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Longitudinal Associations Between Temperament and Socioemotional Outcomes in Young Children: The Moderating Role of RSA and Gender

Santiago Morales¹, Charles Beekman¹, Alysia Y. Bandon¹, Cynthia A. Stifter², and Kristin A. Buss¹

¹Psychology Department at the Pennsylvania State University 278 Moore Building, 16802 PA

²Department of Human Development and Family Studies at the Pennsylvania State University 278 Moore Building, 16802 PA

Abstract

Temperament is an important predictor of socioemotional adjustment, such as externalizing and internalizing symptoms. However, there is not a one-to-one correspondence between temperamental predispositions and these outcomes, implying that other factors also contribute to the development of internalizing and externalizing problems. Self-regulation is believed to interact with temperament, and has been studied as a predictor for later socioemotional outcomes. Respiratory sinus arrhythmia (RSA) is a psychophysiological measure of self-regulation that has been studied as a moderator of risk. The primary aim of the present study was to test if RSA baseline and RSA reactivity would moderate the link between temperament and socioemotional outcomes. Mothers reported the temperament of their infants (20 months; N=154), RSA was collected at 24- and 42-months, and mothers reported externalizing and internalizing behaviors at kindergarten entry. RSA baseline and RSA reactivity moderated the relation between exuberant temperament and externalizing behaviors. However, these results were only significant for girls, such that high RSA baseline and greater RSA suppression predicted more externalizing behaviors when exuberance was high. Fearful temperament predicted later internalizing behaviors, but no moderation was present. These results are discussed in light of recent evidence regarding gender differences in the role of RSA as a protective factor for risk.

Keywords

Respiratory Sinus Arrhythmia; Temperament; Sex Differences; Emotion

INTRODUCTION

Temperamental characteristics have been identified as important predictors for the development of socioemotional problems such as internalizing and externalizing symptoms (Kagan & Fox, 2006; Pérez-Edgar & Fox, 2005; Rothbart & Bates, 2006). However, there is

not a one-to-one correspondence between temperamental predispositions and these outcomes, implying that other factors also contribute to the development of internalizing and externalizing problems. Empirical evidence suggests other factors such as self-regulation moderate the relations between temperament and its socioemotional outcomes (Eisenberg, Smith, & Spinard, 2011; Rothbart, 2011; Rothbart & Bates, 2006). Respiratory sinus arrhythmia (RSA) has been used as a psychophysiological index of self-regulation that may forecast subsequent socioemotional outcomes (Beauchaine, 2001; Porges, 2007). Moreover, RSA has been studied as a moderator of risk (e.g., environmental risk; El-Sheikh, 2001). The present study examined RSA as a moderator of the relation between infant temperament and behavior problem symptoms in kindergarten.

Temperament and Behavioral Outcomes

Most researchers agree that temperament reflects biologically based individual differences that emerge in early life, which predispose the individual to certain feelings, thoughts, and behaviors (Kagan & Fox, 2006; Goldsmith et al., 1987; Rothbart & Bates, 2006). After the revolutionary work of Kagan, Fox, and others, two main temperaments have been the focus of much research: behavioral inhibition and exuberance. Children identified as behaviorally inhibited show high negative reactivity towards novelty, and high levels of social withdrawal, particularly to unfamiliar persons (Garcia-Coll, Kagan, & Reznick, 1984; Kagan Reznick, & Snidman, 1987). This temperament has been mostly studied as behavioral inhibition, but also as, fearful temperament (Buss, Davidson, Goldsmith, 2006; Kiel & Buss, 2006), shyness (Rapee & Coplan, 2010), dysregulated fear (Buss, 2011), social withdrawal, and anxious solitude (Gazelle & Rubin, 2010). However, it is often difficult to theoretically and empirically distinguish among these constructs; therefore the current study uses the broader term “fearful temperament” to encompass this temperamental construct.

Across many studies, fearful temperament has been found to be stable from early childhood to adolescence (e.g., Goldsmith & Lemery, 2000) and even early adulthood (e.g., Caspi et al., 2003). In addition, children characterized as extremely fearful in infancy or childhood tend to show later internalizing disorders, especially anxiety (Caspi et al., 2003; Chronis-Tuscano et al., 2009; Hirshfeld et al., 1992; Schwartz, Snidman, & Kagan, 1999; Stifter, Putnam & Jahromi, 2008; Pérez-Edgar & Fox, 2005 for a review). For example, Schwartz and colleagues (1999) reported that 61% of the children characterized as highly inhibited at age two showed symptoms of social anxiety at age 13, compared with 27% for non-inhibited children. Similarly, Buss (2011) found that children who were characterized as fearful across both high- and low-fear laboratory conditions (displaying dysregulated fear) at age two had higher maternal and teacher reported internalizing symptoms at the beginning of kindergarten. Findings of this nature demonstrate that fearful temperament is an important predictor of later internalizing problems.

Exuberance is characterized by high approach, activity level, impulsivity, displays of high intensity positive affect, and sociable behavior (Fox, Henderson, Rubin, Calkins, & Schmidt, 2001; Putnam & Stifter, 2005; Pfeifer, Goldsmith, Davidson & Rickman, 2002; Degnan et al., 2011). In the broader literature, it has also been referred to as uninhibited temperament (Pfeifer et al., 2002) or surgency (Rothbart, 2011). Exuberance has been shown to be stable

from infancy to childhood (Degnan et al., 2011; Fox et al., 2001) and to be a predictor of externalizing problems (Putnam & Stifter, 2005; Stifter et al., 2008). This is especially true for children who display high approach and low self-regulation. For instance, using cluster analysis on 126 infants, Putnam and Stifter (2005) identified an exuberant cluster characterized by high positivity and behavioral approach. This exuberant group of children was particularly at risk for externalizing behaviors such as aggressive and destructive problems. Hence, exuberant temperament, just as fearful temperament, has been related to later behavioral problems.

Physiological Regulation and Adjustment

Even though temperament is a strong predictor for the development of behavioral problems, not all fearful or exuberant children develop these problems. Therefore, it is imperative to look at what other aspects of children's development interact with temperament to predict maladaptive behaviors. One of such factors is self-regulation. Generally, self-regulation refers to the capacity to control behavior whether automatic or effortful such as the suppression of one behavior in order to carry out another (e.g., Rothbart, 2011). Self-regulation is considered to interact with temperamental reactivity to predict socioemotional outcomes (e.g., Eisenberg et al., 2009). Recent evidence indicates that self-regulatory capacities can be indexed by the psychophysiological measure respiratory sinus arrhythmia (RSA; Beauchaine, 2001; Porges, 2007).

