their children's prosocial behavior may operate as a mediator of CM's negative effects on children's developmental outcomes, driving shifts toward more aversive child behavior over time.

Conclusion

The current results provide evidence that mothers' physiological sensitivities to their child's compliance behavior critically diverges across distal (i.e., CM type) and proximal (i.e., inconsistent parenting) risk factors. Mothers' RSA responses to children's prosocial compliance behavior appear to be positively reinforcing for non-CM mothers and aversive for physically abusive mothers, whereas child compliance does not appear to influence PNS responding in neglectful mothers. Further, regardless of CM subtype, mothers who engaged in more inconsistent parenting displayed less physiological calm in response to their children's trusting and relying behaviors. If independently replicated, these findings may provide new evidence regarding the physiological bases of maladaptive parenting and its adverse effects on children's developmental outcomes.

These patterns of physiological responding in mothers across the spectrum of risk suggest several directions for personalizing and individually tailoring parenting interventions. Among physically abusive dyads, investigation of biofeedback and mindfulness approaches to incorporate into existing evidence-based parenting interventions may yield insights into their ability to facilitate reductions in maternal arousal to children's prosocial behavior or decoupling the time-ordered associations between children's developmentally appropriate bids for parental protection and subsequent RSA withdrawal in mothers (e.g., Skowron, 2015). Given our findings regarding the weakened influence of child prosocial compliance on maternal RSA when mothers frequently vacillate between controlling and supporting their child's autonomy, this pattern of inconsistent parent behavior may be another important target of intervention, regardless of CM background, in order to disrupt physiologically maintained coercive cycles of parent-child interaction.

Financial support. This research was supported by the National Institute of Mental Health grants MH079328 and DA036533 to E.A.S, and in part by grant P50 DA035763 National Institute on Drug Abuse to D.S.D.

References

Barnett, D., Manly, J.T., & Cicchetti, D. (1993). Defining child maltreatment: The interface between policy and research. In D. Cicchetti & S.L. Toth (Eds.), *Advances in applied developmental psychology: Child abuse, child development and social policy*. Norwood, NJ: Ablex Publishing Corp.

Bateson, G., Jackson, D. D., Haley, J., & Weakland, J. (1963). A note on the double bind – 1962. *Family Process*, *2*, 154–161.

Beauchaine, T. (2001). Vagal tone, development, and Grays motivational theory: Toward an integrated model of autonomic nervous system functioning in psychopathology. *Development and Psychopathology*, *13*, 183–214.

Beauchaine, T.P., & Thayer, J.F. (2015). Heart rate variability as a transdiagnostic biomarker of psychopathology. *International Journal of Psychophysiology*, *98*, 338–350.

Belsky, J. (1984). The determinants of parenting: A process model. *Child Development*, *55*, 83–96.

Belsky, J. (1993). Etiology of child maltreatment: A developmental ecological analysis. *Psychological Bulletin*, *114*, 413.

Benjamin, L. S. (1974). Structural analysis of social behavior. *Psychological Review*, *81*, 392–425.

Benjamin, L. S. (1996). A clinician-friendly version of the Interpersonal Circumplex: Structural Analysis of Social Behavior (SASB). *Journal of Personality Assessment*, *66*, 248–266.

Benjamin, L. S, & Cushing, G. (2000) Reference manual for coding social interactions in terms of Structural Analysis of Social Behavior. Salt Lake City: University of Utah.

Berntson, G. G., Cacioppo, J. T., Quigley, K. S., & Fabro, V. T. (1994). Autonomic space and psychophysiological response. *Psychophysiology*, *3*, 44–61.

Berntson, G. G., Thomas Bigger, J., Eckberg, D. L., Grossman, P., Kaufmann, P. G., Malik, M., … & Der Molen, M. V. (1997). Heart rate variability: Origins, methods, and interpretive caveats. *Psychophysiology*, *34*, 623–648.

Biesanz, J. C., Deeb-Sossa, N., Papadakis, A. A., Bollen, K. A., & Curran, P. J. (2004). The role of coding time in estimating and interpreting growth curve models. *Psychological Methods*, *9*, 30–52.

Black, D. A., Heyman, R. E., & Smith Slep, A. M. (2001). Risk factors for child physical abuse. *Aggression and Violent Behavior*, *62*, 121–188.

Bowen, M. (1978). *Family therapy in clinical practice*. New York, NY: Jason Aronson.

