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Early Physiological Regulation Predicts the Trajectory of Externalizing Behaviors across the Preschool Period

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Abstract

Early assessments of children's physiological functioning are shown to predict subsequent developmental outcomes. However, individual changes that occur in the development of physiological systems may be associated with the pattern of change in behavior across time. Thus, we examined change in respiratory sinus arrhythmia (RSA), an index of physiological regulation, as a time-varying predictor in order to assess whether RSA change at ages 3, 4, and 5 uniquely influenced the trajectory of externalizing behaviors from age 3 to age 5. Results indicated that only at age 3 was RSA change significantly associated with decreases in externalizing behaviors over time. RSA change scores at ages 4 and 5 were unrelated to trajectories of externalizing behavior, suggesting that the ability to physiologically regulate by age 3 may contribute to the development of skills that facilitate more control over behavior throughout preschool, and therefore may be more strongly associated with the pattern of change in externalizing behaviors than later physiological regulation.

Keywords

externalizing behaviors; vagal tone; RSA; physiology; preschool

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Biopsychosocial developmental perspectives theorize that maturation of different biological processes provide the platform for behavior we observe as children mature (Lewis & Todd, 2007), and the mastery of early regulatory processes may constrain the development of subsequent skills (Calkins, 2010; Calkins, 2011). Thus, the majority of previous research examining the association between physiological regulation and externalizing behaviors has tested either concurrent correlations or a single early assessment of the change in respiratory sinus arrhythmia (RSA) (i.e., an index of physiological regulation) in response to challenge as a predictor of later behavior problems (e.g., Calkins, Blandon, Williford, & Keane, 2007; Calkins & Keane, 2004). However, although theoretically speculated, research to date has

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not empirically examined whether physiological regulation at a single early time point is in fact more strongly associated with the normative declines in externalizing behavior than physiological regulation at subsequent ages. Physiological systems mature across early childhood (e.g., Bornstein & Suess; Calkins & Keane, 2004; Porges & Furman, 2011), and only mild to moderate stability in RSA change across childhood has been reported (Calkins & Keane, 2004; Feldman, 2009). Therefore, it is possible that children's ability to physiologically regulate at each year during the preschool period is associated with the pattern of decline in externalizing behaviors. Thus, we sought to gain a better understanding of *when* children's ability to physiologically regulate has the strongest association with change in externalizing behaviors by examining whether RSA change at age 3, age 4, and age 5 were unique predictors of the trajectory of externalizing behaviors across the preschool period.

Early externalizing behaviors, characterized by aggressive, destructive, and oppositional acts, can predict more serious behavioral and adjustment problems (Campbell, 1991) and are linked to difficulties in social competence and academic functioning (Campbell, 2002; Moffitt, 1993). Research examining the trajectory of externalizing behaviors in early childhood demonstrates that children's externalizing symptoms decrease with age (for a review see Gilliom & Shaw, 2004) such that most children's externalizing behaviors peak at age 2 and decline throughout early childhood (Tremblay, 2000). However, for a small subset of children, externalizing behaviors continue to persist from preschool into middle childhood, leading to more serious maladaptive outcomes and hindering children's adaptive functioning (Campbell, 2002; Moffitt & Caspi, 2001).

It is likely that increased maturation of language abilities that allow children to express their emotions, and increased behavioral regulation that allows for the control of emotion is associated with greater declines in externalizing type behaviors across early childhood. And indeed, the inability to emotionally regulate is both theoretically and empirically linked to the display of children's externalizing behaviors (Gilliom & Shaw, 2004; Keenan & Shaw, 2003; Hill, Degnan, Calkins, & Keane, 2006; Mendez, Fantuzzo, & Cicchetti, 2002). Importantly, theories of emotion regulation assert that individual differences in children's ability to modulate emotional expressions and experiences are at least partially dependent on physiological regulation of emotion (Rothbart, 2011). Thus, physiological responding to emotionally-charged contexts is associated with the display and development of externalizing behaviors across childhood (Calkins & Keane, 2004).