RSA is a measure of the parasympathetic nervous system control of the heart. RSA is measured by the variation of heart rate with respect to the respiration cycle, which reflects the input from the vagal nerve into the heart. Porges' Polyvagal Theory states that this input from the vagal nerve into the heart or "vagal brake" allows the individual to modulate their internal state and actively engage or disengage with the environment as needed in order to regulate their emotion and behavior in an adaptive manner (Porges, 2007). Suppression (decrease in RSA) from baseline reflects less input from the vagal nerve allowing more engagement of the sympathetic nervous system, mobilizing resources for a flight-flight response. In contrast, augmentation (increase in RSA) from baseline reflects more input from the vagal nerve, inhibiting the sympathetic nervous system and supporting social engagement behaviors. RSA has been used as an indicator of self-regulatory processes such as attention, emotion, and cognition (Beauchaine, 2001). Consistent with the Polyvagal Theory, high levels of RSA during baseline and RSA suppression during challenging experimental conditions (RSA reactivity) are positively related to emotional regulation and socioemotional competence in children (Calkins & Keane, 2004; Liew et al., 2011). Conversely, low baseline RSA and/or lack of RSA suppression have been associated with poor emotional regulation or extreme emotional responses (Buss, Goldsmith, & Davidson, 2005; El-Sheikh, Harger, & Whitson, 2001; Friedman & Thayer, 1998). However, in a few studies this pattern has been found to differ by gender. For instance, Eisenberg et al. (1995) found the expected relation of high baseline RSA and reports of social competence, emotion regulation, and low emotionality in boys, but the opposite pattern for girls—high baseline was related to low social competence, low regulation, and emotionality. These findings highlight the importance of considering the role of gender when evaluating RSA as the

relation between this physiological marker and socioemotional outcomes may differ among boys and girls.

RSA and Behavioral Problems—Substantial evidence has also linked low baseline RSA and lack of RSA suppression with externalizing and internalizing problems (e.g., Beauchaine, Gatzke-Kopp, & Mead, 2007; Beauchaine, Katkin, Strassberg, & Snarr, 2001; Calkins & Dedmon, 2000; Eisenberg et al., 2011; El-Sheikh & Hinnant, 2011). However, some of these findings have been moderated by other characteristics like gender. In addition, several inconsistencies have been found, complicating the interpretation of the findings. Children with low baseline RSA levels show high externalizing problems (e.g., Beauchaine et al., 2007; Beauchaine et al., 2001), while others have found this association to be true only for boys (e.g., Beauchaine, Hong, & Marsh, 2008; Calkins & Dedmon, 2000; Eisenberg et al., 2011; El-Sheikh & Hinnant, 2011). Similarly, low baseline has been related to internalizing behaviors (e.g., Forbes, Fox, Cohn, Galles, & Kovacs, 2006; Shannon, Beauchaine, Brenner, Neuhaus, & Gatzke-Kopp, 2007). However, other research has not found baseline RSA to be related to either externalizing or internalizing problems (e.g., Calkins, Graziano, Keane, 2007; El-Sheikh, Hinnant, Arsiwalla & Erath, 2011; Gentzler, Santucci, Kovacs, & Fox, 2009; Hastings et al., 2008). Moreover, some studies have found high baseline RSA to be related to behavior problems (Conradt et al., 2013; Conradt, Measelle, & Ablow, 2013; Kidwell & Barnett, 2007). For example, Dietrich et al. (2007) found that high baseline RSA measured in supine position was associated with more externalizing disorders, particularly for girls.

High levels of RSA suppression have been related most consistently (see Graziano & Derefinko, 2013) to fewer externalizing (Calkins & Keane, 2004; Calkins, Blandon, Williford, & Keane, 2007; El-Sheikh, Harger, Whitson, 2001; Graziano, Keane, & Calkins, 2007) and fewer internalizing problems (Gentzler, Santucci, Kovacs, Fox, 2009; Calkins et al., 2007); although, some researchers have found this relation to be limited to boys (El-Sheikh et al., 2001; El-Sheikh & Hinnant, 2011; Graziano et al., 2007). Others have found the opposite pattern. For instance, Hastings and colleagues (2008) found that RSA augmentation, and not suppression, during a peer interaction task was associated with fewer internalizing and externalizing problems. Possible reasons for these inconsistencies are discussed below.

RSA as a Moderator of Risk—Patterns of RSA have not only been found to be linked to risk for the development of behavior problems, but have also been found to serve as a protective factor for individuals at risk. In particular, high baseline RSA has been proposed to serve as a protective factor for children at high risk for behavioral problems as higher baseline RSA may allow these children to better regulate their arousal in the presence of risk (El-Sheikh et al., 2001; El-Sheikh & Whitson, 2006; Katz, 2007). El-Sheikh and colleagues (2001) have found that environmental risk, such as marital conflict (El-Sheikh et al., 2001) or parental drinking (El-Sheikh, 2001), differentially affects children with high baseline RSA compared to those with low baseline RSA. Children with higher baseline did not show as many behavioral problems concurrently compared to the low-baseline children and showed decreased problems longitudinally (El-Sheikh & Whitson, 2006). Under a similar

rationale, RSA suppression has also been found to be a protective factor, but not consistently. In the studies previously discussed, El-Sheikh (2001) shows that high RSA suppression to an adult argument had a protective effect on behavioral problems. Nonetheless, in another study, El-Shiekh and colleagues (2001) found this effect only for boys and not for girls. In contrast, recent studies have found the opposite effect—RSA augmentation as a buffer to environmental risk for externalizing and internalizing problems (e.g., Cipriano et al., 2011; Cipriano, Skowron, & Gatzke-Kopp, 2011; Obradovič, Bush, Stamperdahl, Adler, & Boyce, 2010; Obradovič, Bush, & Boyce, 2011). Recent evidence suggests that these inconsistencies might be due to the nature of the tasks used to elicit RSA reactivity (Obradovič et al., 2011).

