Test of Effortful Control as a Moderator of the Relation between RSA & Temperament

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Abstract

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Prior research examining associations between negative affect (NA) in childhood and respiratory sinus arrythmia (RSA) has found mixed results. One possible explanation for inconsistent findings may be that there are moderating factors. One potential moderating factor is effortful control, such that the effect of RSA on negative affect depends on a child's level of effortful control. Another possible explanation is that there may be an understudied quadratic effect of RSA. We hypothesize that 1) at low levels of effortful control there will be a quadratic relation between NA (fear and frustration) and baseline RSA, but at high levels there will be no relation; and 2) these patterns of relations will be the same for RSA reactivity (RSA task – RSA baseline). The present study utilized a sample of 306 children (M_{age} = 3.05, SD_{age} = 0.07). Results did not support curvilinear or interactive effects in the prediction of frustration, however, there was a significant, quadratic interactive effect when using baseline RSA as a predictor of fear. The results suggest the association of RSA with children's negative affect is complex and might depend on the specific emotion.

Children with heightened negative affect and poorer emotion regulation skills are at particular risk for developing internalizing and externalizing disorders (Nigg, 2006) and experiencing poorer adjustment later in childhood (Mesman & Koot, 2001). Specifically, children with increased fear responses are more prone to anxiety and social withdrawal (Buss, 2011) whereas children with increased frustration tend to be more prone to externalizing problems (Eisenberg et al., 2009) and later delinquent behavior (Ialongo, Vaden-Kiernan, & Kellam, 1998). Though the relations between negative affect and increased risk for poor outcomes are robust (Cohen, Janicki-Deverts, & Miller, 2007; Nielsen et al., 2019), the relative contribution of physiological and cognitive regulatory capacities on those relations begs further clarification. This study tested whether self-regulation, as measured by effortful control moderates, the relation between physiological emotion regulation, as measured by respiratory sinus arrhythmia, and behavioral measures of negative affect. In particular, the study tested whether effortful control would moderate the relation between RSA and displays of fear and frustration, respectively.

Fear and frustration in childhood are often studied in the context of temperament which is commonly defined as individual differences in reactivity and regulation that are shaped by experience and based in biology (Rothbart & Bates, 2006). Whereas fear is often operationalized as negative affect shown in response to expected pain or threat (Rothbart & Jones, 1998), frustration tends to be conceptualized as negative affect shown in response to experiencing a blocked goal (Rothbart, Evans, & Ahadi, 2000). Though both fear and frustration fall under the temperament dimension of negative emotionality (NE), it may be important to assess them individually given their differences in relation to neurobiological correlates (Brooker & Buss, 2010; Miller et al., 2013), theorized behavioral function (see Keltner et al., 2016), and psychopathological outcomes (Buss, 2011; Eisenberg et al., 2009).

Just as children are temperamentally primed to experience different levels of reactive fear and frustration, they also demonstrate differences in their ability to regulate those emotions. Emotion regulation stems from both physiological and cognitive processes. Respiratory sinus arrythmia (RSA), a measure of parasympathetic activity, and thus physiological regulation, has been commonly studied as a potential biomarker of emotion regulation (Beauchaine, 2015). Effortful control is a core component of

self-regulation from a temperament perspective, referring to the ability to purposefully override reactive responses and engage in self-monitoring and planning (Rothbart & Rueda, 2005). The aim of this study was to examine whether the association of RSA to children's observed negative affect would be clarified by accounting for possible moderating effects of effortful control. In the next sections, the relation of RSA to negative affect is reviewed, including evidence for both linear and curvilinear effects, and the potential role of effortful control in that relation is discussed.

RSA and Negative Affect

Porges' Polyvagal Theory (Porges, 1995) posits the evolution and function of the two branches of the vagus nerve. The vagus is comprised of a "vegetative" and a "dynamic" branch. The dynamic branch allows for quick changes in metabolic output which provides the organism with the capability to respond to challenges by either engaging in social affiliation or preparing for flight/fight.

It is generally accepted that higher resting RSA and greater RSA withdrawal are suggestive of a healthy stress response system because they are indices of better reactive flexibility to changes in the environment (Porges, 1995). Higher resting RSA is the result of greater parasympathetic influence (e.g. greater physiologic relaxation) during a time absent of immediate threat. In an assumedly maladaptive system, because there is chronically poor parasympathetic influence (low resting RSA), the body remains in a stasis of high stress which taxes metabolic resources and produces deleterious health effects (Cohen, Janicki-Deverts, & Miller, 2007). Typically, individuals with higher resting RSA show better control over their behavior and affect (Graziano & Derefinko, 2013). Given situational context, RSA reactivity resulting in temporarily low RSA (RSA withdrawal from baseline) may be adaptive in response to an immediate threat or challenge as decreases in parasympathetic influence allow for greater metabolic resources needed for a potential fight/flight response. Regardless of whether an emotion-eliciting task was meant to evoke sadness, fear, or frustration, children have been shown to produce RSA withdrawal (Buss et al., 2005; Roos et al, 2017). However, a recent meta-analysis found an effect of significant RSA withdrawal on externalizing, but not on internalizing (Beauchaine et al., 2019), thus suggesting that the relation between RSA and emotional reacting may differ based on the type of emotion experienced.

