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Prospective relations between intrusive parenting and child behavior problems: Differential moderation by parasympathetic nervous system regulation and child sex

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ABSTRACT

This study examined children's parasympathetic nervous system (PNS) regulation, which was indexed by respiratory sinus arrhythmia (RSA) during rest, reactivity, and recovery episodes, and sex as moderators of predicted relations between observed intrusive parenting and later observer-rated child behavior problems. Child-caregiver dyads (N = 250; 50% girls; 46% Latino/a) completed a series of laboratory assessments yielding independent measures of intrusive parenting at age 4, PNS regulation at age 6, and child behavior problems at age 8. Results indicated that intrusive parenting was related to more internalizing problems among boys who showed low RSA reactivity (i.e., PNS withdrawal from pre-startle to startle challenge), but RSA reactivity did not moderate this relation among girls. Interestingly, RSA recovery (i.e., PNS activation from startle challenge to post-startle) moderated these relations differently for boys and girls. For girls with relatively low RSA post-startle (i.e., less recovery), intrusive parenting was positively related to both internalizing and externalizing problems. However, the reverse was true for boys, such that there was a significant positive relation between intrusive parenting and later externalizing problems among boys who evidenced relatively high RSA post-startle (i.e., more recovery). Findings provide evidence for the moderation of intrusive caregiving effects by children's PNS regulation while highlighting the differential patterning of these relations across distinct phases of the regulatory response and as a function of child sex.

1. Introduction

Parenting quality exerts robust and enduring effects on children's development [1]. Parenting characterized by high support, sensitivity, and responsiveness contributes to children's positive academic achievement, mental health, social competence, and behavioral adjustment [2,3], whereas parenting characterized by intrusion or rejection undermines children's adaptation in multiple domains [4–6]. However, ongoing efforts to elucidate factors that account for individual differences in how children respond to parenting behaviors have the potential to inform applied interventions to mitigate risk and promote positive adaptation.

Children's capacity to regulate their emotions and behaviors is a robust moderator of familial influences on child development [7,8]. Likewise, some evidence suggests that children's physiological self-regulation may also moderate the impact of parental psychopathology [9], interparental conflict [10], and/or child maltreatment [11] on children's behavioral adjustment. The current study sought to extend this literature in three important ways. First, we offer one of the first systematic investigations of the moderating influence of children's parasympathetic nervous system (PNS) regulation on intrusive, rather than abusive, parenting effects. Thus, this study provides a unique opportunity to evaluate if and how children's PNS regulation may qualify the effects of more widespread and moderate parental influences. Second, we evaluated multiple facets of the regulatory response in a single investigation. Prior studies have examined either children's autonomic regulation at rest (e.g., [12,98]), or their reaction to a challenge [13,14], but fewer have done so in the same study [15–18], and even fewer have considered the final phase of regulation, namely the child's capacity to recover from challenge and restore homeostasis [19–21]. Third, the current study explicitly evaluated child sex as a moderator of these hypothesized relations given evidence suggesting that sex may further qualify interactive relations of environmental stressors and PNS regulation on adaptation [9,17,18].

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2. Intrusive parenting

Intrusive parenting behaviors communicate a lack of respect for the child as an individual and thwart children's efforts to gain autonomy by verbally and/or physically interfering with the child's interests and behaviors to a degree that goes beyond developmentally-appropriate support for structure and safety [4,22]. Intrusive parenting threatens positive adjustment because it exposes the child to increased (and potentially taxing) stimulation at the same time it limits the child's ability to develop independent coping skills for navigating concurrent arousal and future challenges.

Consistent with theoretical assertions regarding the negative effects of parental overstimulation and inadequate support on child development [23,24], intrusive parenting practices are associated with a range of maladaptive outcomes, such as behavioral and social adjustment difficulties, in both cross-sectional [6,25] and longitudinal studies [22,26,27]. Despite a preponderance of literature indicating that intrusive parenting is associated with negative adaptation, there remains important, yet largely unexplained, variation in the degree to which children evidence problem behaviors in the context of intrusive parenting practices [25,26,28].

Elucidating specific factors that may qualify the impact of intrusive parenting on child development has significant implications for understanding parenting effects in development and for applied efforts to support positive parenting and child development in clinical practice. Intrusive parenting and its effects may be especially salient during the preschool years as children begin to explore and express heightened levels of autonomy [29]. Moreover, these effects may influence children's subsequent transition into formal schooling, which is a major developmental milestone in western cultures, one that is predicated on children's core competencies at the same time it initiates adaptive pathways that canalize across childhood [30]. Thus, the current effort to clarify whether and for whom intrusive parenting during the preschool years may contribute to behavior problems during the transition to school has important implications for understanding and supporting children's adaptation.

3. PNS regulation as a moderator of intrusive parenting effects

Children's capacities to regulate their emotions, behaviors, and bodies in accordance with contextual demands may qualify the effect of intrusive parenting on child behavior [25,31]. Research suggests that parenting effects may be moderated by children's capacity to regulate their autonomic nervous system in infancy [32] and in later childhood [33]. Likewise, in a recent study of 206 infant-caregiver dyads, a composite of behaviorally coded parental intrusiveness and negative regard toward the infant at 6 months predicted children's depressive symptoms 3 years later, and this association was magnified among children who evidenced a higher resting heart rate [27].

The autonomic nervous system is comprised of parasympathetic and sympathetic branches, which serve to control core adaptive systems, such as heart rate, digestion, pupillary dilation, and respiration. Together, these systems modulate cardiac regulation across periods of a) *rest* when PNS inhibition is typically high and sympathetic nervous system (SNS) activation is low to maintain a slow and steady heart rate, b) *reactivity* when PNS inhibition may be reduced *or* augmented and SNS activation increased *or* decreased to mobilize an appropriate challenge response that features activation *or* withdrawal, respectively, and c) *recovery* when parasympathetic and sympathetic systems return toward resting levels and homeostasis after experiencing a challenge [34,35].

Parasympathetic cardiac innervation can be indexed by respiratory sinus arrhythmia (RSA), which is the naturally occurring variation in heart rate as a function of respiration [36,37]. Relative to other biological measures that may moderate caregiving effects via the stable influence of a genetic polymorphism, such as the serotonin transporter gene [38], or the gradual influence of the neuroendocrine system, such as salivary alpha-amylase [39], the acute responsivity of the RSA system permits the examination of distinct regulatory phases across resting, reactivity, and recovery episodes, to examine if and how they differentially moderate the adaptive consequences of caregiving experiences [20].

