Applying the polyvagal theory to children’s emotion regulation:
Social context, socialization, and adjustment

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ABSTRACT

Effective emotion regulation is essential for children’s positive development. Polyvagal theory provides a framework for understanding how parasympathetic regulation of cardiac activity contributes to children’s adaptive versus maladaptive functioning. Maintenance of cardiac respiratory sinus arrhythmia (RSA) under social challenge should support emotion regulation and behavioral adjustment. Children’s effective parasympathetic regulation and behavioral adjustment should be supported by appropriate parental socialization. These proposals were evaluated in a short-term longitudinal study of 94 preschool-aged children. Parenting and basal RSA were measured at home, then 6–10 months later behavioral adjustment and RSA in lab baseline and socially challenging contexts were measured. Children with relatively higher RSA in social challenge than at baseline (ΔRSA) had fewer internalizing problems (IP) and externalizing problems (EP), and better behavioral self-regulation (SR). Mothers who used more negative control had children with lower ΔRSA, more IP and EP, and less SR. Structural equation modeling showed that vagal regulation mediated associations between maternal negative control and children’s adjustment; maternal negative control did not predict EP or SR after accounting for ΔRSA. Associations were consistent across boys and girls, with one exception: Higher ΔRSA was significantly associated with fewer EP in boys only. These findings suggest that the practical significance of physiological regulation might be best revealed in ecologically valid procedures, and that children’s physiological mechanisms of emotion regulation are shaped by their experiences of parental socialization.

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enervation in response to task demands are thought to connote active regulation of arousal to support effective coping (Beauchaine, 2001; Calkins, 1997; Porges, 1995). However, there have been inconsistencies across studies in the relations reported between basal or dynamic RSA and behavioral measures of children’s ER. For example, three recent studies of the relations between children’s externalizing problems (EP) and both their basal and reactive RSA produced contradictory results. In samples ranging from preschool-age to elementary school-age, both basal RSA and RSA change to challenge tasks were reported to be negatively, positively, or non-significantly related to children’s EP (Beauchaine et al., 2007; Calkins et al., 2007; Dietrich et al., 2007). Similarly, across studies of the relations between RSA and children’s internalizing problems (IP), some researchers have reported that children with more IP have lower basal RSA or weaker vagal suppression (e.g., El-Sheikh, 2001; El-Sheikh et al., 2001; Fox and Field, 1989), but many have failed to replicate these associations (e.g., Gerlach et al., 2003; Marshall and Stevenson-Hinde, 1998; Schmidt et al., 1999). Within our own research, neither baseline RSA (Hastings and De, 2008) nor RSA suppression to a cognitive challenge (Hastings et al., 2008) was associated with a variety of indices of preschooled’s IP, EP and self-regulation (SR). These disparate findings call into question either the validity of polyvagal theory (Grossman and Taylor, 2007), or the efficacy of attempts to put polyvagal theory into practice. Alternatively, there could be contexts in which a reduction in parasympathetic enervation of cardiac activity would support adaptive responding, and contexts in which vagal suppression would fail to do so (Porges, 2007). The myelinated vagus has been nicknamed the “vagal brake” because of its tonic impeding of the sinoatrial node, which is normatively set higher than typical resting heart rate (Porges, 2001). The vagal brake inhibits sympathetic arousal, induces a calmer state, and facilitates social engagement “when the environment is perceived as safe” (Porges, 2007, p. 120). Conversely, under conditions of threat, releasing the vagal brake allows the sympathetic–adrenergic system to increase arousal and mobilize defensive reactions. Whether vagal suppression is adaptive, therefore, depends on whether the context that one encounters truly presents a threat which requires mobilization of resources, or whether an objectively safe environment is perceived to be dangerous. Prolonged decreases in RSA in response to non-threatening stimuli or safe contexts should be maladaptive and reflective of parasympathetic dysregulation (Friedman, 2007), by unnecessary mobilization of defensive reactions. To understand the contributions of parasympathetic regulation to children’s maladaptive and adaptive functioning, it might be necessary to study children’s physiological regulation within relevant and ecologically valid contexts that are ambiguous vis à vis the presence of threat.

