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Differential Susceptibility and the Early Development of Aggression: Interactive Effects of Respiratory Sinus Arrhythmia and Environmental Quality

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Abstract

The purpose of the current study was to predict the development of aggressive behavior from young children's respiratory sinus arrhythmia (RSA) and environmental quality. In a longitudinal sample of 213 children, baseline RSA, RSA suppression in response to a film of crying babies, and a composite measure of environmental quality (incorporating socioeconomic status and marital adjustment) were measured, and parent-reported aggression was assessed from 18 to 54 months of age. Predictions based on biological sensitivity-to-context/differential susceptibility and diathesis-stress models, as well as potential moderation by child sex, were examined. The interaction of baseline RSA with environmental quality predicted the development (slope) and 54-month intercept of mothers' reports of aggression. For girls only, the interaction between baseline

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RSA and environmental quality predicted the 18-month intercept of fathers' reports. In general, significant negative relations between RSA and aggression were found primarily at high levels of environmental quality. In addition, we found a significant Sex $\times$ RSA interaction predicting the slope and 54-month intercept of fathers' reports of aggression, such that RSA was negatively related to aggression for boys but not for girls. Contrary to predictions, no significant main effects or interactions were found for RSA suppression. The results provide mixed but not full support for differential susceptibility theory and provide little support for the diathesis-stress model.

Keywords

respiratory sinus arrhythmia (RSA); vagal tone; aggression; socioeconomic status; differential susceptibility

Measures of environmental adversity, such as low socioeconomic status (SES) and marital distress, have been associated with children's aggression and other externalizing behaviors (Dodge, Pettit, & Bates, 1994; Keiley, Lofthouse, Bates, Dodge, & Pettit, 2003). A number of investigators have argued that the quality of the environment interacts with children's physiological reactivity in predicting children's socioemotional outcomes (Boyce & Ellis, 2005; El-Sheikh, 2001; Hastings, Sullivan, et al., 2008). However, predictions regarding the nature of such moderation differ somewhat. Most theorists have argued that reactive children tend to do especially poorly in high-risk settings. However, some theorists have suggested, based on differential susceptibility (DS) theory and the notion of biological sensitivity-to-context (BSC), that these same children are likely to thrive in supportive, low-risk contexts (Belsky & Pluess, 2009; Boyce & Ellis, 2005; Ellis, Boyce, Belsky, Bakermans-Kranenburg, & van IJzendoorn, 2011). From these perspectives, physiologically reactive children are more responsive than less reactive children to variations in the environment in ways that maximize their adaptation to variations in context. In the present study, we examined the developmental trajectories of children's mother-reported and father-reported aggression/defiance in a sample of children from 18 to 54 months of age, and we tested whether physiological measures of parasympathetic nervous system function moderated the relation between supportiveness of the environment and the development of aggression. We also examined sex as a moderator of the relations of physiological reactivity and environment quality with aggression because reduced autonomic function appears to play a different role in aggression for boys and girls (Beauchaine, Hong, & Marsh, 2008).

Conceptual Frameworks for Predicting Children's Adjustments to Their Environment

As previously noted, there are varying perspectives regarding the nature of interactions between demographic/familial environmental affordances and stressors (henceforth labeled *environmental quality*) and individual differences in physiological reactivity when predicting maladjustment. The diathesis-stress (Monroe & Simons, 1991; Zuckerman, 1999) framework suggests that some individuals—due to a “vulnerability” in their behavior/temperament, physiology or endophenotype (e.g., high physiological reactivity), or heredity—are disproportionately or even exclusively likely to be affected adversely by environmental stressors of most sorts. In contrast, according to the DS hypothesis (Belsky & Pluess, 2009; Ellis et al., 2011), individual differences in developmental plasticity (including reactivity) and, more generally, susceptibility to environmental influences result in some people being more affected than others by not only negative, but also positive, contexts. Similarly, according to Boyce and Ellis's (2005; Ellis et al., 2011) BSC hypothesis, stress reactivity is better conceptualized as high biological sensitivity to context (Boyce & Ellis, 2005). Thus, children with heightened biological sensitivity to context are viewed not only

as more vulnerable to stressful, unsupportive contexts but also as having a greater capacity to benefit from positive environments.

According to the DS and BSC perspectives (Belsky & Pluess, 2009; Ellis et al., 2011), individual differences in environmental susceptibility are viewed as evolutionarily *adaptive* and have been conserved by selection pressures that generated different fitness pay-offs across different social, physical, and historical contexts across human evolution. Ellis et al. (2011) further argued that people who are more susceptible (responsive) to context are more likely to experience sustained developmental changes in reaction to contextual factors. Boyce and Ellis (2005) suggested that “BSC increases adaptive competence in highly *stressful* environments by augmenting vigilance to threats and dangers” (p. 272). Thus, in unsupportive environments, it may be adaptive for children to act aggressively to control resources (i.e., to get what they want, get attention from others, overcome social obstacles). In contrast, in supportive environments, children may benefit most from acting in ways that are cooperative, positive, and garner support and social resources from others, including enacting less aggression. These adaptations are viewed as having adaptive advantages. Belsky, Steinberg, and Draper (1991) argued that the effects of an adverse versus supportive family ecology on children’s social behaviors and perceptions tend to be mediated through its effects on parenting, and that changes in children’s behavior due to the quality of the family environment affect the emergence of puberty and reproductive strategies.

Respiratory Sinus Arrhythmia (RSA)

The sympathetic nervous system supports fight/flight responding, whereas the parasympathetic nervous system has opposing effects and promotes rest and restorative behavior (Porges, 2007). Parasympathetic nervous system responding often is assessed using a cardiac measure of RSA, which refers to heart rate variability at the frequency of respiration. Resting RSA is generally considered an index of an individual’s self-regulatory capacity (Beauchaine, 2001; Porges, 2007). In addition to measuring baseline RSA, investigators often measure RSA suppression, which is the decrease (i.e., vagal withdrawal) or increase (i.e., vagal augmentation) in RSA in a given context.

RSA as an Index of Reactivity and/or Adaptation

Most of the research relevant to the DS/BSC perspective has involved measures of temperament, genetics, or autonomic nervous system responding (see Belsky & Pluess, 2009; Obradović, Bush, Stampferdahl, Adler, & Boyce, 2010). RSA responding sometimes has been examined as a moderator of risk (e.g., El-Sheikh, Harger, & Whitson, 2001; Obradović, Bush, & Boyce, 2011; Obradović et al., 2010). However, it is somewhat difficult to make predictions for these indices, as their relations with aggression have been mixed in pattern.

Porges (2007) conceptualizes high RSA as a “brake” on sympathetic nervous system activity that allows flexible responding to stress, active engagement, and coping with mild to moderate stressors. RSA suppression is generally considered a marker of reactivity to environmental demands (Belsky & Pluess, 2009; Obradović et al., 2011, 2010). Because RSA suppression clearly involves a change in physiological responding relative to baseline responding (i.e., a decrease in RSA) in response to environmental events, there is little debate that it is a measure of physiological reactivity.