Boyce, W. T., & Ellis, B. J. (2005). Biological sensitivity to context: I. An evolutionary developmental theory of the origins and functions of stress reactivity. *Development and Psychopathology*, *17*, 271–301.5

Bugental, D. B. (2009). Predicting & preventing child maltreatment: A biocognitive transactional approach. In A. Sameroff (Ed.), *The transactional model of development: How children and contexts shape each other* (pp. 97–115). Washington, DC: American Psychological Association.

Burke, J. D., Pardini, D. A., & Loeber, R. (2008). Reciprocal relationships between parenting behavior and disruptive psychopathology from childhood through adolescence. *Journal of Abnormal Child Psychology*, *36*, 679–692.

Burt, S., McGue, M., Krueger, R., & Iacono, W. G. (2005). How are parent-child conflict and childhood externalizing symptoms related over time? Results from a genetically informative cross-lagged study. *Development and Psychopathology*, *17*, 145–165.

Butler, E. A., Wilhelm, F. H., & Gross, J. J. (2006). Respiratory sinus arrhythmia, emotion, and emotion regulation during social interaction. *Psychophysiology*, *43*, 612–622.

Chamberlain, P., & Patterson, G. R. (1995). Discipline and child compliance in parenting. In M. H. Bornstein & M. H. Bornstein (Eds.), *Handbook of Parenting, Vol. 4: Applied and Practical Parenting* (pp. 205–225). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Cicchetti, D., & Lynch, M. (1993). Toward an ecological/transactional model of community violence and child maltreatment: Consequences for children's development. *Psychiatry*, *56*, 96–118.

Connell, A. M., Dawson, G. C., Danzo, S., & McKillop, H. N. (2017). The psychophysiology of parenting: Individual differences in autonomic reactivity to positive and negative mood inductions and observed parental affect during dyadic interactions with children. *Journal of Family Psychology*, *31*, 30–40.

Creaven, A. M., Skowron, E. A., Hughes, B. M., Howard, S., & Loken, E. (2014). Dyadic concordance in mother and preschooler resting cardiovascular function varies by risk status. *Developmental Psychobiology*, *56*, 142–152.

https://doi.org/10.1017/S0954579419000270 Published online by Cambridge University Press

Crittenden, P., & DiLalla, D. (1988). Compusive compliance: The development of an inhibitory coping strategy in infancy. *Journal of Abnormal Child Psychology*, *16*, 585–599.

Crouch, J. L., Hiraoka, R., McCanne, T. R., Reo, G., Wagner, M. F., Krauss, A., … & Skowronski, J. J. (2018). Heart rate and heart rate variability in parents at risk for child physical abuse. *Journal of Interpersonal Violence*, *33*, 1629–1652.

Crouter, A. C., & Booth, A. (Eds.). (2003). *Children's influence on family dynamics: The neglected side of family relationships*. Mahwah, NJ; Lawrence Erlbaum Associates.

Cui, L., Morris, A. S., Harrist, A. W., Larzelere, R. E., & Criss, M. M. (2015). Dynamic changes in parent affect and adolescent cardiac vagal regulation: A real-time analysis. *Journal of Family Psychology*, *29*, 180–190.

DeGarmo, D. S. (2010). Coercive and prosocial fathering, antisocial personality, and growth in children's postdivorce noncompliance. *Child Development*, *81*, 503–516.

Diaz, A., & Petersen, A. C. (2014). Institute of Medicine report: New directions in child abuse and neglect research. *Journal of the American Medical Association Pediatrics*, *168*, 101–102.

Disbrow, M. A., Doerr, H., & Caulfield, C. (1977). Measuring the components of parents' potential for child abuse and neglect. *Child Abuse and Neglect*, *1*, 279–296.

Dodge, K. A., Bates, J. E., & Pettit, G. S. (1990). Mechanisms in the cycle of violence. *Science*, *250*, 1678–1683.

Egeland, B., Breitenbucher, M., & Rosenberg, D. (1980). Prospective study of the significance of life stress in the etiology of child abuse. *Journal of Consulting and Clinical Psychology*, *48*, 195–205.

Frodi, A. M., & Lamb, M. E. (1980). Child abusers' responses to infant smiles and cries. *Child Development*, *51*, 238–241.

Gardner, F. E. (1989). Inconsistent parenting: Is there evidence for a link with children's conduct problems? *Journal of Abnormal Child Psychology*, *17*, 223–233.