The unfamiliar peer group procedure (e.g., Rubin et al., 2002), which elicits individual differences in children’s confident or anxious reactions, may serve this purpose. This context could be perceived as affording positive opportunities for social engagement, which would be supported by high RSA, or as posing a social threat, which would require decreased RSA to mobilize defensive responses. Furthermore, recent technological advances in ambulatory cardiac monitors with incorporated recording of physical activity permit the recording and analysis of children’s cardiac activity, while controlling for degree of motor activation (Grossman and Taylor, 2007). Relating children’s RSA in a social challenge to indices of adjustment might help to clarify the utility of polyvagal theory for understanding children’s ER.

2. Parental socialization of children’s ER and parasympathetic regulation

Parental socialization of children’s ER has emerged as a major focus of developmental research (Denham et al., 2007; Thompson and Meyer, 2007). Maternal and paternal socialization that is appropriately supportive, responsive and structuring, or that is not overly harsh, punitive and intrusive, is associated with children showing better behavioral SR and fewer IP or EP (Klimes-Dougan et al., 2007; Rubin et al., 2002, 2003). One mechanism by which parental socialization could contribute to children’s adjustment is through influences on children’s regulatory physiology. Animal studies of maternal care-giving behavior have shown that variations in socialization can affect autonomic regulation (Parent et al., 2005). Parallel mechanisms have been proposed in humans (Kofman, 2002), but the evidence for this is limited. Many researchers have failed to find significant associations between children’s RSA and indices of socialization (e.g., Calkins and Johnson, 1998; Kennedy et al., 2004; Rubin et al., 1997), but a small set of studies provide evidence of such links. Mothers who coordinate interactions with their infants contingently and synchronously have infants with higher vagal tone (Haley and Stansbury, 2003; Moore and Calkins, 2004; Porter, 2003). Conversely, lower basal RSA or less vagal suppression has been found in children exposed to marital violence or negative maternal control practices (Calkins et al., 1998; Katz, 2007; Porter et al., 2003). Thus, young children living in adverse or hostile home environments may show less effective or appropriate vagal regulation.

There have been fewer prospective longitudinal studies predicting later children’s RSA from earlier parental socialization. Burgess et al. (2003) found that infant attachment status at 14 months was not associated with basal RSA at 14 or 24 months, but unexpectedly, avoidant infants had significantly higher RSA at 48 months than secure or ambivalent infants. Following children from 2 to 4 years, Kennedy et al. (2004) found that children’s basal vagal tone and mothers’ self-reported responsive, negative and protective parenting were not concurrently associated at either time, and maternal parenting at 2 years did not predict children’s vagal tone at 4 years. Overall, the existing literature has not yet provided consistent evidence that more appropriate parental socialization supports children’s development of effective vagal regulation. Several methodological issues might have limited past attempts to assess the relations between children’s physiological regulation and parental socialization. Most researchers have only assessed children’s basal or resting RSA, rather than dynamic vagal changes to stress or challenge, and it might be unreasonable to expect the normative range of parental socialization to override the genetic and epigenetic determinants of basal physiology. Those researchers who have examined vagal change typically have used the kinds of controlled laboratory tasks that, for the reasons considered previously, may not be effective for engaging the polyvagal system in ways that are appropriate for revealing children’s adaptive ER. Socialization has most often been assessed using only parental self-report measures, but parent reports of their own parenting might be of questionable validity, and multi-method assessments of parenting usually are considered superior (Janssens et al., 2005). Finally, few investigators have considered whether parental socialization might contribute to children’s vagal regulation.

3. Objectives and hypotheses

Dynamic indices of physiology measured in ecologically meaningful contexts are likely to be more robust indicators of individual differences in children’s SR, EP and IP, compared to basal physiology. Similarly, dynamic vagal regulation might serve as
endophenotypes of those aspects of child ER that have been linked to parental socialization. Therefore, in this short-term longitudinal investigation we examined preschool-aged children's RSA in basal and social challenge contexts in relation to their SR, EP and IP, and the associations between maternal and paternal socialization practices and children's RSA and behavioral indices of ER.