Studies have shown that individual facets of PNS regulation can moderate the developmental effects of environmental influences generally (e.g., varying types of adversity; [35,40]), and of parenting practices in particular (e.g., marital conflict or violence; [7,99]). For example, RSA at rest has been shown to influence the impact of childhood maltreatment on adolescents' behavior problems, such that high resting RSA buffered youth from internalizing problems associated with maltreatment exposure [14]. The only study to our knowledge that examined the moderating role of RSA at rest on relations between intrusive parenting and child adjustment outcomes demonstrated stronger relations with disorganized attachment among 6 month old infants who evidenced relatively high RSA during an unstructured play task with the caregiver, which was thought to index RSA resting in comparison to the child's RSA during a stressful still-face paradigm [41].

With regard to RSA reactivity, the optimal parasympathetic reaction to a challenge differs depending on the nature of the stressor. Typically, heart rate increases in response to challenge, and this is enabled by PNS withdrawal and RSA suppression. However, there are instances when PNS activation and RSA augmentation may be called for, as when a child is specifically instructed to regulate an emotional response or calm themselves [42,43]. Across studies, children's capacity to mobilize an adaptive parasympathetic response, whether via suppression or augmentation, has been shown to influence the effects of environmental factors on child outcomes. For example, in a study of cumulative family adversity (e.g., financial stress, parental depression, harsh parenting), adversity exposure was associated with more externalizing behavior problems among preschoolers who evidenced greater RSA suppression in response to a series of social, cognitive, sensory, and emotional challenge tasks [44]. Similarly, Cipriano et al. [13] found that preschoolers who evidenced relatively large RSA suppression in response to a problem-solving challenge evidenced more emotional problems as family violence exposure increased, whereas children with low RSA suppression did not. Interestingly, a recent study found that RSA reactivity (i.e., suppression) moderated the effect of abusive parenting on children's inhibitory control when it was assessed during a challenge task presented to the parent-child dyad, but not when it was assessed during an individual child challenge [45]. In the only study to examine the moderating influence of RSA reactivity on intrusive parenting effects (i.e., over control), Hastings and De [46] found that children who evidenced relatively high RSA suppression in response to a difficult puzzle task with the caregiver, evidenced increased wariness when interacting with peers.

Following a stressful challenge, RSA should return toward resting levels as the PNS restores homeostasis. In cases where RSA suppression is optimal, such as when faced with an unexpected startle that warrants response mobilization and heart rate acceleration, PNS recovery would be indicated by an increase in RSA to support the deceleration of heart rate. Relative to the burgeoning literature on RSA during resting and reactivity measures, however, only a handful of studies have examined RSA recovery. Theoretically, the capacity to restore homeostasis is adaptive, and the few studies that have evaluated direct relations between parasympathetic recovery and adjustment support this assertion [16,20,21,47]. However, to our knowledge, the current study is the first to explore the moderating influence of RSA recovery on the relation between environmental influences and child adaptation.

Importantly, recent studies suggest that there may be significant differences in the moderating effects of autonomic regulation on environmental influences as a function of child sex [9,11,17,18]. For example, El-Sheikh et al. [17] explored three-way interactions among

verbal marital conflict, RSA reactivity while children listened to audio recordings of a family conflict, and child sex as related to internalizing and externalizing behavior problems in a sample of 75 children aged 8 to 12 years. In this study, stronger RSA suppression buffered boys against externalizing problems in the context of marital conflict, but there were no significant interactive effects for girls, nor for internalizing problems. In a study of 110 adolescents, Diamond et al. [9] found that the relation between a negative family environment (i.e., maternal internalizing problems and/or single parent family structure) and children's negative affect was significant for girls who evidenced low RSA suppression in response to a series of subtraction and speech challenge tasks, but this moderation effect was not significant for boys. Although some studies have not supported interactions among PNS regulation, child sex, and environmental stressors (e.g., [48]), the preponderance of evidence suggests that interactive effects between parenting and PNS regulation may vary by child sex in meaningful ways. Moreover, the elucidation of sex-specific patterns of parenting and autonomic regulation processes in development is important to understand how problematic parenting may influence specific behavior problems, and to delineate sex-specific pathways underlying such associations [49].

4. The current study

This investigation sought to evaluate the relation between observational measures of intrusive parenting during the preschool years and independent ratings of children's behavior problems 4 years later as moderated by children's parasympathetic cardiac regulation during periods of pre-startle rest, startle reactivity, and post-startle recovery challenge episodes. As noted earlier, optimal PNS regulation patterns vary depending on task demands. For example, PNS withdrawal in response to challenge (i.e., reduced inhibition indicated by a decrease in RSA from resting levels) is adaptive when there is a need for attentional engagement and behavioral activation, whereas PNS augmentation in response to challenge (i.e., increased inhibition indicated by an increase in RSA from resting levels) may be optimal when there is a need to reduce or control arousal [42,43,50,51].

The current investigation employed a startle challenge procedure because prior studies have demonstrated that children's startle regulation is relevant for understanding children's behavioral adaptation [50,52], and this procedure allowed us to examine RSA at rest, RSA reactivity, and RSA recovery measures to obtain a complete picture of PNS regulation within the same task. In response to a startle challenge, the optimal PNS regulatory pattern would feature relatively high RSA during the pre-startle resting period, followed by a decrease in PNS inhibition as indicated by RSA suppression to enable sympathetic activation in response to the startle, and, finally, a return to homeostasis during the post-startle recovery episode as indicated by an increase in RSA due to the reapplication of PNS inhibition [37]. Given the findings of Skowron et al. [45], wherein PNS regulation measured during a dyadic challenge with the caregiver, but not when measured during an individually-administered child challenge, moderated the child's response to abusive parenting, we assessed RSA during a startling challenge task that was administered to the child-caregiver dyad.