It is less clear whether high or low baseline RSA is indicative of physiological reactivity. On the one hand, high baseline RSA has been conceptualized in terms of the general ability to modulate emotionality and amygdalae activity (Beauchaine, 2009), as facilitating flexible responding to stress (Porges, 2007), and as the ability to adapt to environmental challenges

(e.g., Thayer & Lane, 2000). In fact, there is some empirical support for the view that high baseline RSA reflects greater physiological reactivity as well as flexibility in responding. Gottman and Katz (2002) found that children high in baseline RSA had a greater heart rate increase in response to a stressful parenting environment and a faster recovery than children low in baseline RSA tone. In a review, Beauchaine (2001) argued that children less than 2 years of age who are high in baseline RSA are actively engaged with the environment—both emotionally and in terms of attention (Huffman et al., 1998; Richards, 1985, 1987), which may impact subsequent efforts to adapt to and shape the environment. (He also argued that they are more reactive in terms of negative emotion, but the data are somewhat equivocal, albeit more consistent with the reactivity argument than not; see Buss, Goldsmith, & Davidson, 2005; Reznick et al., 1986; Stifter & Fox, 1990; Stifter & Jain, 1996.) High baseline RSA also has been associated with better adaptation to preschool (Fox & Field, 1989), attention regulation and executive functioning in 5-year-olds and school-age children (Feldman, 2009; Staton, El-Sheikh, & Buckhalt, 2009; Suess, Porges, & Plude, 1994), and executive functioning in 3.5-year-olds (Marcovitch et al., 2010; contrast with Hastings, Nuselovici, et al., 2008) and in adulthood (Hansen, Johnsen, Sollers, Stenvik, & Thayer, 2004; Hansen, Johnsen, & Thayer, 2003); these skills are useful in adapting to diverse contexts. Moreover, high baseline RSA individuals appear to be high in positive emotionality (Beauchaine, 2001; Kagan & Fox, 2006; Oveis et al., 2009), which may reflect emotional reactivity. In addition, degree of variability in baseline heart rate—a characteristic of high baseline RSA—and/or RSA has been positively related to bold, approach behavior and has been negatively related to behavioral inhibition, characterized by high emotional reactivity to novelty (Kagan, Reznick, & Snidman, 1988; see Kagan & Fox, 2006) and lack of social inhibition (Henderson, Marshall, Fox, & Rubin, 2004). Thus, there are some reasons to view high baseline RSA as an index of flexibility in responding to the environment and physiological reactivity. Even clearer, it appears that children with high baseline RSA adapt better than other children in some contexts and have better developmental outcomes. Thus, children with high baseline RSA may do better than children with low baseline RSA in low-risk contexts where their physiological regulatory skills are adequate, but may not differ from children with low baseline RSA in high-risk contexts (e.g., when their ability to adapt is overwhelmed by environmental stress).

However, there are stronger reasons to believe that low baseline RSA reflects reactivity. Baseline RSA has been negatively related to negative emotional reactivity (Beauchaine, 2001; Fabes & Eisenberg, 1997; Kagan & Fox, 2006; Rottenberg, 2007) and motor/affective reactivity in infancy (Kagan & Fox, 2006), especially after early infancy (Stifter & Fox, 1990), and temperamental negative reactivity has been viewed by some as an indicator of susceptibility to the environment (Belsky & Pluess, 2009).

Consequently, it is not entirely clear whether children with low or high baseline RSA should be considered as more reactive to the environments. If negative emotional reactivity is a central component of environmental reactivity (Belsky & Pluess, 2009), then one might expect children with low baseline RSA to be more reactive to the environment. Regardless of the valence of the relation, baseline RSA has been examined as a moderator of environmental stressors (e.g., El-Sheikh, 2005; El-Sheikh et al., 2001; Gottman & Katz, 2002; Hinnant & El-Sheikh, 2009) and has been conceptually and sometimes empirically linked to other indices of reactivity (e.g., negative emotionality); thus, it is informative to examine its role in moderating children's reactions to their environments.

Empirical Relations Between RSA and Aggression or Externalizing Behavior

Several researchers have examined the relations between baseline RSA or RSA suppression and children's externalizing or aggression. According to the BSC perspective, one would not

expect a very consistent pattern of direct relations because the relation of RSA to externalizing behavior varies considerably as a function of environmental risk.

Baseline RSA—In fact, the pattern of direct relations between baseline RSA and children's aggression or externalizing behavior is inconsistent. Researchers have tended to find attenuated resting RSA in youths with clinical levels of externalizing compared to non-disordered children or when externalizing behaviors were examined in a sample at risk for such behavior (e.g., Beauchaine, Gatzke-Kopp, & Mead, 2007; Beauchaine et al., 2008; Beauchaine, Katkin, Strassberg, & Snarr, 2001; El-Sheikh et al., 2001; El-Sheikh, Hinnant, & Erath, 2011). In contrast, baseline RSA has been positively related to externalizing behavior in nonclinical, community samples (e.g., Dietrich et al., 2007), and no relations have been found in some samples of younger children (Beauchaine et al., 2007; Boyce et al., 2001; Calkins, Graziano, & Keane, 2007; Hastings, Nuselovici, et al., 2008). The pattern of relations for young children has not been consistent. For example, in a sample of 2-year-olds, half of whom were selected for high externalizing, boys (but not girls) high in externalizing were low in baseline RSA (Calkins & Dedmon, 2000). In contrast, in a study of children followed from 2 to 5 years of age (apparently including some of the same children as Calkins & Dedmon, 2000), baseline RSA was unrelated to initial levels of parent-reported externalizing behavior, but lower baseline RSA was related to a decline in such problems (Calkins, Bandon, Williford, & Keane, 2007).

Some investigators have tested interactions between baseline RSA and environmental risk or stress when predicting externalizing behavior or aggression. In a sample of children 2 to 5 years of age, the interaction between baseline RSA and a sociodemographic/parenting risk index was not a significant predictor of externalizing (Calkins, Bandon, et al., 2007). Similarly, the interaction between baseline RSA and harsh parenting did not predict externalizing in a sample of inner-city first through fourth graders (Bubier, Drabick, & Breiner, 2009), although power to detect such an interaction was low in this study. In contrast, interactions have been found in some studies of older children. In a sample of children 8 to 12 years of age, the relation between marital conflict and externalizing was positive for children low in baseline RSA but not for those high in baseline RSA (El-Sheikh et al., 2001). Similarly, El-Sheikh (2005) found that parental drinking was positively related to externalizing (for mothers' drinking) as well as change in externalizing (for either parent's drinking) for elementary school children (followed-up 2 years later) who were low, but not high, in baseline RSA. These latter studies support the view that relatively high baseline RSA is protective for school-age children in stressful contexts. Moreover, in both of these studies with older children, the low baseline RSA group was more reactive to a stressful context, but it was unclear whether the differences were significant at both very high and very low levels of stress.

Children's sex may also be a factor moderating relations between baseline RSA and aggression. Many of the studies documenting a negative relation between baseline RSA and externalizing have been limited to male participants (Beauchaine et al., 2007; Mezzacappa et al., 1997; Pine et al., 1998). For samples including both sexes, moderation has sometimes been observed, with negative relations between baseline RSA and externalizing for boys but with null relations for girls (Beauchaine et al., 2008; Calkins & Dedmon, 2000). Sex generally has not been found to moderate the interaction between baseline RSA and environmental risk (El-Sheikh, 2005), but such interactions have not been examined frequently, especially in studies of young children.