Geisler, F., Kubiak, T., Siewert, K., & Weber, H. (2013). Cardiac vagal tone is associated with social engagement and self-regulation. *Biological Psychology*, *93*, 279–286.

Gershoff, E. A. (2002). Corporal punishment by parents and associated child behaviors and experiences: A meta-analytic and theoretical review. *Psychological Bulletin*, *128*, 539–579.

Gross, H. E., Shaw, D. S., & Moilanen, K. L. (2008) Reciprocal associations between boys' externalizing problems and mothers' depressive symptoms. *Journal of Abnormal Child Psychology*, *36*, 693–709.

Hakman, M., Chaffin, M., Funderburk, B., & Silovsky, J. F. (2009). Change trajectories for parent-child interaction sequences during parent-child interaction therapy for child physical abuse. *Child Abuse & Neglect*, *33*, 461–470.

Hawes, D. J., Dadds, M. R., Frost, A. D., & Hasking, P. A. (2011). Do childhood callous-unemotional traits drive change in parenting practices? *Journal of Clinical Child & Adolescent Psychology*, *40*, 507–518.

Hill-Soderlund, A. L., Mills-Koonce, W. R., Propper, C., Calkins, S. D., Granger, D. A., Moore, G. A., … Cox, M. J. (2008). Parasympathetic and sympathetic responses to the strange situation in infants and mothers from avoidant and securely attached dyads. *Developmental Psychobiology*, *50*, 361–376.

Humphrey, L. L., & Benjamin, L. S. (1986). Using structural analysis of social behavior to assess critical but elusive family processes: A new solution to an old problem. *American Psychologist*, *41*(9), 979–989.

Ingjaldsson, J. T., Laberg, J. C., & Thayer, J. F. (2003). Reduced heart rate variability in chronic alcohol abuse: Relationship with negative mood, chronic thought suppression, and compulsive drinking. *Biological Psychiatry*, *54*, 1427–1436.

Joosen, K. J., Mesman, J., Bakermans-Kranenburg, M. J., Pieper, S., Zeskind, P. S., & Van IJzendoorn, M. H. (2013a). Physiological reactivity to infant crying and observed maternal sensitivity. *Infancy*, *18*, 414–431.

Joosen, K. J., Mesman, J., Bakermans-Kranenburg, M. J., & van IJzendoorn, M.H. (2013b). Maternal overreactive sympathetic nervous system responses to repeated infant crying predicts risk for impulsive harsh discipline of infants. *Child Maltreatment*, *18*, 252–263.

Kalb, L.M., & Loerber, R. (2003). Child disobedience and noncompliance: A review. *Pediatrics*, *111*, 641–652.

Kaufman, J., & Ziegler, E. (1989). The intergenerational transmission of child abuse. In D. Cicchetti & V. Carlson (Eds.), *Child maltreatment: Theory and research on the causes and consequences of child abuse and neglect* (pp. 129–150). New York, NY: Cambridge University Press.

Kavanagh, K. A., Youngblade, L., Reid, J. B., & Fagot, B. I. (1988). Interactions between children and abusive versus control parents. *Journal of Clinical Child Psychology*, *17*, 137–142.

Keenan, K., Shaw, D., Delliquadri, E., Giovannelli, J., & Walsh, B. (1998). Evidence for the continuity of early problems behaviours: Application of a developmental model. *Journal of Abnormal Child Psychology*, *26*, 441–452.

Kerr, M. E., & Bowen, M. (1988). *Family evaluation*. New York, NY: Norton.

Kim, J., & Cicchetti, D. (2010). Longitudinal pathways linking child maltreatment, emotion regulation, peer relations, and psychopathology. *Journal of Child Psychology and Psychiatry*, *51*, 706–716.

Kimonis, E. R., Frick, P. J., & McMahon, R. J. (2014). Conduct and oppositional defiant disorders. In E. J. Mash & R. A. Barkley (Eds.), *Child psychopathology* (pp. 145–179). New York, NY: Guilford Press.

Kochanska, G. (1991). Socialization and temperament in the development of guilt and conscience. *Child Development*, *62*, 1379–1392.

Kochanska, G. & Aksan, N. (1995). Mother-child mutually positive affect, the quality of child compliance to requests and prohibitions, and maternal control as correlates of early internalization. *Child Development*, *66*, 236–254.

Kopp, C. B. (1982). Antecedents of self-regulation: A developmental perspective. *Developmental Psychology*, *18*, 199–214.

Kreibig, S. D. (2010). Autonomic nervous system activity in emotion: A review. *Biological Psychology*, *84*, 394–421.