Building on prior findings, and consistent with diathesis stress models of development [53], we predicted that the anticipated positive relation between intrusive parenting practices during the preschool years and later child behavior problems would be larger when children evidenced relatively low RSA during the pre-startle episode (i.e., less PNS inhibition at rest), relatively high RSA during the startle challenge (i.e., less PNS withdrawal), or relatively low RSA during the post-startle episode (i.e., less PNS recovery). Although a few studies have explored the moderation of interactive relations between stress and autonomic regulation by child sex [9,11,17,18,48], prior analyses have been exploratory with few interpretations offered as to the potential meaning of observed patterns. Thus, we explored three-way interactions among intrusive parenting, RSA regulation, and child sex. All analyses included child race/ethnicity as a covariate. Although we recognize that parenting practices are culturally embedded and informed [54,55], we did not examine the influence of race/ethnicity on these relations in light of the already complex interactions of interest, as well as the dearth of evidence supporting racial/ethnic differences in the moderating effects of autonomic nervous system functioning. Child IQ and family SES were included as additional covariates in all analyses given their documented relations with child behavior problems [56,57].

5. Method

5.1. Participants

Participants were 250 children and their primary caregivers who were recruited to participate in “a study of children's learning and development” via flyers posted in community-based child development centers and preschool programs in Southern California. Potential participants were screened by phone to ensure that the child was 1) between 3.9 and 4.6 years of age (M_{age} = 4 years and 1 month, SD = 2.91 months), 2) proficient in English, and 3) not diagnosed with a developmental disability or delay. The total sample was 50% female, 46% Latino/a, 18% African American/Black, 11.2%, European American/White, 0.4% Asian American, 24.4% multiracial/other, and representative of the surrounding community at the time of recruitment [58].

All caregivers were female, and included biological mothers (91.4%), foster/adoptive mothers (3.6%), and grandmothers or other female kin caregivers (5.0%). Education levels were variable (i.e., 19.8% of caregivers had not completed high school, 17.3% had a high school diploma or GED, 62.9% had some kind of technical training or college coursework). Just over half the caregivers were employed (55.6%). The majority of caregivers were married (61.6%) or in a committed relationship (18.8%).

5.2. Procedure

At age 4 (M_{age_W1} = 4 years and 1 month, SD = 2.82 months), 250 caregiver-child dyads completed a 3-hour laboratory assessment, which consisted of measures with the child, the caregiver, and the caregiver and child interacting, including formal assessments of IQ and parenting quality. Additional visits for this study were completed when the children were 6-years-old (M_{age_W2} = 6 years and 1 month, SD = 2.51 months; N = 215), which is when measures of autonomic regulation were first introduced in the study, and then again when the children were 8-years-old (M_{age_W3} = 8 years and 3 months, SD = 4.0 months; N = 213). Across the three waves, 230 dyads (92%) completed one or more follow-up visits. Caregivers were compensated with $25/h for their participation, and each child received a small gift. Written informed consent was obtained from the legal guardian at the beginning of each laboratory visit, and verbal informed assent was obtained from child participants beginning at age 6. All procedures were approved by the University's Human Research Review Board.

5.3. Measures

Intrusive parenting was assessed at age 4 when each caregiver was video recorded with her child during a series of four semi-structured teaching tasks lasting 20 min (i.e., sorting beads by color and shape, building a block structure, naming things with wheels, and playing a collaborative maze game; [59]). Independent coders blind to all other information about the family evaluated intrusive parenting behaviors during each task using a 7-point scale from low (*1*) to high (*7*). Inter-rater discrepancies were resolved through discussion, and consensus scores were averaged across tasks in accordance with prior studies ([100, 101, 22]). Intrusiveness assessed the extent to which the

caregiver lacked respect for the child as an individual and failed to recognize the child's efforts to gain autonomy (M = 2.00, SD = 0.59; ICC = 0.77 across 250 cases).

Child IQ was assessed at age 4 using the Vocabulary and Block Design subtests of the Wechsler Preschool and Primary Scale of Intelligence — III [60]. Verbal IQ was measured using the Vocabulary test in which the child pointed at pictures to identify orally presented words for children who were < 48 months of age, or verbally explained what orally-presented words meant for children who were 48 months or older. The age appropriate measure of vocabulary was used to assess each child's verbal ability (M = 96.87, SD = 15.55). Performance IQ was assessed using the Block Design subtest in which the child was asked to assemble red and white blocks to match models (M = 92.33, SD = 17.67). Estimated Verbal and Performance IQs were averaged to yield a prorated measure of Full Scale IQ (M = 94.97, SD = 13.54).

Family SES was scored at age 4 using the Hollingshead [61] Four-Factor Index of Social Status, based on a composite of caregiver education and occupational status. Education codes ranged from 1 (less than seventh grade) to 7 (graduate or professional training). Occupational scores ranged from 1 (farm laborers and unskilled service workers) to 9 (executives and major professionals). Education codes were multiplied by three and occupation codes were multiplied by five. Scores were summed within caregiver and then averaged across caregivers (in cases with two caregivers in the home) to yield a family SES score. At Wave 1, Family SES scores in the sample ranged from 9 (e.g., unemployed with a 10th grade education) to 66 (e.g., an attorney with a graduate degree) with higher scores connoting higher SES (M_{SES} = 33.22, SD = 13.07, e.g., a licensed vocational nurse with a trade degree).

PNS regulation (i.e., RSA rest, reactivity, recovery) was evaluated for the first time at age 6 using measures of the child's RSA during pre-startle rest, startle challenge, and post-startle recovery phases of a startle task that we adapted from prior work [62]. After spot electrodes were placed in a Lead II configuration on the child's chest, including four impedance electrodes, the child and caregiver were brought into a room where they were told they would be listening to a story. The dyad was instructed to sit quietly and listen as a trained examiner read aloud from the children's book, *Where the Wild Things Are*[63]. Placed on the table in front of the participants were three puppets that corresponded to the characters in the story, but the child and caregiver were instructed not to touch the puppets. After 2 min of reading, the examiner reached a point in the story where a fourth character was introduced, at which time, the examiner stated that s/he forgot the fourth puppet and needed to go and retrieve it so s/he could finish the story with all the characters present. After the examiner left the room, the caregiver lifted the center puppet, which she was secretly instructed to move prior to the interaction. The center puppet was filled with glass beads that crashed onto a metal tray the puppets were placed on producing a loud and startling sound. The remaining two puppets were held upright with water bottles so that all children were exposed to a single startle challenge. One minute after the challenge, the examiner returned with the missing puppet, acknowledged the spilled beads, stated that they must have been there to hold the puppet upright, and returned to reading the story for the remaining 2 min of the task. Given prior suggestions that children may habituate to traditional fire alarm startle challenges [52], the current protocol provided a novel startle challenge while supporting cognitively- and motorically-matched rest (pre-startle story listening) and recovery (post-startle story listening) RSA data collection episodes. The validity of the startle paradigm was supported by paired samples t-tests indicating a significant decline in RSA from pre-startle to startle (t = 6.01, p < 0.001), and a significant increase in RSA from startle to post-startle (t = −9.22, p < 0.001), yet no significant difference between RSA pre-startle and post-startle indices (t = −1.640, p = 0.102).