Given the importance of emotion regulation in children's adaptive functioning, biological markers associated with emotional control are of great interest to developmental scientists. Much empirical work investigating biological markers associated with emotion regulation highlights the role of the parasympathetic branch of the autonomic nervous system (PNS) as important in the development of biobehavioral regulation processes (Calkins, 2007, Porges, 2007, Graziano & Derefinko, 2013). One of the most influential theories identifying the maturation of the PNS as a key contributor to the physiological regulation of emotion is Porges' polyvagal theory (Porges, Doussard-Roosevelt, Portales, & Suess, 1994; Porges 2003). Porges posited that the vagus nerve serves as a vagal brake that can inhibit or disinhibit influences on the heart, thereby mobilizing or calming an individual (Porges, Doussard-Roosevelt, Portales & Greenspan, 1996). During situations that do not present a challenge, the vagus exerts an inhibitory influence on the heart and limits sympathetic influence; subsequently slowing heart rate and producing a relaxed state (Porges, 1995). During times of challenge, the vagal brake is withdrawn to support an increase in heart rate and active coping to environmental challenges.

Respiratory sinus arrhythmia, a component of heart rate variability, is a measure of the functional output of vagal pathways on the heart (Graziano & Derefinko, 2013). Researchers often assess RSA during a resting period and in response to emotional challenge in order to obtain a measure of RSA change. RSA change, as indexed by a decrease in RSA in relation to a resting measurement, is a measure of physiological regulation that is thought to be related to better emotion regulation in that it plays a role in children's ability to transition from maintaining homoeostasis to activating internal resources to cope with challenging situations (Calkins & Keane, 2004; Porges, 2001, 2003; Porges, 1996). Although the direction of effects between physiological regulation and externalizing behaviors is not always clear, and there are likely reciprocal relations between these two constructs over time, a common theoretical assumption is that children who do not show decreases in RSA in response to emotional challenge may be less physiologically equipped to attend to the environment and generate effective and socially appropriate coping strategies (Porges et al, 1996).

Empirical work assessing the association between externalizing behaviors and RSA is quite complex and findings are inconsistent across clinical and normative samples. Studies of older children with clinical levels of internalizing and externalizing problems consistently find children with behavior problems to display excessive RSA change during emotionally-charged contexts (e.g., Beauchaine, Katkin, Strassberg, & Snarr, 2001; Boyce et al., 2001; Crowell et al., 2005). Pang & Beauchaine (2013), for example, found that children displaying both conduct disorder and depression had the greatest RSA change in response to emotion evocation compared to non-clinical controls. In contrast, empirical research conducted with non-clinical populations often demonstrates greater RSA change to be associated with fewer externalizing behaviors and greater social competence in early childhood. For example, in a longitudinal study of preschoolers, Calkins and Keane (2004) found that RSA change during a challenging task at age 2 was negatively related to externalizing behaviors at age 4.5. Further, children who displayed higher degrees of change in response to challenge at both 2 and 4.5 years-old were rated by their mothers to be more socially skilled and less likely to display externalizing behaviors than children who displayed consistently low RSA change at both age 2 and age 4.5. Similarly, a study conducted with 2 year-olds indicated that children who displayed symptoms of aggressive and destructive behavior displayed significantly lower RSA change during challenge than children who displayed few aggressive and destructive symptoms (Calkins & Dedmon, 2000). And Calkins et al. (2007), found 5 year-old children at risk for externalizing problems displayed lower RSA change than a control group.

Although the relation between RSA change and externalizing behaviors is well-established in early childhood and in normative samples, the relation between RSA change and the trajectory of externalizing behaviors during early childhood is investigated far less frequently. To our knowledge there is only one study that has addressed this relation within the preschool period. Utilizing a single early measure of RSA change, Calkins, Blandon, Williford, and Keane (2007) found that RSA change at age 2 influenced externalizing trajectories from age 2 to age 5. Due to methodological constraints, Calkins and colleagues (2007) could only speak to the way in which a single early assessment of RSA change in toddlerhood predicted changes in externalizing behavior and could not examine whether children's ability to physiologically regulate at subsequent ages within the preschool period continued to influence the trajectory of children's externalizing behaviors across preschool. Therefore, the current study is advantageous in that it accounts for change in physiological regulation from year to year and examines which time point during the preschool years is most strongly associated with the trajectory of externalizing problems over time.