RSA suppression—The pattern of relations between externalizing behavior/aggression and RSA suppression is more consistent than for baseline RSA. Investigators frequently have found a negative relation between RSA suppression and preschoolers' or older

children's externalizing, especially in normative samples (Boyce et al., 2001; Calkins, Bandon, et al., 2007; Calkins & Dedmon, 2000; Calkins & Keane, 2004; El-Sheikh et al., 2001; Graziano, Keane, & Calkins, 2007). However, some researchers have observed for the relation for boys but not girls (e.g., Graziano et al., 2007), and others have found no direct relation between school-age children and adolescents' externalizing and RSA suppression (El-Sheikh et al., 2009). Moreover, high RSA suppression has been found for 5-year-olds with combined internalizing and externalizing behavior (but not just the latter; Calkins, Graziano, & Keane, 2007).

Measures of environmental support have been found to interact with RSA suppression when predicting externalizing, although the pattern has not been very consistent. Obradović et al. (2010) found a stronger positive relation between family risk and externalizing behavior for 5- to 6-year-olds with high, in comparison to low, RSA suppression; children with high RSA suppression were especially low in externalizing in low-risk conditions (externalizing was about the same in a high-risk context). Degnan, Calkins, Keane, and Hill-Soderlund (2008) obtained a somewhat similar pattern for 2- to 5-year-olds when the risk factor was quality of maternal parenting; the interaction might have been due to pre-schoolers with lower RSA suppression being less affected by parenting than those with high suppression (Hastings, Sullivan, et al., 2008). In other studies, however, the relation between familial risk and externalizing was found to become more positive for school-age children with low RSA suppression, whereas high RSA suppression was associated with no change in externalizing as a function of risk (El-Sheikh, 2001; El-Sheikh et al., 2001; Katz, 2007). Moreover, others have found little evidence of an interaction between risk and RSA suppression when predicting externalizing (Bubier et al., 2009; Calkins, Bandon, et al., 2007).

Because the environmental risks and age of participants have varied across studies and the critical interactions often have not been examined in sufficient detail, it is difficult to know the reasons for the discrepancies in findings. However, it appears that type of task used to assess RSA suppression may be critical. Obradović et al. (2011) found that marital conflict was positively related to externalizing behavior for kindergartners who showed low RSA reactivity (suppression) to a social stimulus (a film of a child being bullied), whereas marital conflict was positively associated with externalizing only for children with elevated RSA reactivity to a cognitive task. They argued that high physiological reactivity to an interpersonal stressor may buffer children exposed to marital conflict because of the associated physiological hyper-arousal, which inhibits aggression. They further hypothesized that reactivity to a noninterpersonal, cognitive stressor better reflects biological attentiveness and susceptibility to contextual factors than reactivity to an emotional stressor (also see Hastings, Nuselovici, et al., 2008).

The Present Investigation

We examined baseline RSA and RSA suppression as moderators of the relation between environmental quality and children's aggression from 18 to 54 months of age. We predicted an interaction between environmental quality and RSA (baseline and suppression) when predicting aggression above and beyond any main effects of environmental quality and RSA variables, although based on prior research, it was difficult to make predictions with confidence, especially for baseline RSA. Nonetheless, based on DS/BSC notions and the limited relevant research, we predicted that low baseline RSA and high RSA suppression would be positively related to aggression for children in nonsupportive environments and would be negatively related for children in supportive contexts.

This study has several other features that distinguish it from other investigations. First, the measures of RSA were collected at 18 months, which is earlier than most other studies.

There is some reason to believe that relations between RSA and aggression may increase with age (Beauchaine et al., 2007). It is also possible that RSA responding, as well as quality of the sociodemographic and familial environment, has an effect on the young child's adaptation to his or her environment; thus, it makes sense to examine these predictors at a relatively young age.

A second strength of this study is that aggression was reported by mothers and fathers. Maternal and paternal reports of aggression are typically correlated. However, recent behavioral genetic research with thousands of families demonstrates that maternal and paternal ratings differ systematically—a result most likely attributable to children behaving differently with their mothers and fathers (Derks, Hudziak, Beijsterveldt, Dolan, & Boomsma, 2004). By examining the relations of measures of RSA to maternal and paternal ratings of aggression, our study contributes to the elucidation of differential expressions of aggression and the roots of these expressions in the interactions of stress and physiology.

Finally, a number of the studies of family adversity and stress reactivity have not examined prediction across more than 2 years, and few have examined growth trajectories of aggression (but see Calkins, Blandon, et al., 2007; Degnan et al., 2008; El-Sheikh et al., 2011). Our outcome measures were the slope (pattern of change) for aggression from 18 to 54 months of age as well as the intercepts for aggression at 18 and 54 months of age (the start and end points of the study). Thus, we could assess whether the interaction of RSA with environmental quality predicted the pattern of change in aggression, the initial level of aggression at 18 months, and its level 3 years later. Finally, unlike some studies, we also tested whether sex moderated the effects of RSA, environmental quality, and their interaction on children's aggression.

Method

Participants

Mothers and their infants were recruited shortly after birth at three hospitals in a large metropolitan area in the southwestern United States. To be considered for participation in the study, mothers had to (a) be 18 years of age or older, (b) be able to read English fluently, (c) and have infants who were born full term and without birth complications. Initially, 352 families provided consent for us to contact them about possible participation, and 276 families (78%) were both successfully contacted and agreed to participate by providing some questionnaires prior to the first laboratory visit (see Spinrad et al., 2007). Laboratory visits were conducted when the children were about 18 months of age (Time 1; mean age = 17.79 months, $SD = 0.52$; 137 boys, 110 girls), 30 months of age (Time 2; mean age = 29.77 months, $SD = 0.65$; 119 boys, 97 girls), 42 months of age (Time 3; mean age = 41.75 months, $SD = 0.65$; 104 boys, 88 girls), and 54 months of age (Time 4; mean age = 53.89 months, $SD = 0.80$; 89 boys, 79 girls). In addition, questionnaires were mailed to the parent(s) between laboratory visits at 24 and 48 months. About 95% of laboratory visits took place within 1 month of the target age; the longest difference between children's targeted age and the visit was 3.20 months.

At T1, 247 families participated in the first laboratory visit. Twenty children had unusable physiological data because they became distressed during the physiological monitoring; *t* tests were conducted to assess whether these children differed from the children whose distress did not interfere with the physiological recording. The groups did not differ in maternal education, income, or age at visit. An additional nine children had unusable physiological data for other reasons (e.g., equipment failure, artifact caused by poor electrode placement).

Demographic information is reported for the subset of the sample (88%; $n = 213$; 119 boys, 94 girls; mean age at T1 = 17.76 months, $SD = 0.48$) who had complete physiological data at the 18-month assessment. Annual family income was assessed on a 7-point scale, with 19 mothers (9%) not responding at 18 months. For 16 families (of the 19), missing data on income could be replaced by the income reported at the 12-month or 6-month visit. The median annual family income reported was \$45,000–\$60,000 ($M = 4.03$, $SD = 1.76$); 6% had an annual income under \$15,000 (1); 16% had an income between \$15,000 and \$30,000 (2); 19% had an income between \$30,000 and \$45,000 (3); 21% had an income between \$45,000 and \$60,000 (4); 14% had an income between \$60,000 and \$75,000 (5); 12% had an income between \$75,000 and \$100,000 (6); and 12% had an income above \$100,000 (7). One percent had missing data for income. Thus, the sample varied considerably from fairly poor or working class to upper middle class but was primarily working and middle class. The racial composition of the sample was 84% Caucasian; 6% African American; 5% Native American; 2% Asian; and 3% other, mixed, or unknown race. In terms of ethnicity, 23% of the sample reported Hispanic/Latino ethnicity. Data for educational attainment were missing for nine mothers and seven fathers at the 18-month visit; for all the mothers and all but one father, these values were replaced by educational attainment at recruitment. Education was rated on a 7-point scale. One percent of mothers did not attend high school (rated 1), 6% of mothers began but did not complete high school, 15% graduated high school, 33% attended some college, 36% graduated college, 8% had a master's degree, and 2% had a doctoral or professional degree (rated 7; $M = 4.28$, $SD = 1.11$). Thus, education varied considerably, although the sample as a whole was moderately well educated. Analogous figures for fathers were 1%, 8%, 16%, 35%, 26%, 10%, and 3% ($M = 4.20$, $SD = 1.21$). Sixteen mothers (8%) were single parents at the 18-month visit, and 10 mothers (5%) did not report whether they were single parents.