RSA data were collected using Mindware MW1000A ambulatory cardiography via Kendall Medi-Trace #133 spot electrodes. A 5-minute calibration period after initial placement of the electrodes was included at the start of the RSA protocol. RSA data were filtered, extracted, and scored using Mindware's HRV 3.0.10 analysis program (www.mindware.com). This technique utilizes the Mindware software algorithms to calculate the variance in R-R wave intervals. RSA scores were calculated using the interbeat intervals on the ECG reading, respiratory rates derived from the impedance (i.e., dZ/dt) signal, and a specified RSA bandwidth range for 6-year olds of 0.15 to 0.80 Hz [64]. Data cleaning procedures included screening for outliers (i.e., > 3SD; [65]) minute-by-minute in relation to each child's data pattern and deleting a child's data if > 25% of their minutes were not scored (n = 11). RSA values for all three regulatory phases were extracted in 1-minute epochs across the 5-minute task, yielding measures of RSA during the pre-startle rest period (the average of 2 min), RSA startle (1 min), and RSA during the post-startle recovery period (the average of 2 min).

Child behavior problems were assessed by trained examiners who completed The Test Observation Form (TOF; [66]) following a three-hour laboratory assessment at age 8. The TOF is a standardized form for rating observations of behavior, affect, and test-taking style during assessments with children aged 2 to 18. Immediately following the laboratory assessment, the examiner rated the child's behavior on 125 problem items using a 4-point scale from no occurrence of the behavior (*0*), to very slight or ambiguous occurrence of the behavior (*1*), to a definite occurrence with mild to moderate intensity and frequency and less than three minutes total duration (*2*), to a definite occurrence with high intensity, high frequency, or three or more minutes total duration (*3*). The TOF contains two broadband psychopathology scales that assess internalizing (e.g., withdrawn/depressed) and externalizing (e.g., attention, conduct) problems. The TOF was validated in a diverse sample of clinically referred and non-referred children from varied ethnic groups. As with other measures from the Achenbach test battery [67], the TOF was completed by a single examiner, which precluded a measure of interrater reliability. TOF scores are scaled with respect to child age and sex with a t-score ≥ 63 connoting clinically significant problems [66]. Clinical elevations in internalizing and externalizing behavior problems were observed in 16.6% and 9.3% of the current sample, respectively.

5.4. Data preparation & analytic plan

All analyses were performed in SPSS version 22. Data were examined for non-normality to render parametric statistics valid [68]. Missing data were handled using the expectation-maximization (EM) algorithm for imputation to support analyses with the full sample of 250 child-caregiver dyads. This procedure is superior to prior approaches, such as deletion and mean substitution, as well as prior imputation approaches, which with limited numbers of iterations. The EM algorithm estimates expected values of missing data from observed values and then repeats the process until the values stabilize to yield the best and most likely pooled estimate [69]. Fifty iterations were used in this study. Data were missing due to attrition and recording errors for PNS regulation at age 6 (n = 52; 20.8%) and behavior problems at age 8 (n = 45; 18%). Dyads who did not return for follow up after Wave 1 (n = 20; 8.0%) did not differ significantly from those who did return on key demographics, including child sex, race/ethnicity, IQ, SES, and intrusiveness (all ps > 0.08).

Hayes [70] SPSS PROCESS routine for three-way moderation yielded 95% bootstrapped confidence intervals (CIs) for conditional effects of intrusive parenting at low RSA (minus 1 standard deviation [SD]) and high RSA (plus 1 SD) during pre-startle rest, startle reactivity, or post-startle recovery episodes, and by child sex. Bootstrapping is a non-parametric technique that accommodates violations of the assumption that the interaction term is normally distributed to yield a more reliable estimation of moderation effects [70]. Given that children's RSA scores were correlated across pre-startle, startle, and post-startle episodes (rs = 0.257 to 0.507, all ps < 0.01), separate models

Table 1
Descriptive statistics for study variables by child sex and race/ethnicity.

Variable	Total *M* (*SD*)	Child sex		Child race/ethnicity				$F_{race/eth.}$
		Male *M* (*SD*)	Female *M* (*SD*)	White *M* (*SD*)	Black *M* (*SD*)	Latino *M* (*SD*)	Multi *M* (*SD*)	
Child IQ	95.17 (13.46)	93.69 (12.94)	96.66 (13.86)	101.05 (17.01)	94.88 (12.93)	92.41[a] (11.79)	97.85 (13.94)	4.68**
Family SES	32.13 (12.14)	31.39 (12.01)	32.87 (12.26)	40.04 (13.76)	32.40[a] (13.04)	30.49[a] (10.81)	31.42[a] (11.93)	4.53**
Intrusive parenting	2.78 (0.82)	2.77 (0.80)	2.79 (0.84)	2.32 (0.92)	2.93[a] (0.86)	2.79[a] (0.70)	2.87[a] (0.90)	4.20**
Pre-startle RSA	7.02 (0.93)	7.06 (1.04)	6.99 (0.79)	6.86 (0.82)	7.28 (0.83)	6.97 (0.96)	7.01 (0.95)	1.63
Startle RSA	6.59 (0.99)	0.02 (1.06)	− 0.015 (0.94)	0.14 (0.75)	0.00 (1.16)	− 0.00 (0.97)	− 0.06 (1.04)	0.29
Post-startle RSA	7.14 (0.95)	− 0.03 (0.99)	0.03 (1.01)	− 0.14 (0.88)	0.00 (1.04)	− 0.04 (1.00)	0.14 (1.02)	0.63
Internalizing problems	60.73 (5.61)	60.36 (5.67)	61.10 (5.55)	59.44 (4.69)	59.90 (5.00)	62.14 (6.11)	59.30[b] (4.91)	5.14**
Externalizing problems	61.49 (6.21)	61.89 (6.91)	61.09 (5.43)	62.39 (6.99)	61.79 (5.99)	61.14 (6.39)	61.76 (5.76)	0.32

Note: *F*-values for sex are not shown due to nonsignificant omnibus.
RSA = respiratory sinus arrhythmia.
* $p < 0.05$.
[a] Different from white.
[b] Different from Latino.
** $p < 0.01$.

evaluated the moderating influence of each phase of the regulatory response (i.e., rest, reactivity, and recovery) on the association between intrusive parenting and later internalizing and externalizing problems by child sex (male = 0, female = 1), while holding the covariates of child race/ethnicity (non-Latino/a = 0, Latino/a = 1), child IQ, and family SES constant. In models examining RSA startle and RSA post-startle values, previous measures of RSA at pre-startle rest (in startle reactivity analyses) and RSA startle (in post-startle recovery analyses) were also held constant.