Measure and Context—The inconsistencies reviewed above, where some studies find RSA suppression is adaptive but in others RSA augmentation is adaptive, may be explained by the context in which RSA reactivity is measured. Namely, the nature of the experimental tasks that are used to elicit RSA reactivity affects how it is interpreted (e.g., whether RSA suppression is associated with positive or negative outcomes). For example, as reviewed above, Hastings and colleagues (2008) interpreted RSA augmentation to a social/low stress task as adaptive given the nature of their task—a social/low stress task should not suppress vagal tone and engage the fight/flight system, but rather increase vagal input and promote social engagement behaviors. Moreover, Obradovič et al. (2011) found that RSA suppression during cognitive tasks moderated differently the impact of maternal risk to behavioral problems than RSA reactivity during an emotional challenge—children who suppressed RSA in the cognitive task showed more externalizing problems under high-risk conditions. However, children who suppressed during the emotional challenge showed less externalizing problems under high-risk conditions (Obradovič et al., 2011). Similar differences in the moderating effects of RSA reactivity according to the task used have been now found by other research groups (e.g., Hinnant & El-Sheikh, 2013). In sum, in what contexts RSA is measured may, in part, account for the how RSA is associated with problem behaviors.

Consequently, it seems imperative to consider the nature of the tasks used to elicit RSA reactivity when interpreting the RSA reactivity literature. However, this would lead to interpretations limited to the context of task. Moreover, to do this successfully poses some methodological challenges such as having task-specific baselines and baselines between tasks to avoid the sequential dependence across tasks. The present study did not use this type of baseline methodology; thus, the RSA levels of previous tasks would bias the interpretation of a single task. One approach to deal with this methodological issue is to examine RSA across multiple tasks and to capture the shared variance across different contexts. This would be in line with how RSA is commonly discussed: a stable child characteristic that indexes physiological regulatory processes (e.g., El-Sheikh, 2001; El-Sheikh & Erath, 2011). The current study generated latent variables from several experimental tasks of both cognitive and emotional nature in an attempt to capture a more trait-like index of these physiological processes.

RSA Stability—If RSA reflects a trait-like measure of self-regulation, some stability across time would be expected. Individual differences in baseline RSA have been found to be more stable than RSA reactivity in several samples (Borstein & Suess, 2000; Calkins & Keane, 2004; El-Sheikh, 2005; Rigterink, Fainsilber, & Hessler, 2010). Calkins and Keane found stability in baseline RSA from 2 years to 4 years of age and modest stability across the same time span in reactivity in four different tasks. In contrast, El-Sheikh (2005) found stability for older children in baseline and stability in reactivity to a cognitive task but no stability in a social task. Other studies have found RSA to be impacted by the environmental factors (e.g., maternal depression), indicating that lack of stability could be found in some contexts (Propper & Moore, 2006). The current study employed two different time points (24 months and 42 months) to evaluate the stability of the shared variance of RSA reactivity to several tasks across these time points.

The Present Study

As previously discussed, temperament is a predictor for later behavioral problems. However, not all children at risk develop behavioral problems. The present study tested if RSA would moderate the link between temperament and later behavioral problems. To do this, two temperament factors (fear and exuberance) were identified at 20 months based on maternal reports. Internalizing and externalizing symptoms were measured via maternal report at kindergarten entry (approximately age 5). Physiological regulation was based on RSA baseline and reactivity at two different time points (24-months and 42-months). Two main hypotheses were proposed: (1) The exuberant factor would predict externalizing symptoms and RSA would moderate the association such that children with high RSA baseline and suppression would be less likely to develop externalizing problems. (2) The fearful factor would predict internalizing symptoms and RSA would moderate the association such that children with high RSA baseline and suppression would be less likely to develop internalizing problems.

As reviewed above, gender differences are often found, in late childhood and adolescence—boys tend to be higher in externalizing whereas girls tend to be higher in internalizing; and gender has been shown to interact with RSA to predict these outcomes. Therefore, gender was examined as a moderator in each of the planned analyses. However, because there is no clear pattern in previous findings and because these differences in gender might be due to several factors outside the scope of the present study such as the nature of the sample (clinical vs. community); gender differences in the behaviors of interest (e.g., exuberance and externalizing); differences in emotion regulation at both cognitive and physiological levels; the way behaviors are interpreted for each gender by raters; to name a few, no specific hypotheses were made regarding gender differences.

METHODS

Participants

The data used for the current study was gathered as part of a larger longitudinal study of toddlers' temperament designed to investigate socioemotional development and adjustment from 24 months to school entry. Participants were drawn from a small Northeastern city and

surrounding communities via mailings sent to parents identified by local birth records. Interested parents filled out screening questionnaires characterizing their children's emotionality when children were 20 months ($N=485$).

Participants were oversampled for fearful children from 20-month screening questionnaires, which consisted of the Infant-Toddler Social and Emotional Assessment (ITSEA; Carter, Briggs-Gowan, Jones & Little, 2003) and a six-item wariness questionnaire asking parents about their child's fearfulness to common novel situations (e.g. meeting a mascot). Children were characterized as fearful if they scored one SD above the mean on either questionnaire, resulting in 63 fearful children and 62 unselected ($n=125$) for the first laboratory assessment at 24 months. The ethnicity of the selected sample consisted of 90% Caucasian, 1% African American, 1% Hispanic, 5% Asian American, 2% American Indian, 1% Mixed/Other. Most of the sample was middle class (Hollingshead Index: $M=49.72$, $SD=10.72$, $range=21-66$) with 52% of the families having an income above \$60,000, and 39% between \$31,000 and \$60,000. For the 42-month assessment, 36 additional children screened as exuberant (by using the ITSEA at 20 months) were added (note that there were already six children who meet the exuberant criteria in the 24-month assessment) for a total of 42 exuberant children. This resulted in 124 children (71% longitudinal) for the 42-month laboratory visit. For the last laboratory visit (age 5–6), 100 families participated.