Children with higher RSA in the social challenge context, and increases (or smaller decreases) in RSA from basal to social challenge, were expected to show better SR and fewer EP and IP. More supportive and less restrictive parents were expected to have children who showed higher RSA while interacting with peers, better SR and fewer problems. Children's vagal regulation to social challenge was expected to mediate associations between parental socialization and ER. Finally, because young boys are more likely than girls to show signs of poor ER, and in particular more EP (Keenan and Shaw, 1997), and relations between RSA and adjustment can differ for boys and girls (Graziano et al., 2007), we explored whether boys and girls had similar patterns of relations between vagal regulation and adjustment or socialization.

4. Method

4.1. Participants

This study included 94 children (54 girls, 40 boys), their mothers, and 77 of their fathers. Children ranged from 2.08 to 4.92 years old at recruitment (M = 3.48, S.D. = 0.76). There were 71 Caucasian families, 13 families with mixed ethnicities, 5 Asian families, and 5 families of other ethnic groups. There were 78 two-parent and 16 single-mother families. Most parents had completed some college education (M = 15.28 years, S.D. = 2.39), and families were generally of middle- to upper-middle socioeconomic status (M = $83,150 Canadian, S.D. = 48557, Mode = $45,000, range $15,000 to over $200,000). These children were drawn from a larger sample of 133 families (see Hastings et al., 2008), and selected on the basis of providing usable cardiac data during the laboratory baseline and social challenge tasks.

4.2. Procedure

Data for this study were collected during two visits. First, each family was seen at home, where children's basal RSA was recorded, and mothers’ and fathers’ parenting behaviors were observed during parent–child interactions and assessed via self-report. Second, 6–10 months later, families came to the lab. Children were grouped to form sets of three same-age, same-sex unfamiliar playmates (never previously introduced). Each child and mother arrived on their own and were taken to a small room where the cardiac monitor was placed on the child. After recording basal RSA, the three children were brought together in a large playroom with many toys for a free-play period, during which children's social group RSA were measured. While children were in the playroom, mothers sat in an adjacent room and completed questionnaire measures of children's SR, EP and IP.

4.2.1. Vagal tone

Each child's cardiac activity was recorded using the Mini-Logger 2000TM (Mini-Mitter, Inc.), a light-weight ambulatory monitor that recorded continuous inter-beat intervals (IBI) and gross motor movement (activity counts). IBIs were recorded between successive R-waves, to the nearest millisecond, and transmitted from a recording band on the child's chest to the Mini-Logger 2000TM unit, which the child wore in a waist-band. Data were downloaded from the Mini-Logger 2000TM unit using customized software, and then IBI files were transferred to Mxedit (Delta Biometrics, Inc.) for visual inspection and editing of recording artifacts and computation of cardiac RSA. Mxedit uses a moving 21-point polynomial algorithm that isolates heart rate variability at the amplitude and period of the oscillations associated with breathing, reported in units of ln(ms)2. The frequency band-pass parameters to quantify RSA corresponding to developmentally normative spontaneous respiration in this preschool-aged sample ranged from 0.24 to 1.04 Hz.

For the Home Baseline (HB) recordings, M duration = 4 m 46 s, S.D. = 1 m 49 s, parents were asked to sit with their children and watch a low-action animated videotape or read a children's picture book, in order to keep children stationary and arouse little affect. For Lab Baseline (LB), M duration = 2 m 33 s, S.D. = 46 s, each child and mother were observed for 10 min and, then sat in a corner and pretended to complete paper work. RSA was recorded for the entire period that each child was in the room for free play. If a child needed to leave the room (e.g., use the bathroom), the Mini-Logger was removed for the duration of the child's absence, and time-proportionalized RSA and activity were derived from the periods the child was in the playroom.

4.2.2. Child adjustment

The mean of mother-reported Inhibitory Control, Attention Focus and Low Pleasure on the Children's Behavior Questionnaire (CBQ; Rothbart et al., 2001) formed the index of children's self-regulation (SR); mean r between scales = .49, p < .001. Mothers completed the Child Behavior Checklist for 1.5–5 years (CBCL; Achenbach and Rescorla, 2000), which provided T-scores for children's internalizing (IP) and externalizing problems (EP).

4.2.3. Self-reported parenting

To assess patterns of socialization, parents completed the Child-Rearing Practices Report (CRPR, Block, 1981) during the home visit. Paralleling Kennedy et al. (2004), scores were computed for restrictive over-control (15 items: e.g., “I believe scolding makes my child improve,” α = .53 and .56 for mothers and fathers, respectively), and supportive parenting (16 items: e.g., “I respect my child's opinions and encourage him/her to express them,” α = .58 and .67 for mothers and fathers, respectively).