6. Results

6.1. Preliminary analyses

Descriptive statistics for all study variables are shown in Table 1. A MANOVA revealed a significant main effect for child race/ethnicity (Wilks' $\lambda = 0.783$, $p < 0.001$), but not for child sex (Wilks' $\lambda = 0.959$, $p = 0.276$), nor for the interaction of race/ethnicity and sex (Wilks' $\lambda = 0.884$, $p = 0.205$). Follow-up univariate ANOVAs indicated significant differences across racial/ethnic groups for SES, IQ, intrusive parenting, and internalizing problems. Post-hoc Bonferroni-corrected comparisons indicated that White children received lower levels of intrusive parenting and came from families with higher SES than all other groups. In addition, White children obtained higher IQ scores than their Latino peers, and Latino children were rated as having more internalizing problems than their multiracial peers.

Bivariate relations among study variables are shown in Table 2. Child IQ was moderately and positively related to family SES, and negatively related to children's internalizing and externalizing behavior problems. Intrusive parenting was moderately and negatively related to family SES and post-startle RSA. Examiner ratings of internalizing and externalizing behavior problems were moderately and positively correlated, and internalizing problems were moderately and negatively correlated with pre-startle RSA.

6.2. Moderation analyses

Hayes [70] PROCESS routine evaluated the conditional relations between intrusive parenting and child behavior problems as moderated by RSA regulation variables and child sex (see Table 3). Children's *RSA during pre-startle rest* did not moderate relations between intrusive parenting and either internalizing or externalizing child behavior problems, nor were these effects qualified by child sex. Children's *RSA startle* and sex moderated the association between intrusive parenting and internalizing, but not externalizing, behavior problems. Boys who evidenced relatively high RSA during the startle challenge were rated as having more internalizing problems if they experienced intrusive parenting during the preschool years (see Fig. 1; $b = 2.269$, $SE = 0.961$, $p = 0.019$). Children's *RSA post-startle* and sex moderated relations between intrusive parenting and both internalizing and externalizing behavior problems (see Figs. 2 and 3, respectively). Among girls who evidenced relatively low RSA post-startle, intrusive parenting was positively related to internalizing ($b = 1.586$, $SE = 0.790$, $p = 0.045$) and externalizing ($b = 2.008$, $SE = 0.8642$, $p = 0.021$) problems. However, the reverse was true for boys, such that there was a significant positive relation between intrusive parenting and later externalizing, but not internalizing, problems among boys who evidenced relatively high RSA post-startle ($b = 2.802$, $SE = 1.1072$, $p = 0.012$). Effect size indices for all significant interactions were moderate (see Table 3; R^2*-values* = 0.018–0.045).

7. Discussion

This investigation evaluated prospective associations between intrusive parenting behaviors observed during the preschool years and independent ratings of child internalizing and externalizing behavior problems 4 years later as moderated by children's PNS regulation and sex. The obtained results replicated broader patterns in the field revealing complex relations between intrusive parenting and children's behavioral outcomes [22,26], as well as between PNS regulatory processes and children's behavioral adjustment [15,27,32]. At the bivariate level, intrusive parenting evidenced modest relations with negative behavior outcomes, but these relations were qualified by children's PNS regulation, which itself varied in influence across distinct phases of the regulatory response, as well as by child sex.

These data did not support significant interactions between

Table 2
Bivariate correlations among study variables.

	1	2	3	4	5	6	7	8
1. Child IQ	–							
2. Family SES	0.26**	–						
3. Intrusive parenting	− 0.11	− 0.16*	–					
4. Pre-startle RSA	0.04	0.06	− 0.03	–				
5. Startle RSA	− 0.03	0.01	− 0.07	0.26**	–			
6. Post-startle RSA	− 0.05	− 0.12	− 0.14*	0.27**	0.50**	–		
7. Internalizing problems	− 0.22**	− 0.10	0.11	− 0.18**	0.01	− 0.05	–	
8. Externalizing problems	− 0.26**	− 0.10	0.12	− 0.01	0.02	− 0.08	0.24**	–

Note: RSA = respiratory sinus arrhythmia.
* $p < 0.05$.
** $p < 0.01$.

Table 3
Moderation of children's behavior problems on observed intrusive parenting by children's parasympathetic regulation and sex.