The Current Study

The primary aim of the current study was to examine if RSA change at ages 3, 4, and 5 relates to the trajectory of externalizing behaviors from age 3 to age 5. Examining RSA change at each year across the preschool period allows for temporal variation and extends the current literature beyond using a single early predictor. Although some scientists theorize that early physiological functioning may play an important role in the development of later adaptive functioning, assessing multiple time points of RSA change across preschool to identify when physiological regulation is most strongly related to the trajectory of externalizing behaviors, and whether early physiological regulation is indeed more predictive of children's behavior than later physiological regulation, has important developmental implications.

Because the relation between RSA change and externalizing behaviors has not been examined in this way, the hypotheses are somewhat exploratory. As previously stated, RSA change is only low to moderately stable across the preschool period and is thought to influence individuals' ability to control their emotions and behavior (Perry et al., 2011; Porges, 2001). Therefore, it is possible that changes in physiological regulation that occur from year to year are associated with decreases in externalizing behaviors. That is, RSA change at age 3, age 4, and age 5 may each be related to the decline in externalizing behaviors during this developmental time period. In contrast, even after considering RSA change at age 4 and age 5, greater physiological regulation at the beginning of the preschool period (i.e., age 3) may be more strongly associated to externalizing trajectories, suggesting that early physiological regulation may be more influential to the decline in externalizing behaviors across early childhood.

METHOD

Participants

The participants in this project were part of a longitudinal study of early cognitive and emotional precursors to school success. Children were recruited from child care centers and preschools in a mid-sized Southeastern city. Families were enrolled in the study when children were 3 years old and participated in additional laboratory visits when children were 4 and 5 years of age. Two custodial grandmothers were included as mothers in the present study. Fifty-two percent of the children were female, 58% were European American, and 35% were African American. Income-to-needs ratios were calculated such that a score of below 2 was indicative of low-income, a score between 2 and 5 was indicative of middle-income, and a score greater than 5 was indicative of high-income. Average family income-to-needs ratio was 2.89 at age 3, 2.86 at age 4, and 2.76 at age 5. Of the 263 families who participated at age 3, 244 families had data available at the 4-year visit, and 228 had available data at the 5-year visit (87% retention rate). There were no significant differences by child sex or family income-to-needs ratio (total family income divided by the poverty threshold for a particular family size) between families who did and did not have data available at age 4 or 5. Families lost to attrition were more likely to be ethnic minority (χ^2 [1, N=263] = 3.89, $p < .05$).

Procedure

The laboratory visits lasted approximately two hours. Mothers provided written consent, completed questionnaires about the child's behavior, and engaged in a parent-child interaction task during the sessions. Children were videotaped while engaging in multiple tasks, either with an experimenter or with their mothers. Approximately 30 min into the visits, children were asked to wear heart rate electrode stickers and children who complied wore the electrodes for close to an hour while they completed cognitively and emotionally challenging tasks. Families received $40 for the 3-year visit, $60 for the 4-year visit, and $80 for the 5-year visit. Children selected a toy at the end of each visit in appreciation of their participation.

Measures

Demographics—Mothers completed a demographic questionnaire including child sex and ethnicity, maternal age, parents' marital status, and family income. Updated demographic information was obtained at each year's visit.

Externalizing Behaviors—At each assessment point, mothers reported on children's externalizing behaviors with the Child Behavior Checklist (CBCL; Achenbach, 1991). The CBCL includes 118 items that index how well a range of problem behaviors describe the child currently or within the last six months (0 = *not true*, 1 = *somewhat or sometimes true*, 2 = *very true or often true*). The Cross-Informant Program for the CBCL/4–18, purchased from the Child Behavior Checklist, University Medical Education Associates, Inc., was used to score the raw data. The raw externalizing behavior scores, an average of 33 aggression and delinquency items, were used in the analyses; higher scores indicate more aggressive and delinquent child behaviors. We elected to use raw scores because age-related change would be dampened with the use of standard scores, which are normed for child age and sex. The items used to create this variable were internally consistent (Cronbach's alpha of .86, .87, and .89 for years 3, 4, and 5 respectively). Between 5% and 10% of children at each time point had externalizing behaviors in the clinical range, and many more (31 to 37%) displayed high, albeit subclinical, levels of problem behaviors (*T*-scores greater than 50).