Procedure

Laboratory Visit at 24 Months—Before the laboratory visit, parents were mailed a packet containing a consent form and several questionnaires. Upon arrival to the lab, parents were given a detailed description of the various laboratory activities their child would be asked to engage in. Parents had the opportunity to ask questions, and then consented to participate in the study. The mailed questionnaires were then collected and another set of questionnaires was provided. During this visit, toddlers and their parents (mostly mothers) participated in one neutral baseline task and six affective challenge tasks designed to elicit an emotional response. All tasks were videotaped for later scoring and psychophysiological data was collected during these tasks. These activities were modeled after the Laboratory Temperament Assessment Battery (Lab-TAB; Buss & Goldsmith, 2000). All episodes took place in one experimental room with a one-way mirror, which allowed videotaping of the episodes. Parents were with their toddlers during the entire visit, however, they were asked to remain as uninvolved in the tasks as possible unless they thought their toddler needed to be soothed (e.g. high distress). Families were compensated \$40 for their participation, and the child was given a small toy.

Episodes—During *Baseline* the child sat quietly for 5 min, while coloring a book or reading a book with the experimenter. In *Stranger Working*, a female experimenter entered the room where the child was already playing and sat at a desk in the corner, ignoring the child as she pretended to work. In the *Clown* episode, a different female experimenter dressed as a clown entered the room and invited the child to play with a variety of toys (e.g., bubbles, beach balls, musical instruments). For the *Puppet Show* episode, the same female experimenter as in the clown episode acted out a puppet show from behind a puppet theatre, inviting the child to interact with the puppets. In the *Stranger Approach* episode, a male

experimenter came into the room and verbally interacted with the child for 1.5 min. The remaining two episodes exposed the child to novel objects controlled by remote control from the control room. In the *Robot* episode, a one-foot-tall remote control robot moved and made noises randomly on a wooden platform in the corner of the room. In the *Spider* episode, a large stuffed animal spider (placed on top of a remote control car) was driven toward the child and then withdrew to the opposite corner of the room.

Laboratory Visit at 42 Months—The procedure prior to and at the arrival to the laboratory was similar in design to the procedure of the laboratory visit at 24-months. During this visit, children and their parents (mostly mothers) participated in one baseline, one episode, and the child participated in two episodes on his/her own. Two tasks were designed to be emotionally challenging and one task was designed to be a cognitive challenge. All episodes took place in the same experimental room as described above. Families were able to observe the child from the control room and were able to get involved in case the child needed it (e.g. high distress). Families were compensated \$25 for their participation, and the child was given a small toy.

Episodes—*Baseline* was the same as previously described. *Pop-Up Snakes* was divided in two parts. During the first part (Pop-Up Child), the experimenter surprised the child with a pop-out snakes toy. The snakes jumped out of a can of beans, which the experimenter was “attempting” to open. In the second part (Pop-Up Parent), the child was told to surprise the parent by having the parent open the can of beans. *Disappointment Task* (DT) was divided into three parts. In the first part (DT Wait), the child was told that he/she was going to receive a gift, but the child had to wait for 30 s on his/her own before receiving it. In the second part (DT Wrong), the experimenter gave the child the wrong gift. After receiving the wrong gift, in the third part (DT Resolve), the mother interacted with the child for 60 s and the child was then allowed to switch gifts and obtain the correct one. Because each section of the previously described tasks (e.g., DT Wait and DT Wrong) is aimed to elicit a different emotion, each of the sections of the previous episodes was treated as a separate episode from this point forward. In the *Clinical Evaluation of Language Fundamentals* (CELF), the child completed the second edition of this validated verbal assessment (Semel, Wiig, & Scord, 1986).

Measures

Parent Report of Temperament—Parents reported on their infants ($N=485$; $Mean_{age}=20.1$ months; $SD_{age}=1.3$) socioemotional behaviors by using the Infant-Toddler Social and Emotional Assessment (Carter et al., 2003). The ITSEA is a validated measure of socioemotional problems and competencies composed of 169 items, which are gathered in 20 scales. These scales reflect four broad domains of behavior (Externalizing, Internalizing, Dysregulation, and Competencies). In this measure, the primary caregiver reported on the child’s behavior in a 3-point-scale ranging from 0 (Not true/rarely) to 2 (Very true/often). Five scales were selected as indices of temperament (Activity, Impulsivity, Inhibition to Novelty, Sensory Sensitivity, and Attention) as they are believed to reflect emotionality and not competence or maladaptive behaviors. Sample items of the scales include statements like “is restless and cannot stand still” (Activity $\alpha=.71$), “gets hurt so often you cannot take your

eyes off him/her” (Impulsivity $\alpha=.51$), “takes a while to feel comfortable in new places” (Inhibition to Novelty $\alpha=.74$), “plays with toys for more than 5 minutes” (Attention $\alpha=.69$), or “is bothered by loud noises or bright lights” (Sensory Sensitivity $\alpha=.50$). Even though some of these alphas were low, they are comparable to previous reports using this measure (e.g., Carter et al., 2003).

Parent Report of Socioemotional Outcomes—In the fall of kindergarten entry ($N=107$; $\text{Mean}_{\text{age}}=67.9$ months; $\text{SD}_{\text{age}}=4.1$), parents reported on the child’s adjustment to kindergarten by using the MacArthur Health Behavior Questionnaire (HBQ; Armstrong, Goldstein, & the MacArthur Working Group on Outcome Assessment, 2003). This measure is designed to measure the physical and mental health and functioning of children (4–8 years-old). The HBQ parent version contains 172 items and the teacher version 115 items. These items are grouped into four domains: Emotion and Behavioral Symptoms, Physical Health, School Adjustment, and Social Adjustment. In the HBQ, the reporter responds in a dichotomous (“yes” or “no”) or 3-point Likert scale of 0 (“never or not true”), 1 (“sometimes or somewhat true”), and 2 (“often or very true”). The current study used the Externalizing Symptoms (31 items), and Attention-Deficit/Hyperactivity Disorder (ADHD) Symptoms (15 items) scales for the evaluation of externalizing behaviors. For assessing internalizing behaviors, the Internalizing Symptoms scale (29 items) was used. All of the variables were transformed by taking the square root because they did not have a normal distribution. All of the scales used in the study belong to the Emotion and Behavioral Symptoms domain. Sample items from these scales are “has difficulty awaiting turn in games and groups” or “defiant, talk back to adults” (Externalizing/ADHD Scale $\alpha=.92$), and “worries about things in the future” (Internalizing Scale $\alpha=.81$).