Effect	Internalizing behavior problems				Externalizing behavior problems			
	B	Bootstrapped	95% CI (bias-corrected)		B	Bootstrapped	95% CI (bias corrected)	
		SE	LLCI	ULCI		SE	LLCI	ULCI
Pre-startle RSA								
Child IQ	− 0.073**	0.026	− 0.126	− 0.021	− 0.118**	0.029	− 0.176	− 0.059
Family SES	− 0.001	0.029	− 0.058	0.0571	− 0.016	0.033	− 0.081	0.049
Race/ethnicity	2.120**	0.702	0.735	3.505	− 1.246	0.792	− 2.807	0.314
Child sex	0.977	0.679	− 0.360	2.314	− 0.512	0.765	− 2.018	0.994
Intrusive parenting	0.482	0.423	− 0.352	1.315	0.545	0.477	− 0.393	1.484
Pre-startle RSA	− 0.965*	0.389	− 1.733	− 0.197	0.221	0.439	− 0.644	1.086
Intrusive parenting × RSA	− 0.288	0.532	− 1.336	0.760	− 0.640	0.599	− 1.821	0.540
Intrusive parenting × sex	0.462	0.849	− 1.211	2.135	0.864	0.956	− 1.020	2.747
RSA × sex	− 0.760	0.783	− 2.302	0.782	0.794	0.882	− 0.943	2.531
Intrusive parenting × RSA × sex	− 1.394	1.064	− 3.490	0.702	− 2.052	1.198	− 4.413	0.308
	$R^2 = 0.006$		F(10,239) = 1.716		$R^2 = 0.011$		F(10,239) = 2.933	
Startle RSA								
Child IQ	− 0.073**	0.026	− 0.124	− 0.021	− 0.120**	0.030	− 0.179	− 0.061
Family SES	− 0.004	0.029	− 0.061	0.053	− 0.014	0.033	− 0078	0.051
Race/ethnicity	2.105*	0.700	0.726	3.484	− 1.175	0.794	− 2.740	0.390
Child sex	0.889	0.675	− 0.440	2.219	− 0.586	0.766	− 2.095	0.922
Pre-startle RSA	− 0.955*	0.378	− 1.699	− 0.211	0.060	0.429	− 0.785	0.904
Intrusive parenting	0.204	0.417	− 0.118	1.525	0.752	0.473	− 0.181	1.684
RSA	0.299	0.361	− 0.411	1.001	0.296	0.409	− 0.510	1.102
Intrusive parenting × RSA	0.673	0.443	− 0.199	1.545	0.115	0.502	− 0.875	1.105
Intrusive parenting × sex	0.164	0.834	− 1.480	1.808	0.772	0.947	− 1.093	2.637
RSA × sex	0.143	0.707	− 1.250	1.537	1.190	0.803	− 0.391	2.277
Intrusive parenting × RSA × sex	− 1.9607*	0.881	− 3.697	− 0.225	− 1.898	1.000	− 3.868	0.073
	$R^2 = 0.018$*		F(10,239) = 4.949*		$R^2 = 0.013$		F(10,239) = 3.599	
Post-startle RSA								
Child IQ	− 0.078**	0.027	− 0.131	− 0.026	− 0.127***	0.029	− 0.185	− 0.069
Family SES	− 0.008	0.030	− 0.067	0.051	− 0.023	0.038	− 0.088	0.041
Race/ethnicity	2.189**	0.706	0.798	3.580	− 1.473	0.772	− 2.994	0.049
Child sex	0.882	0.689	− 0.476	2.241	− 0.767	0.754	− 2.252	0.718
Startle RSA	0.120	0.403	− 0.674	0.913	0.438	0.441	− 0.429	1.306
Intrusive parenting	0.630	0.430	− 0.218	1.478	0.783	0.471	− 0.145	1.710
RSA	− 0.236	0.428	− 1.079	0.608	− 0.645	0.468	− 1.567	0.278
Intrusive parenting × RSA	0.069	0.443	− 0.803	0.941	0.573	0.484	− 0.381	1.526
Intrusive parenting × sex	0.015	0.858	− 1.675	1.704	0.297	0.938	− 1.551	2.145
RSA × sex	− 0.574	0.738	− 2.028	0.880	0.361	0.807	− 1.229	1.951
Intrusive parenting × RSA × sex	− 2.131*	0.877	− 3.858	− 0.404	− 3.406***	0.959	− 5.294	− 1.517
	$R^2 = 0.022$*		F(10,239) = 5.908*		$R^2 = 0.045$**		F(10,239) = 12.620**	

Note: RSA = respiratory sinus arrhythmia.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

intrusive parenting and RSA during the pre-startle rest period as related to either internalizing or externalizing behavior problems. This contradicts some evidence that RSA at rest can moderate parenting effects on children's behavior [41,71]. However, in contrast to prior studies, which typically assessed RSA at rest during a solitary video task in which the child watched an emotionally neutral film [13,15], the current study obtained measures of RSA at rest during a dyadic pre-startle episode where the child *and* caregiver were engaged in listening to a story read aloud by the examiner. Given that RSA is highly dependent on context, including the nature of the laboratory assessment, the kinds of challenge stimuli used, and the presence of other individuals, particularly caregivers [44,45,72–74], the obtained findings

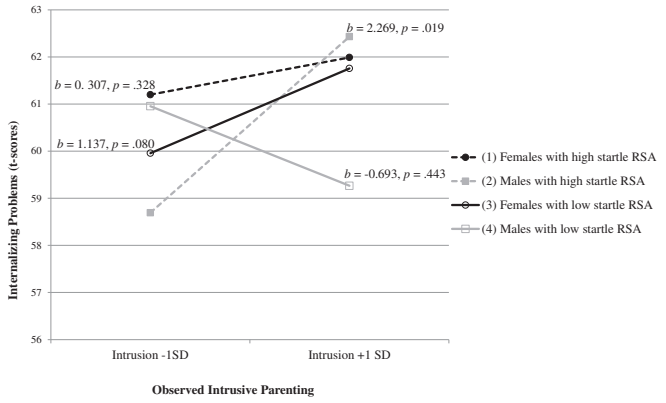

Fig. 1. The relation between observed intrusive parenting at age 4 and examiner-rated internalizing behavior problems at age 8 as moderated by startle reactivity RSA scores at age 6 shown at − 1 and + 1 standard deviations from the mean.

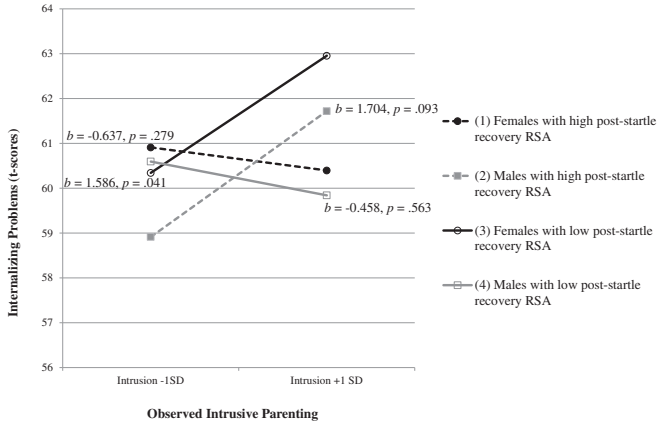

Fig. 2. The relation between observed intrusive parenting at age 4 and examiner-rated internalizing behavior problems at age 8 as moderated by post-startle RSA scores at age 6 shown at − 1 and + 1 standard deviations from the mean.