Measures

Physiological data—At the 18-month laboratory visit, RSA was monitored while the toddlers watched two films. Two electrodes were placed under children's armpits at chest level, and a ground electrode was placed on their back. A respiration bellows was placed around the abdominal area to record respiration. Electrocardiograph and respiration were recorded by a James Long Company five-channel Bioamp. Electrocardiograph data were analyzed with interbeat interval analysis software using the peak-to-valley method (James Long Company, 1999).

Toddlers were seated in a high chair with their mothers present during the films. If the child was distressed by the electrodes during the first portion of the film, a female experimenter blew bubbles to calm the child. The baseline section of the film (181 s) showed neutral and smiling babies with cheerful music, and the second part (42 s) depicted babies crying.

Visual inspection of the distributions of the physiological data revealed that two children's baseline measures of RSA and one child's measure of RSA during the crying baby film were outliers. These data points were recoded to be slightly greater than the largest non-outlier value (Tabachnik & Fidell, 2006); this change did not substantially affect the findings.

The baseline measure of RSA taken during the first portion of the film ($M = 0.02$ s, $SD = 0.01$) was highly correlated with RSA during the distressing portion of the film ($M = 0.03$ s, $SD = 0.02$), $r(211) = .75$, $p < .001$. Based on a simple difference score (baseline minus the distressing portion of the film), 25% exhibited suppression, 6% showed no change, and 69% exhibited augmentation. To remove overlap between baseline RSA and the RSA suppression scores, we computed a residualized change score (Calkins & Keane, 2004). Baseline RSA was regressed on the score for RSA during the distressing film portion; we multiplied the residual from this analysis by -1 to create a measure of RSA suppression that is orthogonal

to baseline RSA. Positive values for this residualized change score correspond to greater than expected declines from baseline (RSA suppression), and negative values correspond to greater than expected increases from baseline (RSA augmentation; Hastings, Sullivan, et al., 2008).

Marital adjustment—Mothers and fathers reported on their marital adjustment on the Marital Adjustment Test (Locke & Wallace, 1959) at 6, 12, and 18 months. The 15 items concern disagreements (e.g., “Select the response that best describes the extent of agreement or disagreement between you and your partner on the following items: Handling Finances, Recreation Matters, Demonstration of Affection, etc....”), happiness in the marriage, and similarities and differences. Items are scored and summed using a weighted system developed by Locke and Wallace (1959) and are averaged across time within reporter. Based on Locke and Wallace’s cutoff point of below 100 for problematic adjustment, 20% of mothers and 18% of fathers who completed the Marital Adjustment Test reported significant problems in marital adjustment. Not all Marital Adjustment Test items are on the same scale, so standardized alpha coefficients were used; α s ranged from .81 to .88 for mothers and fathers. Correlations across time ranged from .74 to .80 for mothers, and from .57 to .71 for fathers, $ps < .001$; thus, scores were averaged across time within reporter (M s = 117.09 and 119.02, SD s = 25.60 and 22.30, for mothers and fathers, respectively). Correlations between mother and father Marital Adjustment Test scores at each time point ranged from .48 to .56, $ps < .001$.

Environmental quality—A composite measure of environmental quality was constructed by standardizing and averaging (a) average mother and father education, (b) family income, and (c) the average mother and father Marital Adjustment Test score (α for three variables = .63). Measures of family finances and marital distress have been used as indices of environmental adversity in other research (e.g., Obradović et al., 2010).

Participants were required to have non-missing data on at least two of these measures (income, education, Marital Adjustment Test) to be included in our analysis; three were missing family income, and 12 were missing marital adjustment data. Average parental education ($M = 4.23$ on a 7-point scale prior to standardization; $SD = 1.05$) was correlated with family income, $r(210) = .61$, $p < .001$, and average marital adjustment scores ($M = 117.41$, $SD = 22.47$; 20% had scores of 100 or less) were correlated with parental education and family income, $r(201) = .27$, and $r(198) = .25$, both $ps < .001$. High scores on the environmental quality composite corresponded to higher SES/better marital adjustment.

Aggression—For the 213 children who had physiological and environmental quality data, mothers ($n = 206$ at 18 months, $n = 154$ at 24 months, $n = 185$ at 30 months, $n = 169$ at 42 months, $n = 147$ at 48 months, and $n = 155$ at 54 months) and fathers ($n = 168$ at 18 months, $n = 118$ at 24 months, $n = 134$ at 30 months, $n = 109$ at 42 months, $n = 95$ at 48 months, and $n = 96$ at 54 months) completed portions of the Infant–Toddler Social and Emotional Assessment (Briggs-Gowan & Carter, 1998). Subscales included relational defiance (e.g., “Misbehaves to get attention from adults”), oppositional/defiant aggression (e.g., “Hits, bites, or kicks you [or other parent]”), dispositional aggression (e.g., “Acts aggressive when frustrated”), and defiance (e.g., “Has temper tantrums”). Based on substantial correlations among these measures, the 12 individual items (rated from 0 to 2) composing these four subscales were averaged within each reporter to form a composite measure of aggression (ranging from 0 to 2; α s = .74–.82 for mothers, and α s = .73–.78 for fathers). Means and standard deviations are in Table 1. All means were greater than .50; thus, the average child was rated as having some behavioral problems on over half of the 12 items. Correlations between mother- and father-reported aggression ranged from .29 at 48 months to .49 at 42 months (average $r = .39$; see Table 1 for correlations at each time for each sex).

Attrition

Attrition analyses were conducted to determine whether parental nonresponse to the questionnaires was related to environmental quality or parent-reported aggression. We correlated the number of times each parent filled out the questionnaires with the environmental quality composite. Environmental quality was positively correlated with the number of mothers' and fathers' responses, $r(211) = .22$ and $.39$, $p < .01$ and $.001$. We also examined the relation between mother or father attrition and mothers' or fathers' reports of aggression. Available scores for aggression were averaged across time for each parent. The only significant correlation (out of four) was between mother-reported aggression and the number of father questionnaires, $r(211) = -.14$, $p < .05$. Thus, parents who scored high on the environmental quality completed more questionnaires, and fathers completed fewer questionnaires if their children were rated as high in aggression by mothers. Residualized RSA suppression was negatively related to mothers' attrition, $r(211) = -.16$, $p < .05$; this was the only relation between attrition and RSA.

Results

Analytic Strategy

Multilevel models using full information maximum likelihood were run in SAS 9.2 to predict the intercept and slope of mother and father reports of aggression. In all analyses, baseline RSA, RSA suppression, and environmental quality were centered around the sample means to reduce nonessential multicollinearity among interaction terms (Aiken & West, 1991). To examine prediction of the intercepts at the start of the study (18 months) and the end of the study (54 months), the analyses were run separately with time centered at 18 and 54 months, respectively. Sex was dummy coded (0 = female, 1 = male). In preliminary analyses, we ascertained that the results did not change when age at T1, which did not vary much across children, was covaried; thus, age was not used as a covariate in the analyses.