Respiratory Sinus Arrhythmia—Electrocardiograms (EKG) were recorded during a baseline procedure, in which children watched an emotionally neutral 5 min video, and during frustration tasks (described below). Two disposable pediatric electrodes were placed on the child. One electrode was placed on the left side under the collarbone just above the heart. The other electrode was placed on the right side near the ribs, creating a path across the heart. The electrodes were then connected to a preamplifier, the output of which was processed through a vagal tone monitor (Series 2000 Mini-Logger, Mini Mitter Co., Inc. Bend, OR) for R-wave detection. The sampling rate the utilized in the current study was 1000 Hz, which has been found to be adequate when analyzing data of healthy populations (Grossman, van Beek, & Wientjes, 1990; Riniolo & Porges, 1997). To derive baseline RSA and RSA change, interbeat interval (IBI) files were edited and analyzed using MXEDIT software (Delta Biometrics, Inc). Editing the files consisted of examining for outlier points and dividing or summing them so that they would be consistent with the surrounding data. For example, when a single artifact IBI was a multiple of the surrounding data values, it was corrected by division (e.g. dividing by 2 or 3 or more). Similarly, if the artifact points were two or more short IBIs they were added to reconstruct the original IBI value. Data files that required editing of more than 10% of the data were not included in the analyses.

Estimates of RSA were calculated using Porges' (1985) method of analyzing IBI data. This method applies an algorithm to the sequential heart period data. The algorithm uses a moving 21-point polynomial to de-trend periodicities in heart period (HP) slower than RSA. A band-pass filter then extracts the variance of HP within the frequency band of spontaneous respiration (.24–1.04 Hz) in young children. Although lower frequency bands may be studied, research with young children has consistently examined this band and identified associations with child functioning (Huffman et al., 1998; Stifter & Fox, 1990). RSA was calculated in 30 s epochs and averaged across epochs to obtain RSA scores for the baseline and the frustration tasks. This epoch duration is typical for studies of short-duration tasks (Calkins & Keane, 2004; Doussard-Roosevelt et al., 2003; Huffman et al., 1998). RSA change was calculated by subtracting RSA during the frustration tasks from baseline RSA so that positive values indicated greater RSA change.

Frustration tasks—At the 3-year, 4-year, and 5-year visits children participated in the Impossibly Perfect Green Circles laboratory task adapted from Goldsmith and Reilly (1993). During the Green Circles task, children were given a sheet of white paper and a green marker. In a neutral tone, an experimenter repeatedly (for 3.5 min) asked the child to draw a perfect green circle and gently criticized previous circles drawn. Critiques did not provide the child with enough information to fix the problem, but they were specific (e.g., too small or too bumpy). When the task was over the children received positive comments and the experimenter told the child that the last circle was perfect in an attempt to bring the child back to baseline.

At the 3-year and 5-year visits, children participated in the Attractive Toy in a Locked Box task ("Locked Box"). The child was seated at a small table and offered a choice of two highly desirable toys to play with. After the child made a selection, the toy was placed in a transparent box that was locked with a padlock. The experimenter supplied the child with a large ring of keys, none of which were the correct key, and instructed the child to find the right key to open the box in order to play with the toy. The experimenter then left the room for 3 min while the child attempted to open the box. When the experimenter re-entered the room, he/she presented the correct key to the child and allowed the child to open the box and play with the toy for 1 min to encourage a return to baseline.

At the 4-year visit only, children participated in the Frustrating Puzzles Task. The child was seated at a small table and given a wooden toy with many holes. The toy had a string laced through the holes; however, the middle of the string was glued to the inside of the toy, thus making it impossible to untangle completely. The experimenter asked the child to untangle the toy while the experimenter left the room for 3 min. Finally, the experimenter re-entered the room and presented a second unglued puzzle to the child and allowed the child to unlace the string and solve the puzzle.