Larrson, H., Viding, E., Rijsdijk, F. V., & Plomin, R. (2008). Relationships between parental negativity and childhood antisocial behavior over time: A bidirectional effects model in a longitudinal genetically informative design. *Journal of Abnormal Child Psychology*, *36*, 633–645.

Leerkes, E. M., Su, J., Calkins, S. D., Supple, A. J., O'Brien, M., & Fiese, B. H. (2016). Pathways by which mothers' physiological arousal and regulation while caregiving predict sensitivity to infant distress. *Journal of Family Psychology*, *30*, 769–779.

Lorber, M. F., & O'Leary, S. G. (2005). Mediated paths to overreactive discipline: Mothers' experienced emotion, appraisals, and physiological responses. *Journal of Consulting and Clinical Psychology*, *73*, 972–981.

Lyons-Ruth, K., Connell, D. B., Zoll, D., & Stahl, J. (1987). Infants at social risk: Relations among infant maltreatment, maternal behavior, and infant attachment behavior. *Developmental Psychology*, *23*, 223–232.

Lytton, H. (1980). *Parent-child interaction: The socialization process observed in twin and singleton families*. New York: Plenum.

Masten, A. S., & Cicchetti, D. (2010). Developmental cascades. *Development and Psychopathology*, *22*, 491–495.

McCanne, T. R., & Hagstrom, A. H. (1996). Physiological hyperreactivity to stressors in physical child abusers and individuals at risk for being physically abusive. *Aggression and Violent Behavior*, *1*, 345–358.

Mills-Koonce, W. R., Propper, C., Gariépy, J. L., Barnett, M., Moore, G. A., Calkins, S., & Cox, M. J. (2009). Psychophysiological correlates of parenting behavior in mothers of young children. *Developmental Psychobiology*, *51*, 650–661.

Moore, G. A., Hill-Soderlund, A. L., Propper, C. B., Calkins, S. D., Mills-Koonce, W. R., & Cox, M. J. (2009). Mother–infant vagal regulation in the face-to-face still-face paradigm is moderated by maternal sensitivity. *Child Development*, *80*, 209–223.

Musser, E. D., Ablow, J. C., & Measelle, J. R. (2012). Predicting maternal sensitivity: The roles of postnatal depressive symptoms and parasympathetic dysregulation. *Infant Mental Health Journal*, *33*, 350–359.

Obradovic, J., Bush, N. R., Stamperdahl, J., Adler, N. E., & Boyce, W. T. (2010). Biological sensitivity to context: The interactive effects of stress reactivity and family adversity on socioemotional behavior and school readiness. *Child Development*, *81*, 270–289.

Pardini, D. A., Fite, P. J., & Burke, J. D. (2008). Bidirectional associations between parenting practices and conduct problems in boys from childhood to adolescence: The moderating effect of age and African-American ethnicity. *Journal of Abnormal Child Psychology*, *36*, 647–662.

Paschall, K. W., & Mastergeorge, A. M. (2016). A review of 25 years of research in bidirectionality in parent-child relationships: An examination of