Pseudo r^2 statistics were calculated for each model by estimating the squared correlation between the predicted scores and the observed scores (Singer & Willett, 2003). Comparing these statistics across models is conceptually similar to examining the change in r^2 in hierarchical multiple regression. We also report the proportional reduction in the intercept and slope variances relative to a baseline model without substantive predictors (Singer & Willett, 2003). This alternate measure of variance explained is useful because it ignores within-person residual variability (i.e., deviations from an individual's linear trajectory); it is not possible to reduce this variance component without including time-varying predictors, and all of our predictors were measured at the start of the study and not at older ages. For all models, an unstructured covariance matrix and the Satterthwaite method for calculating the denominator degrees of freedom for statistical tests were used.

As is described below, the probing of interactions was designed to test predictions of DS and BSC theory. Moreover, according to Ellis et al. (2011), the measures of susceptibility and risk should not be correlated in an ideal test of DS/BSC. As can be seen in Table 1, the measures of RSA and environmental quality were not correlated in this study. Moreover, sex was unrelated to study variables.

Unconditional Growth Model

Adopting a model-building approach (Singer & Willett, 2003), we used likelihood ratio tests to compare nested models to determine the unconditional growth model that best fit the data. Modeling an effect for a random linear slope improved model fit compared to a model with a random intercept term and a fixed linear slope for both reporters: for mother report, $\chi^2(2)$

$= 28.0, p < .001$; for father report, $\chi^2(2) = 10.0, p < .01$. Subsequently adding a fixed quadratic effect to these models also improved model fit for both reporters: $\chi^2(1) = 51.1$ and $11.3, ps < .001$, for mother and father reports, respectively. However, adding a random effect for the quadratic slope did not improve model fit for either model: for mother report, $\chi^2(3) = 5.7, p = .13$; for father report, $\chi^2(3) = 5.7, p = .13$. In the interest of parsimony, we selected the simpler model with random effects for the intercept and linear slope, and fixed effects for the linear and quadratic slopes, as the basis for subsequent models (see Table 2). The combination of linear and quadratic fixed effects of time (i.e., the average slope in the absence of substantive predictors) accounted for 2.2% and 1.0% of the variance in mothers' and fathers' reports of aggression (see Figure 1).

Substantive Models

Baseline RSA—Next, we ran models examining the main effects of baseline RSA, sex, and environmental quality (but not the interactions) on aggression. For mother-reported aggression, environmental quality (but not RSA or sex) negatively predicted the 18- and 54-month intercepts, $bs = -0.05$ and $-0.11, ts = -2.14$ and $-3.66, ps < .05$ and $< .001$. In addition, baseline environmental quality was a significant predictor of the slope, $b = -0.02, t = -1.99, p < .05$, and baseline RSA was marginally related to the slope, $b = -1.14, t = -1.86, p < .07$. Children with higher baseline RSA and a higher quality environment exhibited more of a relative decline in aggression over time. The pseudo r^2 increased from 2.2% in the unconditional growth model to 5.8% in the main effects model. Relative to the unconditional growth model (with no substantive predictors), the main effects of baseline RSA and environmental quality reduced the residual 18-month intercept variance by 4.0%, the 54-month intercept variance by 8.2%, and the slope variance by 9.8%. For fathers' reports, none of the main effects were significant.

We then added the Sex $\times$ Baseline RSA interaction as a predictor of the intercept and slope. None of these interactions were significant for mothers' reports. However, for fathers' reports, there was a significant interaction predicting the 54-month intercept and the slope, $bs = -10.12$ and $-4.34, ts = -2.59$ and $-2.98, ps < .05$ and $< .01$. This model explained 3.2% of the variance in fathers' reports—an increase of 2.2% over the random effects model. Relative to the unconditional growth model (with no substantive predictors), this model reduced the 18-month intercept residual variance by 1.6%, the residual 54-month intercept variance by 11.8% and the slope variance by 27.2%. For boys, baseline RSA was negatively related to the 54-month intercept and the slope, $bs = -6.36$ and $-2.61, ts = -2.37$ and $-2.62, ps < .05$ and $< .01$; although boys with high baseline RSA did not initially have lower aggression than their peers with low baseline RSA, they declined in aggression over time and had lower aggression at the end up the study. For girls, however, there was no relation between baseline RSA and the 54-month intercept or slope, $bs = 3.76$ and $1.74, ts = 1.33$ and $1.63, ns$.

We then added interactions among the baseline RSA, sex, and environmental quality to the models (see Table 3). To simplify interpretation, in the final models, sex was dropped from the analyses for mothers' reports because there was neither a significant main effect for sex nor any significant interactions between sex and other predictors.

For mothers' reports, environmental quality was a significant negative predictor of the 18-month intercept, $b = -0.06, t = -2.37, p < .05$, but neither baseline RSA nor the interaction between baseline RSA and environmental quality predicted this intercept. However, the interaction between baseline RSA and environmental quality predicted the 54-month intercept, $b = -7.31, t = -2.39, p < .05$, and was a marginally significant predictor of the linear slope, $b = -1.72, t = -1.66, p < .09$ (see Figure 2). This model explained 7.6% of the variance in the data. This model reduced the unconditional model variance by 4.2% for the

18-month intercept, 12.3% for the 54-month intercept, and 12.7% for the slope. The difference in variance reduction between the main effects model and the interaction model was 0.3% for the 18-month intercept, 4.1% for the 54-month intercept, and 2.9% for the slope. Given widely acknowledged challenges to detecting interaction effects in non-experimental studies (McClelland & Judd, 1993), we examined the latter interaction.

Ellis et al. (2011) asserted that a crossover interaction must be present for DS/BSC, with the risk factor related to the outcome for individuals high on the reactivity factor but not for individuals low on the reactivity factor. Thus, from a statistical perspective, two conditions must be met to provide full support for the DS hypothesis. First, the risk factor should be significantly related to the outcome for individuals who are high, but not low, on the plasticity (i.e., reactivity) factor (Ellis et al., 2011). Second, the relation between the plasticity factor and the outcome should be positive for individuals high on the risk factor and should be negative for individuals low on the risk factor. Although the second requirement seldom has been tested empirically, we present the simple slopes for each interaction in two different ways to test whether both conditions were met. Because we modeled the average quadratic slope, which causes the average linear slope to vary across time, all simple effects for the slope represent a deviation from the average slope. As such, they indicate an increase or decline relative to the sample average, rather than a slope that is positive or negative in absolute terms.

To assess whether the first condition was met (i.e., whether baseline RSA can be considered an index of reactivity to environmental quality), we examined simple effects of environmental quality at varying levels of baseline RSA (Aiken & West, 1991; see Figure 3). For children with high (+1 *SD*) and average baseline RSA, environmental quality was negatively related to mother-reported aggression at 54 months, $b = -0.21$ and -0.13 , $t_s = -4.02$ and -4.24 , $p_s < .001$. However, for children with low (−1 *SD*) baseline RSA, environmental quality was unrelated to 54-month aggression, $b = -0.04$, $t = -1.10$, *ns*. Similarly, environmental quality was negatively related to the slope of mother-report aggression for children with high and average baseline RSA, $b_s = -0.04$ and -0.02 , $t_s = -2.52$ and -2.35 , both $p_s < .05$, and was unrelated to the slope for low RSA, $b = -0.00$, $t = -0.27$, *ns*.