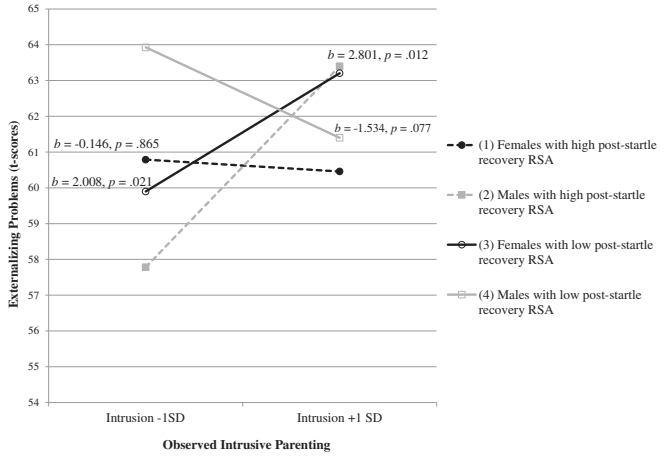

Fig. 3. The relation between observed intrusive parenting at age 4 and examiner-rated externalizing behavior problems at age 8 as moderated by post-startle RSA scores at age 6 shown at − 1 and + 1 standard deviations from the mean.

may have diverged from prior studies due to our assessment of RSA during the pre-startle rest period.

Consistent with prior studies suggesting that PNS withdrawal in response to a challenge that warrants behavioral activation signals an adaptive regulatory system [6,75], there was not a significant relation between intrusive parenting and internalizing behavior problems among boys who evidenced relatively strong RSA suppression (i.e., low RSA startle). However, among boys who evidenced relatively weak RSA suppression (i.e., high RSA startle), intrusive parenting was positively related to later internalizing problems. Interestingly, RSA reactivity to the startle challenge did not moderate relations between intrusive parenting and externalizing problems for boys, nor did it moderate associations with either internalizing or externalizing problems for girls. The pattern of findings for boys is consistent with prior work showing that RSA suppression in response to challenge may mitigate the negative developmental effects of pernicious environmental or caregiving influences [9,75,76], particularly with respect to internalizing pathology [71]. Although it is not clear why these patterns were not evident among girls, the obtained findings are consistent with prior evidence that RSA reactivity moderates parenting effects for boys, but not girls [17,18]. It is interesting to note, however, that El Sheikh et al. [17] found significant moderation of the relation between marital conflict exposure and boys' externalizing, but not internalizing, problems as a function of children's RSA reactivity when exposed to audio clips of marital conflict. In addition, an investigation of delinquency trajectories across childhood found that boys in high conflict homes who evidenced lower RSA at rest *and* RSA augmentation in response to a frustration task evidenced increased delinquency symptoms from ages 8 to 10 [18]. In contrast to prior findings with externalizing problems, the patterns that emerged in the current sample of younger boys is consistent with prior suggestions that boys may be more sensitive to intrusive parenting effects [77], and that internalizing problems, particularly depressive symptoms, may be especially salient among boys relative to girls prior to puberty [78].

Very few studies have evaluated the influence of RSA recovery on development (see [102,20,21] for notable exceptions), even though the capacity to recover from a state of elevated arousal is important in everyday adaptive functioning. In this study, the three-way interaction among intrusive parenting, post-startle RSA, and child sex indicated contrasting relations between intrusive parenting and later behavior problems for girls and boys as a function of their PNS recovery from the startle challenge. Consistent with prior suggestions that the capacity to recover is related to positive adaptation to stress [20,47], intrusive parenting was related to more internalizing *and* externalizing behavior problems among girls who displayed a relatively small increase in RSA from challenge to recovery (i.e., low RSA post-startle), but this relation was not significant among girls with relatively good RSA recovery capacities (i.e., high post-startle RSA). In contrast, the positive relation between intrusive parenting and externalizing, but not internalizing, behavior problems was significant among boys who displayed higher levels of PNS recovery (i.e., high RSA post-startle), but it was not significant among boys with relatively poor RSA recovery (i.e. low RSA post-startle). The moderating impact of PNS recovery on girls' behavior problems in the context of preschool exposure to intrusive parenting is consistent with prior evidence that difficulties with self-regulation exacerbate the negative effects of harsh parenting [8,79]. However, the unexpected inverted pattern for boys is difficult to explain and warrants further consideration and replication in future studies. Of note, all the boys in this study were members of a cross-sex caregiver-child dyad, whereas all the girls' experiences occurred within a same-sex caregiver-child dyad. Sex match within parent-child dyads is a known moderator of parenting effects [80], and may have influenced the obtained pattern of results in undetectable ways. Although these findings are preliminary, they illustrate the importance of considering recovery processes when trying to understand the adaptive implications of children's autonomic regulation.

7.1. Strengths and limitations

The current study provides new information about the relation between intrusive parenting and children's behavioral adjustment, as moderated by multiple facets of children's PNS regulatory response and

child sex. Notable strengths of this investigation include our use of a large and diverse sample of caregiver-child dyads, multiple methods, and multiple informants, including behavioral observations of parenting behaviors, a laboratory assessment of PNS regulation with task-inclusive measures of RSA during pre-startle rest and post-startle recovery periods, and examiner ratings of children's behavior problems. However, several features of this study introduced both strengths and limitations to the interpretation of the obtained data.

First, we utilized a novel startle paradigm to assess children's PNS regulation. Previous investigations with this age group have used similar procedures with a fire alarm to assess PNS response to startle [81], but researchers have since expressed concern about habituation effects as fire alarms and drills have become commonplace in child care settings [52]. Moreover, the design of this startle task sought to address the need to consider task-specific cognitive and physical demands across measures of rest, reactivity, and recovery [82], as well as recent evidence that PNS regulation assessed during parent-child dyadic tasks may have greater relevance for understanding parenting effects than those administered to the child in isolation [45]. However, despite some task consistencies across the regulatory episodes examined herein, there remained significant variation between the startle episode and the other two episodes (e.g., the examiner was not present and no story was read during the startle episode). Although preliminary analyses supported the effectiveness of this novel startle paradigm, additional studies are needed to provide further validation and our capacity to compare our findings with prior studies was necessarily limited.

Second, although the TOF is a well-validated measure of observer-reported behavior problems, which mitigated shared informant effects across maternal parenting behavior and maternal report of the child's behavior, the TOF yields a necessarily limited view of the child's adjustment in the context of a single assessment protocol. Therefore, we conducted a post-hoc evaluation of the current hypotheses using maternal reports of child behavior problems on the Child Behavior Checklist (CBC; [83]). In support of the current findings, the pattern of interactive effects obtained for both RSA reactivity and recovery across maternal reports of internalizing and externalizing problems were identical to those with the TOF, though they were somewhat stronger for internalizing outcomes and did not attain significance overall.