4.2.4. Observed parenting behavior

Each parent–child dyad was videotaped completing a series of activities in the home; order of observing mother–child versus father–child dyad first in two-parent homes was randomized. Parental behaviors were observed in three activities. (1) In co-constructed narratives, the parent and child used figures and toy props to resolve two social situations involving peers. The first depicted the dyad arriving in a situation where three other children were already playing, and the second depicted the target child acting shyly when the dyad met one unfamiliar peer and adult. Different stories were used for the first and second parent–child dyad. (2) In origami teaching, the parent guided the child in how to fold paper into an origami shape, but the parent was asked not to touch the paper herself or himself. Different origami shapes were used for the first and second parent–child dyad. (3) In clean-up, the parent was asked to have the child tidy the interaction area by returning all materials to their original containers (see Hastings et al., 2008, for more detail).

In co-constructed narratives, event sampling was used to code parent behaviors. Supportive behaviors included modeling greeting or interacting with peers and providing reasons for child interacting with peers. Critical/Negative behaviors included verbal disapproval, criticism of child's behavior, and introducing social dilemma (e.g., peer not liking child's actions). In origami, time-sampling was used to rate parents' teaching behaviors every 20 s on 5-point Likert-style scales (1: absent to 5: strong, repeated). Codes reflected Instructive (point out steps, show illustrations, explain necessary actions, provide reasons), Positive (warmth, affection, praise, encouraging), and Critical/Negative parenting (criticism, disapproval, derision, threats of failure or consequences). In clean-up, time-sampling was used to evaluate parents' management behaviors in every 10-s time-sample as absent (0) or present (1). Codes included Positive (praise, affection); Encouragement (gentle control and requests and reasoning); and Critical/Negative (criticism, disapproval, derision, threats of consequences, strict or angry control efforts). Across the three procedures, inter-coder agreement was computed from independent evaluations of 20% of the tapes using coefficient alpha for ratings and Kappa's coefficient for behaviors; α or γ > .71 for all codes.

4.3. Analytic plan

After creating indices of vagal regulation and parental socialization, one-tailed first-order correlations in SPSS were used to examine relations between measures of RSA, parenting and adjustment. Variables that met criteria for mediation analyses (Baron and Kenny, 1986) were then examined using structural equation modeling (SEM) in MPlus (Muthén and Muthén, 2006) to determine whether RSA mediated associations between parenting and SR or behavior problems, using criteria recommended by McDonald and Ho (2002). Finally, SEM path weights were evaluated to determine whether associations between RSA and parenting or between RSA and adjustment indices differed significantly between boys and girls. For all analyses involving RSA, adjustment, and maternal parenting, N = 94; for analyses involving paternal parenting, N = 77.

5. Results

5.1. Preliminary analyses

5.1.1. Respiratory sinus arrhythmia

The activity monitors of the Mini-Loggers recorded almost no gross motor movement in children for HB, low activity in some children for LB, and at least some activity in all children for SG. Physical activity can affect mean heart period (HP). LB activity was not significantly correlated with LB RSA, r = .09, although SG
activity was weakly correlated with SG RSA, \( r = -.17, p = .10 \). To remove the contributions of activity to children's vagal scores, LB and SG activity were regressed onto LB and SG RSA, respectively, and the standardized residuals were used as the indices of LB and SG RSA, independent of gross motor movement.

These RSA values were then used to measure children's RSA change from LB to SG, using residualized change scores (e.g., Krantz et al., 1996; Nazzaro et al., 2005). LB RSA and SG RSA were significantly positively correlated, \( r = .76, p < .001 \); therefore, the standardized residual of the prediction of SG RSA from LB RSA was an appropriate index of change in vagal tone (\( \Delta RSA \)) under social challenge conditions. Children with higher \( \Delta RSA \) scores had higher SG RSA, after accounting for individual differences in children's LB RSA. Vagal suppression (lower SG RSA than LB RSA) was shown by challenge conditions. Children with higher basal RSA at home also had higher Negative and two scores for fathers' origami Critical/Negative, were brought to within 3 standard deviations of score means. The transformations and corrections to outliers removed the skews.