Pearson correlations between the RSA change scores in the two tasks at ages 3, 4, and 5 were .60, .59, and .61, respectively (all *p*s < .001), all considered large effects according to Cohen (1988). RSA change scores for the frustration tasks were averaged to create a composite at each age.

RESULTS

Analysis Plan

Previous literature informed our selection of covariates. Research has demonstrated that child sex and family income are relevant demographic factors for children's externalizing behaviors (e.g., Sanson, Oberklaid, Pedlow, & Prior, 1991) and physiological regulation (e.g., Anderson, McNeilly, & Myers, 1993; Quas, Hong, Alkon, & Boyce, 2000). Thus, we included family income as a time-varying covariate and child sex as a time-invariant covariate. Because baseline RSA is thought to impact the magnitude of RSA change during challenge such that higher baseline levels allow for greater decreases in RSA (Graziano & Derefinko, 2013), baseline RSA was also included as a time-varying covariate. In order to utilize all available information in the dataset without excluding participants with partial data, we used full information maximum likelihood (FIML) in the current analyses. FIML is an effective modeling method that estimates parameters based on available and implied values (Schlomer, Bauman, & Card, 2010).

The analyses proceeded in a series of steps. First, we conducted preliminary analyses to examine correlations between study variables. Second, we examined trajectories of children's externalizing problem behavior over the preschool years using latent growth modeling and identified the pattern of growth in the sample. Third, we tested a time-varying covariate growth model, a common model that has been used extensively in research on developmental processes (see Grimm, 2007, for a methodological explanation). In addition to the controls, we added RSA change at ages 3, 4, and 5 as a time-varying covariate in this growth model to test at which time points RSA change was associated with children's initial externalizing problems at age 3 (the intercept) and the rate of change in externalizing behaviors across the preschool period (the slope). Figure 1 displays the analytic growth model with a time-varying predictor. According to Bollen and Curran (2006), the predictor should be associated with the dependent variable at each year to account for time effects, and repeated measures of the same variable are correlated.

Preliminary Analyses

We conducted preliminary analyses to examine descriptive information for and correlations between study variables (shown in Table 1). Measures of externalizing behaviors were highly correlated at each time point; measures of RSA change were moderately correlated only at adjacent waves; and externalizing behaviors and RSA change were uncorrelated. A repeated-measures ANOVA with a Greenhouse-Geisser correction, $\varepsilon = .93$, revealed that the externalizing means at age 3 ($M = 7.92$, $SD = 5.27$), age 4 ($M = 6.99$, $SD = 4.34$), and age 5 ($M = 6.84$, $SD = 5.04$) years were significantly different from one another, $F(1.86, 418.53) = 6.51$, $p = .002$.

Trajectory Analyses

Before RSA change could be assessed as a time-varying predictor of the trajectory of externalizing behaviors, the nature of change in externalizing behaviors needed to be identified. Thus, we examined trajectories of children's externalizing problem behavior at ages 3, 4, and 5. We tested three growth models using Mplus v6 (Muthén & Muthén, 2012): an intercept only model, a linear model, and a nonlinear latent basis model (Grimm, 2007). The intercept only model tests no significant change with slope coefficients set to 0. In the linear model, slope coefficients are fixed linearly, and consistent change from age 3 to 4 and age 4 to 5 is modeled. In the latent basis model, slope coefficients for the first and last time points are fixed to 0 and 1, and the middle time point is freely estimated; this allows for a variety of nonlinear developmental patterns (Grimm, 2007). We tested a nonlinear model in place of a quadratic model because only three waves of data were available in the current study; at least four waves would have been needed to test quadratic change (Bollen & Curran, 2006). Given that the intercept only model, the linear model, and the nonlinear latent basis model are nested, we used a chi-square difference test to determine which model fit the data best. Fit statistics are presented in Table 2.