Third, alternative analytic approaches, which were not feasible with the current data design, may have allowed for a deeper understanding of the PNS regulatory processes examined here. For example, recent studies have adopted multilevel modeling approaches to support inferences about the influence of parenting on patterns of RSA over time utilizing growth curve modeling [20,21]. Although the nature and timing of the current startle task precluded our ability to adopt these approaches due to limited data points, a recent comparative analysis between residualized and latent change analytic approaches found that, though the latent approach provide more detailed information about the sources of change, both procedures revealed the same overall pattern of parenting effects on executive functioning [84]. Likewise, a comparative analysis by Brooker and Buss [103] indicated that both dynamic indices in growth curve models and more traditional, static change scores offered incremental knowledge to understanding observed relations among both shyness and boldness in fearful toddlers. Finally, future studies should advance beyond linear analytic models to evaluate quadratic and curvilinear patterns of physiological functioning given evidence of complex relations where more responding (augmentation, suppression, recovery) may not uniformly support better functioning [85,86].

Fourth, although the longitudinal design of this study provided modest support for inferences regarding prospective relations between intrusive parenting and child behavior problems as moderated by children's PNS regulation and sex, the absence of concurrent PNS measures at wave 1 necessarily limited our ability to draw clear conclusions about the ordering of these effects. Likewise, the current study evaluated the moderating influence of PNS regulation on intrusive parenting effects to examine whether and for whom intrusive parenting practices may undermine children's behavioral adaptation. However, future studies in and beyond this sample may evaluate if and how children's autonomic regulation may explain obtained relations between intrusive parenting and behavior problems (i.e., indirect effects). That said, autonomic regulation is typically conceptualized as a moderator of experience, particularly beyond the early childhood years, given evidence that physiological functioning at rest is fairly stable following the preschool years [65,87].

Fifth, as noted earlier, the obtained differences by child sex were confounded by the potential influence of same- versus cross-sex caregiver-child dynamics. This is an important limitation because research has shown that expressions of parenting, including intrusion, and their effects on children may vary between mothers and fathers [88,89], and as a function of the sex match between parent and child [80]. Thus, we are limited in our capacity to interpret and generalize our findings with regard to child sex and parenting effects beyond mother-child dyads.

Finally, the current investigation offers unique insights into PNS regulatory processes, but greater consideration of sympathetic nervous system (SNS) effects await further examination. Moreover, although individual regulatory systems may be important for understanding parenting effects on child development, the interdependent PNS and SNS regulatory processes suggests that how these regulatory branches work in concert may advance of our understanding of these same effects. Future studies should examine profiles across the stress response phases (i.e., resting, reactivity, and recovery), as well as across PNS and SNS stress response systems (i.e., RSA in conjunction with pre-ejection period, which is a measure of SNS activation) as they relate to early parenting effects on later adjustment [52,72,90,91].

7.2. Implications and applications

Together, these findings provide further evidence that facets of PNS regulation, at least as indicated by RSA, are not universally protective, but instead have context- and sex-specific implications for children's internalizing and externalizing behavior problems. Children's behavior problems are heterogeneous and multi-determined. The current study speaks to some of that complexity by revealing both environmental and physiological processes that shape distinct pathways toward internalizing and externalizing problems among young girls and boys. In the ideal, these findings should inform intervention efforts aimed at re-routing these pathways prior to the canalization of behavior problems in later development. However, given the paucity of studies and efforts to translate findings about RSA and behavior or mental health to applied practice, this remains an area in dire need of greater research attention. The current study demonstrates that RSA regulation matters for understanding when and for whom intrusive parenting may be associated with child internalizing and externalizing problems, but ongoing research is needed to explicate why these moderating effects exist in order to translate these findings to practice with the greatest impact.

Polyvagal theory supports the role of adaptive vagal regulation in the development and execution of social engagement behaviors, such as response control and support-seeking [35], and research has supported these relations [92]. One reason that PNS regulation may be related to child behavior problems in the wake of intrusive parenting is because these regulatory processes influence social engagement skills that may offset the risks posed by problematic parenting. Thus, an important implication of the current findings is that efforts to bolster children's social engagement skills via behavioral training and rehearsal may be an alternate path to support positive adaptation in risky parenting contexts.

In the future, researchers should examine the specificity of the moderating influence of PNS regulation on children's behavior problems in greater depth. With respect to internalizing problems, children's response to and ability to recover from an unpredictable startle may speak to their capacity to navigate a dynamically changing

environment, such as the transition to formal schooling. With respect to externalizing problems, PNS suppression versus augmentation in response to a challenging startle may be differentially related to reactive versus proactive aggression, and/or to physical versus relational dimensions of aggression. In this view, increased RSA suppression may support response mobilization and increase propensities for reactive or physical aggression [93], whereas RSA augmentation may support the kind of restraint and planning required to undertake more proactive or relationally aggressive actions. Of course, we can only speculate as to possible explanations underlying the obtained associations in this study, but these refined analyses may further clarify them.

The current findings have the potential for significant applied impact given that shifts within internalizing and externalizing behavior problems as a result of complex interactions among intrusive parenting, PNS regulation, and sex may result in some children expressing clinical, rather than subclinical, levels of problem behavior in the future. Although biological systems themselves are difficult to alter, encouraging mind-body awareness and connection to influence physiological regulation in children may promote their well-being, especially in contexts of caregiving risk [94,95]. That said, our findings regarding RSA recovery suggest that future clinical interventions may need to target boys and girls differently. Whereas increased RSA recovery buffered girls against future problems, boys who evidenced more RSA recovery were at increased risk for externalizing problems in the wake of intrusive parenting. These findings highlight the need for earlier and more targeted efforts toward understanding young boys' RSA recovery and its implications for boys' later behavioral adjustment. The application of longitudinal methodology in the current study revealed optimal periods for intervention. For example, periods of developmental reorganization, such as the transition to formal schooling, heighten opportunities for re-directing maladaptive pathways [96,97]. During these times, altering caregiver-child relationships may play an especially important role in influencing adjustment outcomes. Future research and clinical practice focused on the study and modification of psychobiological mechanisms that heighten or mollify children's vulnerability to specific parenting influences may be best implemented during these optimal windows of opportunity. Importantly, these data suggest that, in addition to parenting extremes of support or maltreatment, everyday parenting variants, such as individual differences in intrusiveness, may have important implications for understanding children's long-term development. Disseminating knowledge about the influences of intrusive parenting practices at both biological and behavioral levels provides convincing evidence for the need to address these parenting behaviors at in early development.

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