Four confirmatory factor analyses were used to determine whether the five scores for observed supportive parenting and three scores for observed Critical/Negative parenting could be aggregated for mothers and for fathers. Single factor solutions were supported in each analysis. For supportive parenting for mothers and fathers, respectively, eigenvalue = 1.76 and 1.79, Variance = 35.25% and 35.83%, mean factor loadings = .58 and .57. For Critical/Negative parenting for mothers and fathers, respectively, eigenvalue = 1.24 and 1.31, Variance = 41.26% and 43.61%, mean factor loadings = .52 and .66. To generate the observed supportive parenting scores, the Supportive score from narratives, Positive and Instructive scores from origami, and Positive and Encouraging scores from clean-up were \( z \)-transformed and averaged. To generate the Critical/Negative parenting scores, the three Critical/Negative scores from narratives, origami, and clean-up were \( z \)-transformed and averaged.

Mothers' and fathers' self-reported supportive parenting was significantly, positively correlated with their observed supportive parenting, \( r = .26 \) and \( .29, \) respectively, both \( p < .05 \). Mothers' self-reported restrictive control was significantly, positively correlated with their observed Critical/Negative parenting, \( r = .24, p < .05 \), although fathers' self-reported and observed negative control were not significantly correlated, \( r = .07. \) (Although low in magnitude, this level of correspondence between independent measures of parenting is typical of multi-method studies, e.g., Janssens et al., 2005.) To create multi-method aggregate scores for parental Supportiveness and Negative Control, reported and observed parenting scores were standardized via \( z \)-transformation, and corresponding scores were averaged.

5.2. Descriptive analyses and associations between RSA and adjustment

Descriptive statistics and one-tailed first-order correlations for children's RSA and adjustment measures are provided in Table 2. Boys and girls did not differ significantly in any measures of RSA or \( \Delta RSA \), or adjustment problems, all \( |t| < 1.50 \). Girls had greater SR scores, \( M = 5.30, \) S.D. = 0.61, than boys, \( M = 5.00, \) S.D. = 0.53, \( t(92) = 2.55, p < .05 \). Older preschoolers had higher HB RSA, LB RSA and SG RSA, \( r = .23, .22 \) and .23, respectively, \( p < .05 \), but age was not associated with \( \Delta RSA \), \( r = .09, \) or any measures of behavioral adjustment, all \( |r| < .13 \).

HB RSA, LB RSA and SG RSA were all positively inter-correlated. As well, children with higher basal RSA at home also had higher \( \Delta RSA \). As expected, only \( \Delta RSA \) was significantly associated with adjustment. After accounting for basal RSA and activity levels, children with higher RSA in the social group context had fewer EP and IP, and greater SR.

### Table 1

<table>
<thead>
<tr>
<th>Parenting</th>
<th>Mothers</th>
<th>Fathers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>S.D.</td>
</tr>
<tr>
<td>Observations</td>
<td></td>
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<tr>
<td>Narratives</td>
<td></td>
<td></td>
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<tr>
<td>Supportive</td>
<td>.21</td>
<td>.13</td>
</tr>
<tr>
<td>Critical/Negative</td>
<td>.03</td>
<td>.10</td>
</tr>
<tr>
<td>Origami</td>
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<td></td>
</tr>
<tr>
<td>Instructive</td>
<td>1.94</td>
<td>.44</td>
</tr>
<tr>
<td>Positive</td>
<td>1.44</td>
<td>.30</td>
</tr>
<tr>
<td>Critical/Negative</td>
<td>1.13</td>
<td>.17</td>
</tr>
<tr>
<td>Clean-up</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive</td>
<td>.13</td>
<td>.10</td>
</tr>
<tr>
<td>Encourage</td>
<td>.14</td>
<td>.08</td>
</tr>
<tr>
<td>Critical/Negative</td>
<td>.08</td>
<td>.01</td>
</tr>
<tr>
<td>Reported Parenting</td>
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<td></td>
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<tr>
<td>Supportive</td>
<td>5.93</td>
<td>.46</td>
</tr>
<tr>
<td>Restrictive over-control</td>
<td>2.66</td>
<td>.48</td>
</tr>
</tbody>
</table>

Notes: \( N = 94 \) for all maternal parenting variables, \( N = 77 \) for all paternal parenting variables. Time-proportionalized means, based on length of procedure, are reported for observed parenting variables.