The latent basis model revealed that three-fourths of the decline in externalizing behaviors from age 3 to 5 occurred between age 3 and 4, $b = .76$, $p < .01$; this model fit significantly better than the level-only model, which assumes no change in externalizing scores across time, $\chi^2_D(3) = 29.21$, $p < .01$, and the linear change model, which assumes consistent changes from one time point to the next, $\chi^2_D(1) = 8.49$, $p < .01$. Together, these findings indicated that children's externalizing behaviors decreased substantially during the first half of the preschool years, and then continued to decrease at a slower rate during the second half of the preschool period. The latent basis growth model indicated that there was a significant mean decrease in children's externalizing behaviors, $b = -1.06$, $p < .01$, significant variation in children's initial externalizing behaviors at age 3, $b = 21.35$, $p < .01$, and significant variation in how children's behavior changed over time, $b = 8.81$, $p < .01$. There was also a significant correlation between the intercept and the slope, $r = -.46$, $p < .01$, indicating that children with higher initial externalizing behavior problems experienced slower declines over time.

RSA Change and Children's Trajectories

Controlling for child sex, family income, and baseline RSA, we examined RSA change as a time-varying predictor of children's externalizing behavior scores using the latent change model (see Table 3). Only the 3-year RSA change score was included as a predictor of the intercept; RSA change at ages 3, 4, and 5 were included in predicting the slope. The model had excellent fit to the data, χ^2 (18) = 22.29, p = .22, RMSEA = .03 [90% C.I. = .00, .07], CFI = .99. RSA change was not associated with initial levels of externalizing behaviors at the start of preschool; however, greater RSA change at age 3 was significantly associated with decreases in externalizing problem behavior over time, $b = -.53$, $\beta = -.25$, $p = .037$, after controlling for sex, family income, and baseline RSA. Children's RSA change scores at ages 4 and 5 were unrelated to trajectories of externalizing behavior.

DISCUSSION

Research demonstrates that changes in the PNS occur across childhood (e.g., Bornstein & Suess, 2000), but previous empirical work investigating physiological regulation as a predictor of externalizing behaviors utilized only an early measure of RSA change to predict the trajectory of behavior problems and did not account for the possibility that RSA change at later ages may also be associated with change in externalizing behaviors over time (Calkins et al., 2007). A primary strength of the current study is that we have extended this work and examined how children's RSA change at age 3, age 4, and age 5 are each associated with the pattern of change in externalizing behaviors across the preschool period. Results indicated that greater RSA change at age 3 was significantly associated with decreases in externalizing behaviors from age 3 to age 5. However, children's RSA change scores at age 4 and age 5 were unrelated to externalizing trajectories. Although these findings are in accordance with previous theoretical and empirical work and indicate that physiological regulation plays an important role in the trajectory of behavior problems across preschool (e.g., Calkins, 2011; Calkins et al. 2007; Lewis & Todd, 2007), this is the first study to empirically account for multiple assessments of RSA change and show the greater significance of early physiological regulation in relation to subsequent measures.

The importance of early physiological regulation has significant developmental implications. The current findings highlight the beginning of preschool as a critical time period for children to be physiologically well-regulated and suggest that greater RSA change by age 3 may be associated with a more adaptive externalizing trajectory. RSA change in response to emotion-eliciting contexts is thought to be related to emotion regulation in that it plays a role in the activation of biological resources that allow children to attend to environmental contexts and generate responses to environmental challenge that are both socially appropriate and effective at reducing arousal and returning an individual to a calm resting state. Therefore, early physiological regulation at the start of preschool may give children a physiological advantage that allows them to learn more efficiently, gain and respond to more information from their environment, engage in more positive social interactions, develop attentional, cognitive, and behavioral regulation, thus resulting in greater emotional competence, social skills, and behavioral regulatory abilities at an earlier age (Calkins, 1997; Calkins & Keane, 2004). Developing more advanced social, emotional, and cognitive skills at the beginning of preschool may then allow children to transition to school with less frustration and develop better relationships with teachers and peers, thus influencing decreases in externalizing behaviors over time. The nature of our data does not allow us to directly assess this possibility. Future work, however, assessing bi-directional and transactional associations among RSA and these developmental constructs, may provide additional insight into the importance of timing in developmental models. Moreover, it is possible that children become better behavioral and emotional regulators, and subsequently begin to rely less on physiological regulation, specifically because earlier physiological skills have influenced the developmental patterns of social and emotional competencies. Thus, future research should examine the way in which early physiological regulation is associated with changes in social and emotional skills across early childhood, and the way in which trajectories of these social and emotional skills co-vary with children's externalizing trajectories.