We then tested whether children in low-quality environments (−1 *SD*) would show a positive relation between the plasticity factor and the outcome, whereas a negative relation would be found for children in high-quality environments (+1 *SD*). Baseline RSA was negatively related to the mother-report 54-month intercept at high levels of environmental quality, $b = -8.46$, $t = -2.50$, $p < .05$, and was unrelated at average and low environmental quality, $b_s = -2.72$ and 3.01 , $t_s = -1.39$ and 1.08 , *ns*. Baseline RSA was also negatively related to the slope at high and average environmental quality, $b_s = -2.63$ and -1.32 , $t_s = -2.46$ and -2.13 , both $p_s < .05$, but was unrelated to the slope at low environmental quality, $b = -0.02$, $t = -0.02$, *ns*.

For fathers' reports, there was a significant baseline RSA $\times$ Environmental Quality $\times$ Sex interaction predicting the 18-month intercept, $b = 13.40$, $t = 2.48$, $p < .05$ (see Figure 2); this model accounted for 5.7% of the variance in fathers' reports of aggression and reduced the unconditional model variance by 9.1% for the 18-month intercept, 13.1% for the 54-month intercept, and 29.5% for the slope. The difference in variance reduction between the model with and without the three-way interactions was 7.5% for the 18-month intercept, 1.2% for the 54-month intercept, and 2.3% for the slope. The two-way interaction between baseline RSA and environmental quality was a significant predictor of the intercept for girls, $t = -2.62$, $p < .01$, but not for boys, $t = 0.86$, *ns*. Given this significant two-way interaction, we computed the simple effect of environmental quality at varying levels of baseline RSA for

girls. Environmental quality was unrelated to aggression for girls with low RSA, $b = 0.05$, $t = 0.99$, ns , was marginally negatively related to aggression for girls with average RSA, $b = -0.07$, $t = -1.82$, $p < .08$, and was negatively related to aggression for girls with high RSA, $b = -0.19$, $t = -2.78$, $p < .01$ (see Figure 3). We also tested the simple effects of baseline RSA on the 18-month intercept of girls' aggression at varying levels of environmental quality: Baseline RSA was unrelated to aggression at low levels of quality, $b = 2.77$, $t = 0.94$, ns , was marginally negatively related at average quality, $b = -5.00$, $t = -1.82$, $p < .08$, and was negatively related at high levels of quality, $b = -12.76$, $t = -2.59$, $p < .05$ (see Figure 4).

We also calculated the regions of significance (Johnson & Neyman, 1936), which correspond to the range of values of a moderator over which a variable is significantly related to an outcome. We report the regions of significance up to 2 *SDs* from the mean on the moderator. For mothers, the relation of environmental quality to aggression was significant at values of RSA $-.73$ *SD* below the mean for the 54-month intercept and 0.22 *SD* below the mean for the slope; the relation of RSA to aggression was significant at values of environmental quality $.29$ *SD* above the mean for the 54-month intercept, and $.08$ *SD* below the mean for the slope. Thus, the relation between environmental quality and aggression was apparent for children with baseline RSA slightly below average or higher; the relation between baseline RSA and aggression was found only for children somewhat above the mean in environmental quality. For fathers, the relation of environmental quality to girls' 18-month aggression intercept was significant for baseline RSA values $.07$ *SD* above the mean; the simple effect of RSA on the 18-month intercept was significant at values of environmental quality $.10$ *SD* above the mean.

RSA suppression—A similar analytic strategy was used to examine the results for RSA suppression. There were no significant main effects of RSA suppression on aggression, and there were no significant interactions between RSA suppression and environmental quality or sex (and the main effects of environmental quality were similar to in the analyses for baseline RSA). There also were no significant interactions when Marital Adjustment Test and SES were analyzed separately. In addition, because curvilinear relations have been found between RSA suppression and variables related to aggression (e.g., executive functioning; Marcovitch et al., 2010), we examined whether the quadratic effect of RSA suppression (alone or in interaction with environmental quality) predicted aggression; none of these effects were significant.

Discussion

In this study, we examined the prediction of children's aggressive behavior from both RSA (baseline or suppression) and environmental quality, as well as their interaction. We tested whether the pattern of interactions was consistent with predictions from DS/BSC or diathesis-stress perspectives. Unlike in most studies of the DS and BSC perspectives, we examined not only the prediction of aggression at discrete ages (18 and 54 months) but also the pattern of change in aggression from 18 to 54 months. Moreover, unlike most studies, we examined not only the DS/BSC prediction that children high in physiological reactivity vary in their behavior as a function of environmental quality but also that children varying in physiological reactivity differ from one another at both high and low levels of risk, albeit in opposite directions.

The findings are partly consistent with DS/BSC models but not the diathesis-stress model. For mother-reported aggression at 54 months but not at 18 months, children with high or moderate levels of baseline RSA were more likely to be low in aggression as environmental quality increased, whereas aggression was unrelated to environmental quality for children with low baseline RSA. The pattern of findings for the slope of mother-reported aggression

across time was similar to those for the 54-month intercept: A significant negative relation between environmental quality and the development of aggression was found for children with average and high baseline RSA but not for children with low baseline RSA. Thus, children with high baseline RSA appeared more reactive than those with low RSA, but only in supportive contexts, and children with low RSA appeared to be prone to relatively high aggression regardless of the level of environmental quality.

For fathers' reports of aggression, the baseline RSA $\times$ Environmental Quality interaction was further moderated by sex; this interaction was only significant for girls. In relatively supportive environments, girls with high and low baseline RSA differed in aggression (with high baseline RSA girls being lower in aggression), whereas girls with high and low baseline RSA both exhibited fairly high aggression in unsupportive environments. The interaction was similar to that found for mothers' reports; however, this interaction predicted girls' early aggression (18 months) for fathers' reports and later aggression (54 months) for mothers' reports, with the change over time in the slope for mother-reported aggression reflecting an increasing difference in children with high versus low baseline RSA in supportive contexts.

Thus, looking across the findings for baseline RSA, the most consistent finding was that environmental quality was more negatively related aggression for children with high baseline RSA, and children with high and low baseline RSA differed primarily in especially supportive contexts. For children low in baseline RSA, the pattern of findings is similar to that labeled as vulnerable-stable (Luthar, Cicchetti, & Becker, 2000). Perhaps because of a higher level of regulation, children with high baseline RSA (relative to children with low baseline RSA) were better equipped to take advantage of the potential benefits of such a context. There may be little need for aggression in supportive, resource-rich contexts, and low levels of aggression may be most likely to elicit social support and resources in such contexts. The apparent adaptability of children with high baseline RSA at least in supportive contexts, is consistent with other work suggesting that high baseline RSA is associated with attentional skills, regulation, and the ability to adapt (Feldman, 2009; Fox & Field, 1989; Marcovitch et al., 2010; Staton et al., 2009; Suess et al., 1994).

Our findings clearly do not support the notion that low baseline RSA is reflective of reactivity to the environment, at least at 18 months of age (see Calkins, Bandon, et al., 2007, for a similar finding with children 2 to 5 years of age). Moreover, baseline RSA was negatively related to aggression in supportive environments; it was not related to aggression in less supportive contexts. The lack of findings for children low in baseline RSA and in contexts low in support is not consistent with either DS/BSC or diathesis-stress perspectives. The pattern of findings may reflect restriction of range on measures of environmental quality, as the sample was generally relatively working and middle class and, hence, fairly low risk. In moderately nonsupportive contexts, aggression may be less adaptive (and generate more problems than advantages) than in highly nonsupportive environments. Also, our statistical models weight people with more data more heavily in the estimation: Because risk was related to attrition, we likely had more ability to detect differences at the low end of risk (because parents of low-risk children filled out more questionnaires). It is also possible that with age and increased cognitive and social skills, children with high RSA are better able to adapt in unsupportive as well as supportive contexts.