Physiological Data—Measures of the physiological (cardiac and respiratory) data were collected with the use of Mindware WiFi ACQ software, Version 1.0 (Mindware Technologies, Ltd, Westerville, OH) during baseline and the previously described tasks. The collected RSA data was analyzed offline. To accomplish this, the ECG signal was sampled at a rate of 500 ms and bandpass filtered at 40 and 250 Hz. The Mindware editing program Mindware HRV, Version 2.51 identified interbeat-intervals (IBIs) and detected physiologically improbable intervals based on the overall distribution using a validated algorithm (Berntson, Quigley, Jang, & Boysen, 1990). All data were visually inspected for artifact identification and editing. Using the Mindware HRV program, data were detrended using a first-order polynomial to remove the mean and any linear trends, cosine tapered, and submitted to fast Fourier transform (FFT). RSA was operationalized as the natural log integral of the .24 to 1.04 Hz power band and calculated in 30-second epochs. For baseline and each task, the mean RSA was calculated by averaging across 30-second epochs. In order to calculate RSA reactivity (change from baseline), the obtained baseline-average was subtracted from each of the obtained task-averages, providing a difference score for each episode. Even though this way of assessing reactivity does not control for initial levels of baseline, it was chosen because it is more easily interpretable.

The same procedure was used for the acquisition and analysis of data at the 42-month visit.

Analytic Strategy

Missing Data—All participants had a temperament score. Hence, only RSA and internalizing and externalizing scores had missing data. The patterns of missing data did not violate the assumption that the data was missing completely at random (Little's MCAR test, $\chi^2 [10]=80.272, p=.207$). However, given the recruiting procedures used in this study (recall that participants for the 24-month visit were oversampled fearful children and at the 42-month visit, a group of exuberant children was added), children with RSA data for the 24-month visit were more temperamentally fearful at 20 months than children that did not have RSA data for that visit ($t(152)=3.02, p=.003$). The rest of the missing data did not relate to any of the variables used in this study (all t 's $<1.71, p$'s >0.05). Missing data was handled with multiple imputation in SPSS (Version 21) by generating 10 datasets.

Regression Analysis—All statistical analyses were performed in SPSS (Version 21). In order to test the main set of hypotheses, the relation between exuberant temperament and externalizing problems and its moderation by physiological regulation, a set of hierarchical regressions was completed. To evaluate the role of RSA as a moderator, interaction terms were created by centering to the mean the continuous variables and then calculating their cross products. Because two different time points were used (24- and 42-months), there were several interaction terms. In order to avoid a large number of predictors in each model and given that RSA reactivity scores at both ages were highly correlated ($r=.62, p < .05$) separate regressions were done for each time point (24- and 42-months), yielding a total of four models. For the first regression model (24-month RSA), the variables were entered in the following order: (step 1) gender and exuberance, (step 2) RSA baseline and the rest of the interactions terms (e.g., Exuberance $\times$ 24m-RSA, Exuberance $\times$ Gender, etc), (step 3) the three-way interaction (Exuberance $\times$ 24m-RSA $\times$ Gender). For the second regression, the same procedure was used, substituting the 42-month RSA and its interactions with the exuberance factor and gender for the 24-month RSA. The third and fourth models were the same but including RSA reactivity instead of baseline.

In order to test the second set of hypotheses, the relation between fearful temperament and internalizing problems and its moderation by physiological regulation, the same set of regressions were tested but with fearful temperament predicting internalizing problems.¹

RESULTS

Data Reduction

Temperament—In order to obtain temperamental dimensions, a principal component analysis with orthogonal rotation (Varimax) was performed using the five ITSEA scales previously mentioned. All of the screened children (children $N=485$) were used in this analysis in order to avoid selection bias. A two-factor solution fit the data best. The first factor had an eigenvalue of 1.9 (37%) and the second 1.2 (23%). The Activity and

¹It is worth noting that the same pattern of results holds when doing the analyses without imputing data (listwise deletion), when using different data imputation method (Expectation Maximization), when using a different estimate of RSA reactivity (average reactivity rather than factor scores), and while controlling for the patterns of missingness in the regressions—increasing the confidence in our findings.

Impulsivity scales loaded positively into the first factor with loading of 0.85 and 0.75, respectively. The Attention scale loaded negatively into the first factor with a loading of -0.062 . Previous research on exuberant temperament (e.g., Fox et al., 2001) found similar characteristics; hence, this factor was labeled Exuberance and factors scores were created from this factor. The scales of Inhibition to Novelty and Sensory Sensitivity loaded positively onto the second factor with loadings of 0.82 and 0.71, respectively. Consistent with the literature previously reviewed (Buss, 2011; Kagan & Fox, 2006), this factor was labeled Fear and factor scores were created for this factor.

RSA Reactivity—In order to obtain latent variables for each time point when RSA was collected, a principal component analysis was performed on the six difference scores. This was done at each time point separately. This way, the shared variance in RSA reactivity across all different tasks for each occasion was estimated in order to identify the underlying factor. For 24-months, all six change scores loaded into one factor (eigenvalue of 3.9; 65.4% of variance explained). This factor was called RSA-24m. For 42-months, all six difference scores loaded into one factor (eigenvalue of 3.1; 52.1% of variance explained). This factor was called RSA-42m. The factor obtained at each age was used to estimate factors scores.

Descriptive Statistics and Bivariate Relations

Descriptive statistics for all key variables are shown in Table 1. The exuberance temperament factor was positively associated with externalizing symptoms, $r(152)=.38$, $p=.001$, as well as with RSA-42m, $r(152)=.18$, $p=.029$, meaning that as children were reported as more exuberant they tended to show more RSA augmentation at 42 months. The fearful temperament factor was positively associated with internalizing symptoms, $r(152)=.18$, $p=.025$. RSA reactivity was not associated with internalizing or externalizing. RSA baseline at 24 months was positively related to RSA baseline at 42 months, $r(152)=.31$, $p=.001$, and negatively associated with RSA-24m, $r(152)=-.49$, $p=.001$, and RSA-42m, $r(152)=-0.26$, $p=.001$, indicating that children with a higher baseline tended to suppress more. Similarly, RSA baseline at 42 months was negative related to RSA-42m, $r(152)=-.26$, $p=.001$. RSA reactivity was related across time, $r(152)=.62$, $p=.001$.