Interestingly, RSA change did not show concurrent associations with externalizing behaviors at ages 3, 4, or 5 in the current study. RSA change during frustration is theoretically linked to externalizing behaviors through children's ability to manage affective reactivity, and previous empirical work utilizing both clinical and non-clinical samples supports the concurrent association between the two constructs in childhood (e.g., Beauchaine, Gatzke-Kopp, & Mead, 2007; Pang & Beauchaine, 2013). However, some empirical studies have not been able to find a significant association between RSA change during distress and externalizing behaviors (e.g., Fortunato, Gatzke-Kopp, & Ram, 2013). Given these mixed findings, further research is needed to better understand the relation between externalizing behaviors and RSA change. It is possible that change in RSA in a laboratory context is not always directly related to general reports of children's overall externalizing problems, but that the ability to physiologically regulate in response to frustration is related to the pattern of decrease in externalizing behaviors over time. These findings suggest an underlying developmental process and highlight the need for future research to continue to examine these relations concurrently and longitudinally.

Although the current study provided insight into the way in which RSA change across preschool predicts the trajectory of externalizing behaviors, it is not without limitations. The sample utilized was a community sample of typically-developing preschool children, and although we did find significant variation in how children's externalizing behaviors changed over time, most of the children did not display severe externalizing behaviors. Further, it has been well-documented that the association between RSA and behavior varies across clinical and non-clinical samples (e.g., Beauchaine et al., 2001) such that children with clinical levels of externalizing behaviors often display excessive RSA to emotional challenge. Thus, examining these relations in a more at-risk sample would provide information regarding the role RSA change among children who maintain high levels of problem behaviors, or even increase in these behaviors, into the school years. However, the aggressive and under-controlled behavior that characterizes even mild to moderate externalizing behaviors does not allow children to engage in appropriate social interactions or to perform well academically, both of which are crucial for continued adaptive functioning. Thus, understanding predictors of normative externalizing trajectories, rather than focusing exclusively on clinical-level trajectories, provides valuable information.

Prior research also indicates that the relation between physiological functioning and child adjustment may differ for children in particularly stressful environments (El-Sheikh et al., 2009). Thus, the current study is limited in that it cannot speak to the relation between changes in RSA and behavior problems for children exposed to specific adverse environmental conditions. In addition, we utilized maternal report as the sole source of information on children's externalizing behaviors. Although this measure provides insight into children's externalizing behaviors in a variety of situational contexts, future work should examine whether the relation between observed externalizing behaviors and RSA change is similar to the present findings. Finally, we did not have access to ages younger than three. It could be that if we had included RSA during infancy or toddlerhood, RSA change at age 3 would not have been a significant predictor of the decline in externalizing behaviors across preschool above and beyond the influence of earlier abilities; the ability to physiologically regulate even earlier than age 3 may have been more influential. More research is needed to extend this work and examine earlier ages in an attempt to gain additional insight into when children's physiological skills are most important for the change in developmental processes over time.

Examining the decline in externalizing behaviors in a normative sample and assessing the way in which RSA change at ages 3, 4, and 5 is associated with the decrease in externalizing behaviors across preschool both extends the current literature and allows for a greater understanding of when children's ability to physiologically regulate may be most important. Findings from the current study suggest that RSA change by age 3 may be a more important predictor of developmental trajectories than at later ages, thus highlighting the need to better understand factors that may increase young children's physiological capabilities.