However, it is also possible that some aspects of physiological reactivity help children adapt only in certain kinds of environments. Children vary in physiological and emotional reactivity on a variety of dimensions, and some may contribute to adaptation in positive and challenging circumstances, whereas others contribute to adaptation in more circumscribed ways. Alternatively, baseline RSA may provide adaptive advantages for children (in some if

not all contexts) but is not an index of reactivity to the environment per se. Of course, it is also possible that baseline RSA contributes to flexible behavior in all types of contexts and that this flexibility provides sufficient benefits that children with high baseline RSA are only average in aggression (rather than high in aggression) in challenging sociodemographic contexts because they find other ways to adapt and obtain desirable resources (e.g., using covert externalizing behaviors or learning to manipulate other people). In other words, aggression may not be the only way for reactive children to adapt to unsupportive environments.

It is unclear why the Baseline RSA $\times$ Environmental Quality findings were obtained only for the 18-month intercept for girls for father-reported aggression, whereas it was found at older ages for both sexes for mother-reported aggression. The sample with father- and mother-reported data was smaller and, in supplemental analyses, higher on income, education, and marital adjustment than the sample with solely mother-reported aggression; it is more difficult to obtain significant change in outcomes across levels of a variable if its range is curtailed. Because the interactions were similar for mothers and fathers, albeit at different times, it suggests that parents' perceptions of aggression may differ over time. Perhaps fathers are particularly attuned to blatant acts of aggression in toddlers, whereas mothers are more likely to dismiss such acts as normative and are more attuned to aggression as children age and it tends to be less normative (Dodge, Coie, & Lynam, 2006). Moreover, given greater cultural prohibitions against aggression for girls than boys and findings that fathers enforce gender roles more than do mothers (Siegal, 1987), it may be especially adaptive for girls in positive circumstances to inhibit their aggression when interacting with their fathers.

Unexpectedly, we found no main effects of RSA suppression or interactions of suppression with environmental quality. Perhaps RSA suppression in situations demanding more sustained attention on a difficult task or involving a cognitive rather than social stimulus would produce a different pattern of responding. Our task for measuring RSA suppression, a film of babies crying, was different from some other studies that commonly use tasks designed to elicit specific emotional responses (e.g., anger) or that use cognitively challenging tasks. Nonetheless, Gentzler, Santucci, Kovacs, and Fox (2009) found that, compared to an initial baseline, a greater decrease in 5- to 13-year-olds' RSA in response to a sad film clip predicted more adaptive emotion regulation, which tends to relate to less aggression (see Eisenberg, Spinrad, & Eggum, 2010). Thus, it was reasonable to expect our task to relate to aggression, although it is possible that an evocative film is a better elicitor of RSA suppression for older than younger children. Indeed, Calkins and Dedmon (2000) found that 2-year-olds exhibited less suppression during an audiotape of a crying toddler than during other frustrating, fear-inducing, or problem-solving episodes. In the present study, the majority of the children exhibited RSA augmentation rather than suppression. Given recent work demonstrating a positive relation between externalizing and marital conflict for kindergartners who were low in RSA suppression during a social stimulus (Obradović et al., 2011), one might have expected low RSA suppression to crying infants to predict low aggression. Perhaps older children would exhibit relations between RSA suppression and aggression. Children's regulatory/executive functioning and social skills are fairly limited at 18 months of age (Rothbart & Bates, 2006) and, consequently, may be insufficient for optimal adaptation to the environment. However, as discussed previously, the findings for RSA Suppression $\times$ Environmental Quality have not been consistent in studies with older children.

Baseline RSA interacted with sex to predict fathers' reports of aggression. Baseline RSA was negatively associated with aggression at 54 months for boys but not girls. Moreover, baseline RSA was associated with a decline in aggression over time for boys; for girls, the same relation was near significantly positive. This pattern is consistent with some other

findings of sex differences in the relation of RSA to externalizing (Beauchaine et al., 2008; Calkins & Dedmon, 2000). Beauchaine et al. (2008) argued that there is evidence that biological markers of genetic risk for externalizing behaviors are largely heritable for boys but not girls, and, thus, relations of RSA with conduct problems are more evident for boys. As suggested by Beauchaine et al. (2008), vulnerabilities among aggressive girls may be driven by different etiological mechanisms, including stronger environmental/social influences.

In models that contained only main effects, we found that high baseline RSA predicted a near significant decline over time in mothers' reports of children's aggression. As is evident from the interaction of risk group with baseline RSA, this pattern held for the majority of children who were not at high risk. This main effect is consistent with some (Calkins & Dedmon, 2000), but not all (Calkins, Blandon, et al., 2007), findings with younger children. As previously implied, the lack of consistency in findings across studies in relations between baseline RSA and aggression might be due to the variations in children's environments as well as their age.

Moreover, in the main effects models for RSA, environmental quality positively predicted the 18- and 54-month intercepts and the slope of mother-reported aggression. This finding is in line with other research (Dodge et al., 2006), although our interaction effects suggest that this relation is more likely to be true for children with high baseline RSA after 18 months. Similar main effects may not have been found for father-reported aggression due to less statistical power or less variation in environmental quality (but note that the same relation was near significant for the father-reported 18-month intercept).

For both mother and father reports, there was a negative quadratic slope to the data, with aggression/defiance increasing at the start of the study but starting to decline between 30 and 42 months. This pattern is consistent with some other findings suggesting that aggression peaks at about 3 years of age (see Dodge et al., 2006). The relatively marked increase in children's self-regulation between 2 and 4 years of age (Rothbart & Bates, 2006) may account for the decline in aggression at this age.

In summary, the results of this study provide mixed support for the DS/BSC perspectives, but only in supportive contexts. It is unclear whether the lack of support for these perspectives when the environment was lower quality is due to the nature of the sample (not high risk), baseline RSA not reflecting biological reactivity, or some other features of the sample or study. Perhaps not all types of reactivity are equivalent in the domains in which they confer an advantage. The model provides no support for diathesis-stress perspective. The results do support the view that high baseline RSA is associated with more plasticity in behavior and development than is low RSA at a young age, at least across the range of contexts examined in this study. Children with high baseline RSA may be biologically predisposed to capitalize on rewarding affordances in their social environment. Strengths of this study include the longitudinal design, the focus on the change in aggression in the early years, and the use of multiple reporters of aggression. In addition, because the measure of plasticity was RSA responding, the potential problem of the same reporter providing measures of individual differences in plasticity and the outcome variables was avoided. Weaknesses include the moderate rather than large sample size and somewhat limited heterogeneity in the sample (i.e., there was not a large group of very high-risk children). Moreover, although having a racially/ethnically homogeneous sample is an advantage for testing DS (Ellis et al., 2011), the fact that a majority of our sample was Caucasian and working or middle-class means that the results may not be generalizable to other samples. In addition, because the data are correlational, we cannot ascertain causal relations. Finally, a

stronger test of DS/BSC theory could have been conducted if we had been able to identify families with exceptionally unsupportive environments.