Regression Analyses—The results from the hierarchical regressions used to test the main hypotheses are shown in Tables 2 and 3. The first hypothesis expected exuberance to predict externalizing behaviors and that this relation would be moderated by the two RSA time points—children high in the exuberant factor and with adaptive physiological regulation (high RSA baseline and RSA suppression) would be less likely to develop externalizing symptoms than children with comparable levels in the exuberant factor but with less-adaptive physiological regulation (low RSA baseline and RSA augmentation). For the second hypothesis, it was predicted that fear would predict internalizing problems and that this relation would be moderated by the two RSA time points—children high in the fearful factor and with adaptive physiological regulation (high RSA baseline and RSA suppression) would be less likely to develop internalizing symptoms than children with comparable levels in the fearful factor but with non-adaptive physiological regulation (low RSA baseline and RSA augmentation).

Predicting Externalizing with Exuberance and 24m-RSA Baseline—Externalizing was predicted by the three-way interaction between exuberance, RSA baseline, and gender, $\beta=0.32$, $p=0.011$. This interaction (and all of the following) was probed using the simple slope procedure suggested by Aiken and West (1991). Specifically, the levels of externalizing according to the level in exuberance are compared at high (i.e., 1 *SD* above the mean) and low (i.e., 1 *SD* below the mean) levels of 24m-RSA baseline for boys and girls separately. This procedure demonstrated that the two-way interaction between exuberance and RSA was significant for girls, $t=2.8$, $p=.005$. As illustrated in Figure 1A, exuberance was predictive of externalizing behaviors only at high levels of RSA baseline ($b=.13$, $p=.001$), but not for low levels of baseline ($b=.02$, $p=.431$). As depicted in Figure 2A, this interaction was not significant for boys, $t=-.9$, $p=.349$.

Predicting Externalizing with Exuberance and RSA-24m—For this model, the three-way interaction between exuberance, RSA-24m, and gender was significant, $\beta=-.26$, $p=.027$. The two-way interaction between exuberance and RSA-24m was significant for girls ($t=-2.7$, $p=.008$), but only marginally significant for boys ($t=1.9$, $p=.055$). As illustrated in Figure 1B, exuberance was predictive of externalizing behaviors only when girls suppressed RSA ($b=.14$, $p=.001$), and not when they augmented ($b=.03$, $p=.205$). Even though for boys the interaction was only marginally significant ($p=.055$), the opposite was true—as shown in Figure 2B—exuberance was predictive of externalizing when children augmented RSA ($b=.09$, $p=.001$), but not for boys who suppressed ($b=.03$, $p=.117$).

Predicting Externalizing with Exuberance and 42m-RSA Baseline—The only significant predictor of externalizing at this age was exuberance, $\beta=0.30$, $p=0.007$, having no significant interactions in the model.

Predicting Externalizing with Exuberance and RSA-42m—At this age, only exuberance was a significant predictor, $\beta=.32$, $p=.010$. However, the three-way interaction was marginally significant, $\beta=-.18$, $p=.105$. In probing this interaction, in the same way as with RSA-24m, the two-way interaction between exuberance and RSA-42m was significant only for girls ($t=-2.1$, $p=.041$)—exuberance was only predictive of externalizing behaviors at RSA suppression ($b=.12$, $p=.001$), and not RSA augmentation ($b=.03$, $p=.263$).

Predicting Internalizing—Even though fearful temperament was predictive of later internalizing, $\beta=.18$, $p=.024$, none of the regression models reached significance as none of the RSA variables, second level interactions, and third order interactions were statistically significant.

DISCUSSION

The purpose of the present study was to examine the relation between factors of infant temperament and externalizing and internalizing behaviors at kindergarten entry, as well as the potential moderation of these longitudinal relations by RSA baseline and RSA reactivity. As expected, and consistent with the previous literature, the findings indicate that temperament is a significant predictor of socioemotional outcomes, but that this link can be moderated by gender and RSA.

Exuberance, RSA, and Gender Predict Externalizing

It was hypothesized that exuberance would be predictive of externalizing behaviors. This hypothesis was supported by the results showing that the exuberance factor was a strong predictor of externalizing problems. This result is in line with previous literature (e.g., Putnam & Stifter, 2005; Stifter et al., 2008; Tackett, Martel, & Kushner, 2012 for a review), which links the exuberant temperament with externalizing behaviors. However, this relation was moderated by the child's gender, RSA baseline at 24-months, and RSA reactivity at 24- and 42-months of age. The temperament by 24m-RSA baseline interaction was significant only for girls, such that girls with high baseline and high exuberance had more externalizing problems. Similarly, the temperament by 24m-RSA reactivity interaction was only significant for girls, such that RSA suppression and high exuberance predicted more externalizing symptoms. In contrast, for girls who displayed RSA augmentation, the relation between exuberance and externalizing was not present. Importantly, an identical pattern emerged when using RSA at 42-months. However, in this model, the three-way interaction was only marginally significant. On the other hand, when probing the gender by exuberance by 24m-RSA reactivity interaction for boys a different pattern emerged. Even though this two-way interaction was only marginally significant, RSA augmentation acted as a risk factor and high RSA reactivity buffered the exuberance-externalizing relation. Comparable results were recently found by Hinnant & El-Sheikh (2013), who observed that girls with RSA suppression were more likely to be in a profile characterized by high externalizing and high internalizing symptoms across three different time points; whereas boys were more likely to be in the profile if they displayed low RSA reactivity/RSA augmentation (Hinnant & El-Sheikh, 2013). In addition, similar gender differences were observed in Obradovi et al. (2010), in which high RSA reactivity was related to positive outcomes for boys, but for girls, low RSA reactivity was related to the same positive outcomes.

These findings are contrary to previous reports, in which high RSA baseline and RSA suppression served as protective factors in the context of environmental risk factors (e.g., El-Sheikh, 2001; El-Sheikh et al., 2001; Katz et al., 2007). However, they are consistent with other literature that finds that high RSA baseline (Conradt et al., 2013; Kidwell & Barnett, 2007) and RSA augmentation may buffer environmental risk for externalizing and internalizing problems (e.g., Cipriano et al., 2011; Cipriano, Skowron, & Gatzke-Kopp, 2011; Keller et al., 2014; Obradovi et al., 2010; Obradovi et al., 2011). Nevertheless, it is difficult to interpret the present results in this manner because we assessed another kind of risk (temperament) and the environment was not considered in these analyses—an important future direction.