### Table 2

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>S.D.</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
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<tr>
<td>1. Home Baseline RSA</td>
<td>5.30</td>
<td>1.33</td>
<td>.53***</td>
<td>.53***</td>
<td>.20</td>
<td>-.15*</td>
<td>-.03</td>
<td>-.06</td>
</tr>
<tr>
<td>2. Lab Baseline RSA</td>
<td>5.14</td>
<td>1.18</td>
<td>.76***</td>
<td>.66***</td>
<td>.06</td>
<td>-.03</td>
<td>-.16*</td>
<td>-.21*</td>
</tr>
<tr>
<td>3. Social Group RSA</td>
<td>5.19</td>
<td>1.10</td>
<td>.05</td>
<td>.19</td>
<td>-.21*</td>
<td>-.16*</td>
<td>-.45**</td>
<td>-.69**</td>
</tr>
<tr>
<td>4. ( \Delta RSA )</td>
<td>0.05</td>
<td>0.85</td>
<td>.57</td>
<td>.63***</td>
<td>-.21*</td>
<td>-.21*</td>
<td>-.45**</td>
<td>-.69**</td>
</tr>
<tr>
<td>5. Self-regulation</td>
<td>5.17</td>
<td>0.59</td>
<td>48.53</td>
<td>10.31</td>
<td>49.99</td>
<td>10.75</td>
<td></td>
<td></td>
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<tr>
<td>6. Externalizing Problems</td>
<td>48.53</td>
<td>10.31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>7. Internalizing Problems</td>
<td>49.99</td>
<td>10.75</td>
<td></td>
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</table>

Notes: \( N = 94 \) for all variables. Descriptive statistics for LB RSA and SG RSA are prior to controlling activity levels. Descriptive statistics for \( \Delta RSA \) are based on arithmetic difference score (SG RSA–LB RSA). Standardized residuals of LB and SG RSA after controlling activity levels, and residualized change score in RSA from LB to SG, controlling for activity, were used in all analyses, including correlation statistics reported in this table and Table 1.

\( **p < .05. \)

\( ***p < .001. \)
5.4. Did children’s vagal regulation mediate associations between parenting and adjustment?

Because Age was significantly positively correlated with HB, LB, and SG RSA, analyses were re-examined using partial correlations, controlling for Age. None of the identified significant associations were reduced; all remained significant at $p < .05$ or less.

5.5. Did boys and girls differ in the relations between vagal regulation and adjustment or parenting?

The $\chi^2$ difference test was used to examine whether the path weights in the final, partially mediated model differed significantly between boys and girls. The fit criteria for the fully constrained model, in which all paths were constrained to have equal weighting for boys and girls, were compared to the fit criteria of a series of five partially constrained models. In each partially constrained model, one of the five paths was unconstrained such that the path weight could vary between boys and girls. Only one comparison led to a significantly better model fit, as shown by the $\chi^2$ difference test, $\chi^2(1) = 4.02, p < .05$; the model fit the data better when the path from $\Delta$RSA to IP was allowed to vary. This path was significant for boys, $\beta = -.42, p < .05$, but not girls, $\beta = -.06$. Thus, vagal dysregulation to the social group context was associated with IP in boys only.

6. Discussion

This study showed that preschool-aged children who maintained relatively higher RSA in transitioning from a quiet state with mother to a social interaction with unfamiliar peers were less likely to have difficulties arising from poor ER than children who showed more vagal suppression. These findings conform to the proposal of the polyvagal theory that cardiac regulation by the myelinated vagus supports calm and positive social engagement, and that decreased parasympathetic influence sets the stage for dysregulation to the social group context. Children showed poorer vagal regulation under conditions of social challenge when their mothers used more negative control, in accord with proposals that parenting practices might impact...
children’s physiological self-regulatory mechanisms (Parent et al., 2005; Repetti et al., 2007). Moreover, children’s vagal regulation mediated associations between their experience of negative control and their displays of EP and SR, pointing toward vagal dysregulation as a possible endophenotype or mechanism by which maladaptive socialization is associated with adjustment difficulties. Finally, exploratory analyses replicated some previous evidence of sex differences (e.g., Graziano et al., 2007), in that vagal dysregulation was more strongly linked to EP in boys than girls. These findings extend our understanding of the links between psychophysiology, socialization and children’s ER.