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Figure 1.
Average mother-reported and father-reported aggression trajectories.

Figure 2.

Trajectories of mother-reported aggression (for boys and girls) and father-reported aggression (for girls only). RSA = respiratory sinus arrhythmia.

Figure 3.

Simple slopes of environmental quality on the 54-month intercept and the slope of mother-reported aggression at different levels of baseline respiratory sinus arrhythmia (RSA).

Figure 4. Simple effect of environmental quality on the 18-month intercept of girls' father-reported aggression at different levels of baseline respiratory sinus arrhythmia (RSA).

Table 1

Zero-Order Correlations and Descriptive Statistics

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Baseline RSA	—	.04	-.05	.03	.02	-.03	-.14	-.06	-.05	-.01	.24	.03	-.34	-.14	-.23
2. RSA suppression ^a	-.09	—	-.10	-.04	.01	.17	.08	.09	.13	.01	-.00	.06	.04	-.05	.01
3. Quality	.03	.14	—	-.09	-.11	-.16	-.25	-.22	-.20	.01	.04	-.05	-.20	-.08	-.08
4. Mother 18-month AGG	.09	.11	-.10	—	.71	.56	.51	.48	.56	.51	.29	.35	.38	.24	.13
5. Mother 24-month AGG	.15	-.08	-.16	.62	—	.67	.60	.70	.71	.27	.27	.45	.32	.19	.13
6. Mother 30-month AGG	.16	.09	-.23	.60	.73	—	.56	.55	.64	.22	.21	.46	.40	.21	.15
7. Mother 42-month AGG	.14	-.02	-.19	.44	.64	.71	—	.67	.68	.22	.08	.44	.56	.22	.32
8. Mother 48-month AGG	.08	-.06	-.26	.38	.53	.66	.75	—	.76	.18	.02	.50	.26	.29	.21
9. Mother 54-month AGG	-.04	-.01	-.23	.33	.49	.71	.61	.61	—	.25	.30	.50	.49	.37	.33
10. Father 18-month AGG	-.00	-.04	-.15	.37	.34	.37	.26	.27	.30	—	.28	.40	.39	.34	.35
11. Father 24-month AGG	-.05	-.10	-.03	.33	.46	.40	.27	.36	.31	.48	—	.47	.13	.29	.33
12. Father 30-month AGG	-.06	-.13	-.03	.21	.46	.33	.44	.34	.35	.60	.63	—	.43	.47	.39
13. Father 42-month AGG	.08	.08	-.14	.09	.24	.23	.41	.23	.32	.18	.54	.40	—	.59	.63
14. Father 48-month AGG	.15	.23	-.27	.09	.26	.23	.28	.28	.37	.23	.49	.61	.47	—	.65
15. Father 54-month AGG	.06	-.11	-.09	.12	.23	.38	.33	.44	.56	.32	.56	.47	.57	.58	—
<i>M</i>	.02	.00	-.02	.50	.56	.63	.65	.54	.58	.50	.55	.58	.59	.53	.53
<i>SD</i>	.01	.01	.78	.28	.30	.30	.34	.30	.34	.29	.28	.29	.28	.28	.28

Note. AGG = Infant-Toddler Social and Emotional Assessment aggression/defiance. Correlations for boys are above the main diagonal, and correlations for girls are below the main diagonal. Means for all variables did not differ as a function of sex. Numbers in bold are significant at $p < .01$ or higher; numbers in italics are significant at $p < .05$. RSA = respiratory sinus arrhythmia.

^aResidualized RSA suppression (with baseline RSA partialled out).

Table 2

Unconditional Growth Model for Aggression

Fixed effects	Mother report		Father report	
	<i>b</i>	<i>t</i>	<i>b</i>	<i>t</i>
Intercept (18 months)	0.51		0.51	
Linear slope ^a	0.17	7.83 ***	0.10	3.54 ***
Quadratic slope	-0.05	-7.29 ***	-0.03	-3.39 ***
<hr/>				
Random effects ^b	σ		σ	
		<i>z</i>		<i>z</i>
Intercept	.054	7.38 ***	.039	5.61 ***
Linear slope	.004	3.96 ***	.004	2.68 **
Intercept/slope covariance	-.001	-0.64	-.004	-1.57
Residual	.033	17.56 ***	.041	14.60 ***
<hr/>				
Pseudo r^2 (%)	2.2		1.0	

^aDue to the presence of a significant quadratic fixed effect for the slope, the linear slope coefficient varies as a function of time. The values presented in this row of the table are for time centered at 18 months.

^bThe random effects differ as a function of time. The random effects presented here correspond to the values at 18 months.

**
 $p < .01$.

 $p < .001$.

Table 3

Models Predicting the Development of Aggression From Baseline RSA, Risk, and Sex

Fixed effects	Mother report		Father report	
	<i>b</i>	<i>t</i>	<i>b</i>	<i>t</i>
Intercept (18 months)	0.51		0.50	
Baseline RSA	1.25	0.76	-5.00	-1.82 [†]
Quality	-0.06	-2.37 [*]	-0.07	-1.82 [†]
Quality × Baseline RSA	-2.32	-0.91	-10.22	-2.61 ^{**}
Sex			0.00	0.10
Sex × Baseline RSA			6.77	1.95 [†]
Sex × Quality			0.10	1.87 [†]
Sex × Quality × Baseline RSA			13.40	2.48 [*]
Intercept (54 months)	0.56		0.50	
Baseline RSA	-2.73	-1.39	2.30	0.75
Quality	-0.13	-4.24 ^{***}	-0.07	-1.44
Quality × Baseline RSA	-7.31	-2.39 [*]	-4.41	-0.93
Sex			0.04	0.84
Sex × Baseline RSA			-8.72	-2.12 [*]
Sex × Quality			0.03	0.43
Sex × Quality × Baseline RSA			7.37	1.12
Linear slope ^a	0.17	7.88 ^{***}	0.10	3.32 ^{**}
Baseline RSA	-1.32	-2.13 [*]	2.43	2.09 [*]
Quality	-0.02	-2.35 [*]	0.00	0.08
Quality × Baseline RSA	-1.66	-1.72 [†]	1.94	1.08
Sex			0.01	0.67
Sex × Baseline RSA			-5.16	-3.36 ^{**}
Sex × Quality			-0.02	-0.97
Sex × Quality × Baseline RSA			-2.01	-0.82
Quadratic slope	-0.05	-7.30 ^{***}	-0.03	-3.49 ^{***}
Random effects^b				
	σ	<i>z</i>	σ	<i>z</i>
Intercept	.051	7.30 ^{***}	.036	5.38 ^{***}
Linear slope	.004	3.64 ^{***}	.003	2.08 [*]
Covariance: Intercept/linear slope	-.002	-0.92	-.003	-1.19
Residual	.033	17.56 ^{***}	.041	14.60 ^{***}
Pseudo <i>r</i> ² (%)	7.6		5.7	

Note. The coefficients above were those that were obtained when all predictors and their interactions were entered simultaneously. Sex is coded as follows: 0 = female, 1 = male. Baseline respiratory sinus arrhythmia (RSA) and environmental quality are centered around the sample means.

^aDue to the presence of a significant quadratic fixed effect for the slope, the linear slope coefficient varies as a function of time. The values presented in this row of the table are time centered at 18 months.

^bThe random effects differ as a function of time. The random effects presented here correspond to the values at 18 months.

[†] $p < .10$.

^{*} $p < .05$.

^{**} $p < .01$.

^{***} $p < .001$.