In further support for these differences, parallel findings with RSA baseline by Eisenberg et al. (1995) have been previously discussed. These findings suggest important gender differences in the process of physiological regulation used to cope with the cognitive and emotional challenges as the ones used in the current study. Following Hinnant and El-Sheikh (2013) interpretation of their findings, for girls, showing high RSA reactivity during these tasks was maladaptive, suggesting that strong parasympathetic suppression in response to a stressful situation was associated with more externalizing problems when a temperamental predisposition was already present—possibly indicating overarousal or

dysregulation towards stressors as suggested by an excessive physiological response, which has been related with a sympathetic (flight–fight) response (Beauchaine, 2001). On the other hand, for boys showing a lack of physiological response predicted externalizing problems at high levels of exuberance possibly signifies a lack of engagement with the challenge via lack of active allocation of attentional resources and emotional engagement, which are important in academic and socioemotional competence. To our knowledge, no previous research has addressed the cause for these differences. Potential causes include, but are not limited to: differences in how boys and girls interpret and cope with stressful situations; biases in parents' interpretation of their children's behavior, which may lead them to rate differently boys and girls behavioral problems; RSA reactivity as a regulatory process acts differently in boys and girls; or differences in fetal programming as prenatal stress seems to differentially impact children based on gender, leading girls to increased suppression and boys to heightened augmentation (Tibu et al., 2014). Nevertheless, these findings highlight the importance of considering the role of gender when examining RSA reactivity and its relations to other predictors of psychopathology and socioemotional adaptation.

Fear Predicts Internalizing

It was hypothesized that the fearful temperament factor would predict internalizing behaviors. The results showed that the fearful factor was the sole predictor of internalizing problems. This result supports a large corpus of literature, which shows that fearful temperament is one of the best predictors of later internalizing symptoms (e.g., Buss, 2011; Chronis-Tuscano et al., 2009; Pérez-Edgar & Fox, 2005; Klein, Dyson, Kujawa, & Kotov, 2012 for reviews). However, the regression models including RSA and the interaction of RSA with fearful temperament did not reach significance. A potential explanation for the lack of interactions with RSA to predict internalizing is that physiological regulation might not be as salient of a predictor for internalizing as it is for externalizing.

Although deficits in self-regulation are likely related to both externalizing and internalizing behaviors, the specific aspects of self-regulation may be different between externalizing and internalizing.

RSA Measurement and Stability

The similarity in the results at 24 and 42 months in RSA reactivity is not surprising given that, in this study, RSA reactivity showed high stability ($r=0.62$). Findings on the stability of RSA has been mixed in previous literature, especially RSA reactivity. We suggest that the method by which RSA reactivity was estimated may be important to consider. By creating latent variables of RSA reactivity across several different tasks, the RSA reactivity factor score in the current study represented a more global/trait-like measure of reactivity. Most studies in the literature rely on a reactivity score from just one task, thus, assessing stability across development may be more difficult given that a task of equivalent emotional valence and magnitude is needed at two or more developmental time-points. The latent approach is not as affected by this problem given that it is more trait-like measure of children's physiological regulation. Initial analyses support that the latent method is consistent with a trait approach (Morales, Beekman, Davis, & Buss, 2012). This measure of RSA reactivity was related to parental reports of temperament, whereas using the score of just one task

related to the observed behaviors during that task, but not to temperament reports. This implies that the single task RSA reactivity is an indicator of behavior during that specific situation and context, but not necessarily of trait-like reactivity (Morales et al., 2012). Consequently, when conceptualizing physiological reactivity, it is not only important to note the kind of task that is being used to elicit physiological reactivity (Obradovi et al., 2011), but also take special consideration on the way that reactivity is being estimated (Obradovi & Burt, 2012).

Limitations

It is important to consider the findings and interpretations of this study in light of its limitations. The first limitation is that both the predictor (temperament) and the outcome (internalizing and externalizing) were based on maternal reports. An important future direction will be to corroborate the interpretations offered by using the behavioral observations gathered during the tasks used to elicit the physiological response. In addition, exploring other potential mediators or moderators of these longitudinal associations would be of interest as well. Such mediators or moderators could be environmental or psychological factors (e.g., marital conflict; El-Sheikh & Hinnant, 2011) as well as measures that index other physiological systems (e.g., cortisol; El-Sheikh et al., 2011) that have been documented to impact the outcomes of interest as well as physiological reactivity itself, generating more complex interactions.

A second limitation is that this study used composites of externalizing and internalizing problems as outcomes, blurring potential interesting disorder-specific associations with temperament and physiological reactivity. These more specific associations would be of particular interest for forthcoming investigations in an attempt to better explain the comorbidity found in this and other studies when even using these broader composites of symptoms. Moreover, the measures of externalizing and internalizing were not done with a clinical instrument; hence, externalizing and internalizing are discussed as behaviors rather than symptoms. Even though the discussion of the present results was framed towards psychopathology, the results can also be interpreted as temperament continuity/personality development.

Another important limitation to consider is the relatively small sample size, which might impact the power to detect some of the complex interactions explored in this study. In addition, there was missing data due to attrition and the design of the study. However, the present study used the best-known method, multiple imputation, for dealing with missing data (Graham, 2009). Moreover, these analyses were performed in several ways (not shown in this study) such as using temperament groups instead of a continuous measure, using residualized change scores for RSA reactivity, or imputing missing data via different methods yielding the same general findings; together with the similar results recently found by other research groups, gives the authors confidence regarding the main results of this study. A significant shortcoming of this study is the lack of diversity in the sample used, which limits the generalization of the findings to other populations. Future studies should test if similar results are present in other ethnicities and cultures. Finally, this study uses a relatively early window in the development of socioemotional outcomes. Prospective

longitudinal studies are needed in order to test if these results extend to the developmental stages where the emergence of externalizing and internalizing behaviors are more prevalent.

CONCLUSION

This study provides several interesting findings. First, it is support for the large corpus of evidence showing a strong relation between early temperament and socioemotional problems. Second, the relation between temperament and externalizing problems can be moderated by physiological measures believed to index self-regulation processes. However, it was also observed that these processes might act in a different manner in boys and girls, highlighting the importance of exploring the contributions of gender in forthcoming investigations. With these findings, we hope to encourage future investigations to test similar longitudinal relations in order to increase our knowledge of the complex interplay between infant temperament and physiological indices of self-regulation across development to better understand socioemotional disorders.

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FIGURE 1.