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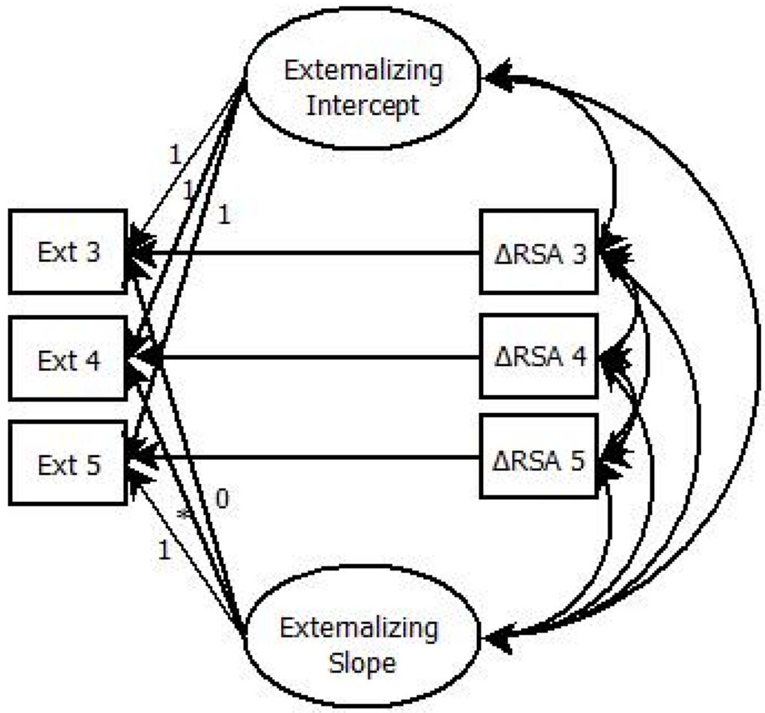

Figure 1.

Analytic growth curve model. The trajectory of externalizing behaviors ("Ext") across preschool is predicted by RSA change ("*ΔRSA*") as a time-varying predictor, controlling for child sex (time-invariant) and family income-to-needs ratio (time-varying).

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Table 1

Descriptive Information and Correlations for Study Variables.

	Descriptives				Correlations				
	M	*SD*	Range	Skew (*SE*)	2	3	4	5	6
1. 3yr Externalizing	7.92	5.27	0–28	1.05 (.15)	.65**	.61**	−.02	−.02	−.08
2. 4yr Externalizing	6.99	4.34	0–19	.54 (.16)		.73**	−.06	−.10	−.01
3. 5yr Externalizing	6.84	5.04	0–23	.93 (.16)			−.03	−.04	−.10
4. 3yr RSA change	.96	.69	−1.53–2.72	−.20 (.16)				.35**	.12
5. 4yr RSA change	1.07	.62	−.52–2.87	.01 (.17)					.20**
6. 5yr RSA change	.98	.62	−.63–3.05	.27 (.17)					

** $p < .01$.

Table 2

Model Fit and Model Comparisons.

Model	χ^2	*df*	$\Delta\chi2/\Delta df$	CFI	RMSEA
Level only, no change	46.47**	6	---	0.87	0.16
Linear change	17.26**	3	29.21(3)**	0.96	0.14
Latent basis, nonlinear change	8.77*	2	8.49(1)**	0.98	0.11

* $p < .05$.

** $p < .01$.

Table 3

RSA Change Predicting Children's Externalizing Trajectories

	B (SE B)
Intercept	
Mean	11.72 (1.60) **
Variance	22.10 (2.56) **
Child sex	.31 (.16)
Income-to-needs ratio 3 years	−.65 (1.02)
Baseline RSA 3 years	.97 (.59)
RSA change 3 years	.40 (.30)
Slope	
Mean	−.82 (.31) **
Variance	9.81 (2.35) **
Child sex	−.14 (.14)
Income-to-needs ratio 3 years	.48 (.53)
Income-to-needs ratio 4 years	−.18 (.51)
Income-to-needs ratio 5 years	.34 (.50)
Baseline RSA 3 years	−1.09 (.50) *
Baseline RSA 4 years	−.08 (.34)
Baseline RSA 5 years	.07 (.39)
RSA change 3 years	−.53 (.26) *
RSA change 4 years	−.11 (.20)
RSA change 5 years	.28 (.21)

* $p < .05$.

** $p < .01$.