One of the most salient findings was that only children’s dynamic vagal regulation under conditions of ambiguous social challenge was associated with their adjustment. The suggestion has been made that basal RSA denotes children’s physiological reservoir of emotion regulation capacity, or their trait-like level of arousability (Beauclaire, 2001), whereas changes to RSA under conditions of stress or challenge correspond to state-like applications of emotion regulation efforts (Porges, 1995). Trait-like individual differences in RSA were evident in children’s stability of RSA across measurement contexts and over several months. Despite this, basal state RSA at home and laboratory were not associated with SR, EP or IP. Rather, evidence of emotion dysregulation was seen in those children who manifested low ΔRSA, that is, lowered RSA while interacting with unfamiliar peers relative to their basal RSA. Unlike some other studies (e.g., Calkins, 1997; Calkins et al., 2007), effective self-regulation was not reflected in vagal suppression to the social challenge context, but in maintenance of higher RSA, or what has been called vagal augmentation (Katz, 2007). This conforms to Porges’ (2001, 2007) proposal that when the environment is perceived as safe, the myelinated vagus inhibits the sino-atrial node and sympathetic activation of the fight-flight response, thereby facilitating social engagement. Those preschoolers who reacted to unfamiliar peers with vagal suppression, a mobilization of defensive reactions that was unnecessary given the safe context, also manifested evidence of adjustment difficulties.

Vagal suppression is not always maladaptive or indicative of dysfunction. It is normal and adaptive for RSA to decrease under conditions of active challenge (Lovatto, 2005), and brief RSA decreases to non-threatening cognitive tasks may serve as an index of appropriate PNS flexibility to support allocation of attention (Suess et al., 1994). This aspect of dynamic vagal functioning, however, may not be the most relevant for understanding the physiological basis of children’s ER and social functioning. The specificity of associations between ΔRSA and adjustment indicates that physiology must be understood in relation to the meaning of the context within which it is measured.

The second goal of this investigation was to identify associations between parental socialization and children’s vagal regulation. Most contemporaneous (e.g., Rubin et al., 1997) and longitudinal (e.g., Kennedy et al., 2004) studies have failed to provide evidence for such links. One moderately consistent pattern is that children exposed to inappropriate or adverse socialization experiences, such as parental negativity or family discord, have lower vagal regulation (Calkins et al., 1998; Katz, 2007; Porter et al., 2003). Strikingly, that is exactly the association that was evident in this study. The children of mothers who used more negative control practices had lower ΔRSA in the social challenge context, measured 6–10 months later. Similarly consistent with past research, maternal negative control also predicted increased levels of behavior problems (e.g., Rubin et al., 2003). Critical, angry and punitive parenting threatens a young child’s sense of security with the parent–child relationship and the child’s own self-confidence, creating a socializing environment that fails to support the normative development of effective emotional self-regulation (Denham et al., 2007). This is one of the first studies to document that negative parenting is linked to both behavioral and autonomic indicators of ER.

More specifically, modeling analyses revealed that children’s vagal regulation mediated associations between mothers’ negative control and children’s adjustment, in accord with the third hypothesis of this investigation. Although such physiological pathways of parental influence on behavioral indices of adjustment have been shown in animal studies (Parent et al., 2005), there has been a lack of such evidence from socialization research on humans (Repetti et al., 2007). Studies that have included aspects of parenting or other components of socialization typically have treated RSA as a moderating variable, demonstrating stronger ties between socialization and adjustment in children with lower vagal regulation (e.g., El-Sheikh et al., 2001; Hastings et al., 2008). This study’s non-experimental design cannot be interpreted as showing a sequence of causal influence, but to our knowledge, this is the first investigation to show that vagal regulation might play a role in the often-documented links between maternal negative control and children’s EP and SR. Children who experienced maternal parenting that could undermine their security, autonomy and efficacy showed a parasympathetic response to an ambiguous social situation concordant with perceived threat or danger, and this response was linked to their manifestations of behavioral maladjustment.