methodological approaches. *International Journal of Behavioral Development*, *40*, 442–451.
Patterson, G. R. (1982). *Coercive family process*. Eugene, OR: Castalia Press.
Patterson, G. R., Reid, J. B., & Dishion, T. J. (1992). *Antisocial boys*. Eugene, OR: Castalia Press.
Pettit, G. S., & Arsiwalla, D. D. (2008). Commentary on special section on "bidirectional parent child relationships": The continuing evolution of dynamic, transactional models of parenting and youth behavior problems. *Journal of Abnormal Child Psychology*, *36*, 711–718.
Pollak, S. D., Cicchetti, D., Hornung, K., & Reed, A. (2000). Recognizing emotion in faces: Developmental effects of child abuse and neglect. *Developmental Psychology*, *36*, 679–688.
Porges, S. W. (2001). The polyvagal theory: phylogenetic substrates of a social nervous system. *International Journal of Psychophysiology*, *42*, 123–146.
Raudenbush, S. W., Bryk, A. S., Cheong, Y. F., Congdon Jr., R. T., & du Toit, M. (2013). *HLM 7: Hierarchical linear and nonlinear modeling*. Lincolnwood, IL: Scientific Software International, Inc.
Reid, J. B., & Patterson, G. R. (1989). The development of antisocial behavioral patterns in childhood and adolescence. *European Journal of Personality*, *3*, 107–119.
Reijman, S., Alink, L. R., Block, L. H. C. D., Werner, C. D., Maras, A., Rijnberk, C., … & Bakermans-Kranenburg, M. J. (2014). Autonomic reactivity to infant crying in maltreating mothers. *Child Maltreatment*, *19*, 101–112.
Rogosch, F. A., Cicchetti, D., & Aber, J. L. (1995). The role of child maltreatment in early deviations in cognitive and affective processing abilities and later peer relationship problems. *Development and Psychopathology*, *7*, 591–609.
Sameroff, A. (1975). Transactional models in early social relations. *Human Development*, *18*, 65–79.
Serbin, L. A., Kingdon, D., Ruttle, P. L., & Stack, D. M. (2015). The impact of children's internalizing and externalizing problems on parenting: Transactional processes and reciprocal change over time. *Development and Psychopathology*, *27*, 969–986.
Shaw, D. S., & Bell, R. Q. (1993). Developmental theories of parental contributors to antisocial behavior. *Journal of Abnormal Child Psychology*, *21*, 493–518.
Singer, J. D., & Willett, J. B. (2003). *Applied longitudinal data analysis: Modeling change and event occurrence*. New York: Oxford University Press.
Skowron, E.A. (2015). Understanding autonomic physiology and relationship processes in high-risk families. In R. Noone & D. Papero (Eds.), *The family emotional system: An integrative concept for theory, science, and practice*. Rowman & Littlefield.
Skowron, E. A., Cipriano-Essel, E., Benjamin, L. S., Pincus, A. L., & Van Ryzin, M. J. (2013). Cardiac vagal tone and quality of parenting show concurrent and time-ordered associations that diverge in abusive, neglectful, and non-maltreating mothers. *Couple and Family Psychology: Research and Practice*, *2*, 95–115.
Skowron, E. A., Kozlowski, J. M., & Pincus, A. L. (2010). Differentiation, self–other representations, and rupture–repair processes: Predicting child maltreatment risk. *Journal of Counseling Psychology*, *57*, 304–316.
Smith, J.D., Woodhouse, S., Clark, C., & Skowron, E.A. (2016). Attachment status and mother-preschooler parasympathetic response to the Strange Situation Procedure. *Biological Psychology*, *114*, 39–48.
Stifter, C. A., Spinrad, T., & Braungart-Rieker, J. (1999). Toward a developmental model of child compliance: The role of emotion regulation in infancy. *Child Development*, *70*, 21–32.
Stith, S. M., Liu, T., Davies, L. C., Boykin, E. L., Alder, M. C., Harris, J. M., … & Dees, J. E. M. E. G. (2009). Risk factors in child maltreatment: A meta-analytic review of the literature. *Aggression and Violent Behavior*, *14*, 13–29.
Toth, S. L., Maughan, A., Manly, J. T., Spagnola, M., & Cicchetti, D. (2002). The relative efficacy of two interventions in altering maltreated preschool children's representational models: Implications for attachment theory. *Development and Psychopathology*, *14*, 877–908.
Trickett, P. K., & Kuczynski, L. (1986). Children's misbehaviors and parental discipline strategies in abusive and nonabusive families. *Developmental Psychology*, *22*, 115–123.
Trickett, P. K., & Susman, E. J. (1988). Parental perceptions of child-rearing practices in physically abusive and nonabusive families. *Developmental Psychology*, *24*, 270–276.
Verhoeven, M., Junger, M., van Aken, C., Deković, M., & van Aken, M. A. (2010). Parenting and children's externalizing behavior: Bidirectionality during toddlerhood. *Journal of Applied Developmental Psychology*, *31*, 93–105.
Wahler, R. G., & Dumas, J. E. (1986). Maintenance factors in coercive mother-child interactions: The compliance and predictability hypotheses. *Journal of Applied Behavior Analysis*, *19*, 13–22.
Weisman, O., Zagoory-Sharon, O., & Feldman, R. (2012). Oxytocin administration to parent enhances infant physiological and behavioral readiness for social engagement. *Biological Psychiatry*, *72*, 982–989.
Wilson, S. R., Rack, J. J., Shi, X., & Norris, A. M. (2008). Comparing physically abusive, neglectful, and non-maltreating parents during interaction with their children: A meta analysis of observational studies. *Child Abuse & Neglect*, *32*, 897–911.

https://doi.org/10.1017/S0954579419000270 Published online by Cambridge University Press