Externalizing symptoms as a function of the exuberant factor and RSA baseline (A) and RSA reactivity (B) at 24-months for girls only. Low RSA baseline/RSA suppression is defined as 1 *SD* below the mean and high RSA baseline/augmentation as 1 *SD* above the mean.

FIGURE 2.

Externalizing symptoms as a function of the exuberant factor and RSA baseline (A) and RSA reactivity (B) at 24-months for boys only. Low RSA baseline/RSA suppression is defined as 1 *SD* below the mean and high RSA baseline/augmentation as 1 *SD* above the mean. The interaction above is not significant (A). The interaction below is marginally significant (B).

Table 1

Means Standard Deviations, and Intercorrelations of the Factors Scores for Exuberance and Fearful Factors, Gender, RSA Reactivity at 24- and 42-Months, Externalizing, and Internalizing

Variable	Mean	SD	1	2	3	4	5	6	7	8
1 Gender	**	**	–							
2 Exuberance	.05	1.02	–.12	–						
3 Fear	.00	1.09	.09	–.11	–					
4 RSA BL 24m	4.46	.87	.07	.02	.02	–				
5 RSA BL 42m	5.38	.79	.03	–.03	.01	.31*	–			
6 RSA 24m	.00	.56	.05	–.02	.10	–.49*	–.15	–		
7 RSA 42m	.00	.50	.01	.18*	.01	–.26*	–.26*	.62*	–	
8 Externalizing	.50	.19	–.10	.38*	.01	.07	.06	–.01	.02	–
9 Internalizing	.43	.16	–.02	.00	.18*	–.08	–.06	–.10	–.06	.39*

SD, standard deviation; R, reactivity; BL, baseline. The mean RSA was zero because they are factor scores. However, using an averaged composite measure of RSA reactivity, we find at 24 months marginal RSA suppression ($t(88)=-1.734, p=.086$; Meandifference=–.138) and at 42 months significant RSA augmentation ($t(84)=7.478, p<.001$; Meandifference=.447).

* Bolded= $p<.05$.

** Gender=78 boys and 76 girls. Boys coded as 0 and girls as 1.

Table 2

Summary of Two Hierarchical Regressions of Gender, Exuberance, RSA at 24-months, and their Interactions on Externalizing

Model	Variable	R ²	R	B	S.E. β	β	p
24-months RSA Baseline							
1	Gender	.134*	.145*	-.019	.028	-.051	.499
	Exuberance			.068	.014	.371	.001
2	Gender	.149	.037	-.03	.029	-.081	.288
	Exuberance			.056	.02	.305	.006
	RSA			-.013	.024	-.06	.587
	Gender $\times$ Exuberance			.019	.028	.074	.499
	Gender $\times$ RSA			.042	.033	.142	.205
	Exuberance $\times$ RSA			.033	.015	.163	.033
3	Gender	.180*	.035*	-.03	.028	-.079	.29
	Exuberance			.054	.02	.296	.007
	RSA			-.005	.024	-.024	.83
	Gender $\times$ Exuberance			.02	.028	.077	.471
	Gender $\times$ RSA			.038	.033	.127	.25
	Exuberance $\times$ RSA			-.02	.025	-.101	.429
	Gender $\times$ RSA $\times$ Exuberance			.081	.031	.324	.011
24-month RSA reactivity							
2	Gender	.113	.006	-.026	.030	-.069	.381
	Exuberance			.054	.021	.291	.012
	RSA			.030	.046	.084	.518
	Gender $\times$ Exuberance			.026	.029	.102	.376
	Gender $\times$ RSA			-.023	.059	-.049	.691
	Exuberance $\times$ RSA			-.012	.025	-.040	.634
3	Gender	.137*	.028*	-.028	.029	-.075	.340
	Exuberance			.062	.021	.336	.004
	RSA			-.007	.048	-.020	.885
	Gender $\times$ Exuberance			.023	.029	.089	.432
	Gender $\times$ RSA			.007	.059	.014	.908
	Exuberance $\times$ RSA			.050	.037	.167	.183
	Gender $\times$ RSA $\times$ Exuberance			-.113	.050	-.263	.027

* Indicate significant steps. Bolded= $p < .05$. The values presented for RSA reactivity are controlling for RSA baseline in order to control for initial status.

Table 3

Summary of Two Hierarchical Regressions of Gender, Exuberance, RSA at 42-months, and their Interactions on Externalizing

Model	Variable	R ²	R	B	S.E. β	β	p
42-month RSA baseline							
1	Gender	.125*	.145*	-.019	.028	-.051	.499
	Exuberance			.068	.014	.371	.001
2	Gender	.131	.02	-.021	.029	-.057	.457
	Exuberance			.056	.02	.306	.007
	RSA			.001	.022	.006	.948
	Gender $\times$ Exuberance			.021	.028	.081	.463
	Gender $\times$ RSA			.052	.04	.123	.193
	Exuberance $\times$ RSA			.002	.019	.008	.917
3	Gender	.126	.00	-.021	.029	-.057	.457
	Exuberance			.056	.021	.304	.007
	RSA			.001	.023	.003	.974
	Gender $\times$ Exuberance			.021	.028	.082	.457
	Gender $\times$ RSA			.051	.04	.122	.198
	Exuberance $\times$ RSA			-.001	.024	-.004	.964
	Gender $\times$ RSA $\times$ Exuberance			.009	.041	.021	.82
42-month RSA Reactivity							
2	Gender	0.123	0.012	-.023	.029	-.062	.426
	Exuberance			.054	.021	.293	.012
	RSA			.026	.046	.057	.576
	Gender $\times$ Exuberance			.026	.029	.102	.366
	Gender $\times$ RSA			-.084	.071	-.118	.236
	Exuberance $\times$ RSA			-.02	.32	-.05	.949
3	Gender	.133	.015	-.016	.029	-.042	.585
	Exuberance			.056	.021	.302	.009
	RSA			.018	.046	.040	.696
	Gender $\times$ exuberance			.025	.029	.096	.390
	Gender $\times$ RSA			-.091	.071	-.128	.200
	Exuberance $\times$ RSA			.049	.045	.118	.275
	Gender $\times$ RSA $\times$ Exuberance			-.105	.064	-.176	.105

* Indicate significant steps. Bolded= $p < .05$. The values presented for RSA reactivity are controlling for RSA baseline in order to control for initial status.