Intriguingly, this association between ΔRSA and adjustment was most robust for EP and SR, and for young boys. When the covariances between the three indices of adjustment were accounted for in the SEM model, the unique association between ΔRSA and IP was reduced in magnitude. As well, although there were no sex differences in children’s RSA or problem scores, and the links between maternal negative control and vagal regulation were concordant for girls and boys, ΔRSA was significantly associated with EP in boys only. The only other sex difference was that mothers reported that sons were lower in behavioral SR than daughters. These observed sex differences can be understood in light of developmental theory and research. Compared to young girls, young boys are particularly prone to manifesting adjustment difficulties involving disruptive, oppositional or aggressive behavior that appear to reflect poor self-regulation (Keenan and Shaw, 1997). Girls with regulatory difficulties are more likely to show internalizing difficulties of shyness or anxiety than EP, although it is not until late childhood or adolescence that more girls than boys manifest elevated IP (Nottelmann and Jensen, 1995). Thus, our finding that lower parasympathetic regulation in the context of social challenge predicted more EP in boys only supports some previous reports (Graziano et al., 2007), echoes arguments that vagal dysregulation is strongly linked to the development of disruptive behavior problems (Beaucahine, 2001), and conforms to gender models of developmental psychopathology (Zahn-Waxler et al., 2006). While young boys and girls with poor self-regulation may both be likely to have the ‘flight’ aspect of mobilized defensive responses activated, young boys may be particularly susceptible to having their ‘fight’ responses activated. If vagal dysregulation in ambiguously challenging social circumstances supports aggressive responses in boys, this may point toward a biopsychological mechanism that confers relatively greater stability to boys’ EP.

Vagal regulation did not fully mediate all associations between socialization and adjustment, of course. It did not account for the positive links between maternal negative control and IP, and the lack of association between ΔRSA and mothers’ supportive parenting suggests that other mechanisms must account for the links between positive socialization and better ER. Children’s development of competence versus anxious adjustment have both
been linked to mothers’ critical or dismissive (Rubin et al., 2002) and supportive (Hastings et al., 2008) parenting in past research. Across analyses, the magnitudes of the relations between ∆RSA and both adjustment and parenting were generally small, such that the documented associations should not be interpreted as indicating that vagal regulation is the predominant mediating pathway between socialization and adjustment. There are a number of other biological, affective or cognitive factors that could play a mediating role in these associations, and further research will be needed to elucidate these pathways (Repetti et al., 2007).

Polyvagal theory is not without its critics (e.g., Grossman and Taylor, 2007), and vagal regulation should be recognized as one of many physiological systems contributing to self-regulation (Porges, 2007). Greater attention to the processes by which multiple and interacting intrinsic and extrinsic factors support or undermine girls’ and boys’ adaptive development is needed. Despite the brief longitudinal design and repeated assessment of RSA, this correlational study could not demonstrate causal effects in the associations between socialization, RSA and ER. The multi-method measurement of parenting was an improvement over previous studies (e.g., Kennedy et al., 2004), but the modest correspondence between observed and parent-reported measures must be noted as a potentially attenuating the strength of the analyses. In particular, the aggregate measure of paternal negative control was not robust, and thus relations between fathers’ critical and punitive parenting and children’s vagal regulation might have been underestimated. Although it is common for studies to report that paternal parenting is less strongly related to children’s adjustment than is maternal parenting (e.g., Hastings et al., 2007), the smaller number of participating fathers in the current study may have limited our ability to detect paternal effects, and did not allow us to test for the combined influence of paternal and maternal socialization. As well, the behavioral indices of children’s adjustment were based exclusively on mothers’ reports; it will be important for future studies to include other objective measures of children’s effective ER. More research also needs to examine whether the associations between physiological regulation and behavioral adjustment differ for community and clinical samples (Beauchaine, 2001).

Nonetheless, this study provided evidence for the utility of polyvagal theory for examining the physiological underpinnings of children’s emotion regulation and adjustment. Effective vagal regulation reflects children’s appropriate reactions to the contexts they encounter, and may represent an endophenotype of maternal socialization of children’s emotion regulation. Investigating context- and gender-specific associations between physiology, socialization, regulation and psychopathology will advance our understanding of children’s development and may inform future efforts to promote their health and well-being.

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