One of the impetuses of this study was to better understand why we may be seeing contradictory findings in the RSA literature. For example, though some studies report relations between higher baseline RSA and less negative affect others report no significant relation between the two (Blandon et al., 2010; Calkins, 1997). Some have also found that higher RSA reactivity associates with worse adjustment outcomes, however, others have found the opposite to be true as well in that higher RSA reactivity has been shown to associate with better outcomes (Aults et al., 2015; Gentzler et al., 2009). Eisenberg et al. (2012) examined whether these associations could be explained by the differential susceptibility model which posits that reactive children may thrive in supportive environments, but do especially poorly in aversive environments. Only part of this model was supported by their findings; reactive children did better in enriching environments but did not do worse in lower quality environments than their less reactive peers. As opposed to examining children through dichotomies (e.g. less reactive or more), relatively recent work has demonstrated the potential promise of examining quadratic RSA effects.

Curvilinear RSA Effects

Recent work analyzing RSA effects have suggested that it may be important to curvilinear or quadratic effects (Holzman & Bridgett, 2017). As relates to emotion regulation, adults higher in emotional suppression have an inverted-U shaped relation between resting RSA and their executive functioning (EF), such that those of moderate levels of RSA have the highest EF (Spangler, Bell, & Deater-Deckard, 2015). Children show a similar association between executive functioning and RSA baseline to the effect that children with only moderate RSA withdrawal have the best performance on EF tasks (Marcovitch et al., 2010). One potential interpretation of these findings is that, as with many biological processes, there may be upper and lower bounds of RSA beyond which cognitive and emotional functioning may be more limited. Expressed another way, there may be homeostatic ranges of RSA which may allow for optimal functioning. Thus, examining curvilinear associations of RSA and negative affect expression might clarify inconsistent associations observed in the literature. However, another reason for inconsistent associations may be that other self-regulation resources further, such as effortful control, modulate physiological regulation, altering the association of RSA with negative affect.

Effortful Control and Negative Affect

One conceptual framework of emotion regulation suggests that cognitive resources act as a limiting factor in one's ability to engage in emotional control processes. According to Sheppes (2014) there are two key processes involved in emotion regulation, attentional selection and semantic meaning. Both steps rely on effortful control, in that they necessitate attentional focus and, more particular to semantic meaning, working memory processes. Differences in emotion regulation due to effortful control have been found as early as infancy. One longitudinal study on infants found that increases in effortful control predicted increases in delaying an angry response during an emotion induction task (Tan, Armstrong, & Cole, 2013), thus demonstrating that even infants can recruit cognitive processes to modulate their behavior. Additionally, in a study on executive attention in children, Rothbart (2007) found that children who performed better on a cognitive attention task showed less frustration and impulsivity than those with poorer attentional skills. Effortful control can act as a buffer for the negative outcomes that can be associated with high negative affect and many studies have demonstrated that those with both low effortful control and high negative affect show the greatest risk for psychopathology (Muris 2006; Oldehinkel et al. 2007).

Effortful Control, RSA, and Negative Affect

Appropriate and adaptive responding to environmental stressors depends on the synchronicity of temperament, effortful control, and RSA. Thus, to understand observations or expressions of negative affect, reactive, physiological and cognitive regulatory processes need to be examined in conjunction with each other. In studies of emotion regulation, baseline RSA levels have been strongly correlated with stable temperamental features (Beauchaine, 2001; Sulik et al., 2013), whereas RSA reactivity levels have been more context dependent (Beauchaine, 2001). In a comprehensive literature review, Beauchaine et al. (2019) found that only negative emotion induction tasks (as opposed to neutral, positive emotion induction, or attention tasks) produced significant RSA withdrawal. This suggests that RSA baseline and withdrawal can facilitator our understanding of children's stable characteristics of reactivity and context-related regulation, respectively.

Further, RSA withdrawal has been shown to associate differentially with frustration/anger and fear. Children who are more anger-prone have greater RSA withdrawal when having to rely more on self-regulation than on external constraints (i.e. parental influence) (Miller et al., 2013). In contrast, children who are more fearful show less RSA withdrawal during fear-eliciting paradigms than non-fearful children (Brooker & Buss, 2010). Children of different temperamental constitutions and baseline measures of RSA may show RSA reactivity responses that are specifically adaptive to their level of physiological arousal to stimuli.

Finally, cognitively-based regulation, as indicated by effortful control may alter the associations of baseline RSA and RSA withdrawal with negative affect. In emotion eliciting contexts, physiological and cognitive regulation capacities might offset each other if an individual has greater capacity in one or the other. In an individual with lower RSA regulation, effortful control might be compensatory and mitigate affective displays or experiences, thus moderating observed associations between RSA and negative affect.

Present Study

The primary aim of the present study was to examine relations among RSA, effortful control, and negative reactivity. We hypothesized that effortful control would moderate the association of RSA with negative reactivity, such that children with greater effortful control would display less negative emotional reactivity regardless of their level of baseline RSA, whereas for children with low effortful control, there will be an inverse relation between baseline RSA and negative reactivity behavior. In other words, the association of baseline RSA with displays or tendencies toward negative emotional reactions will depend on effortful control, such that at low levels of effortful control, baseline RSA and negative reactivity will be significantly associated, and at high levels of effortful control, there will be no association. We predict the same pattern of effects for RSA reactivity, as there is typically a moderate to high correlation between RSA withdrawal and baseline scores (Calkins, 1997; Marcovitch et al., 2010). As the preschool years are ones of rapid change in the development of the stress response, effortful control, and emotion regulation,

a secondary aim was to determinate whether these patterns of effects remain consistent when children are ages 3 and 5 years old.

Method

Participants

Participants were 306 mothers and their 3-year old children (*M* = 3.06, *SD* = 0.07, Range = 2.96-3.36) who were part of a larger longitudinal study assessing relations among income, parenting, child effortful control, and child temperament over 4 time points. For the purposes of this study, we will be examining data from Time 1 when children were 3 and from Time 4 when children were 5 (*M* = 5.00*, SD* = 0.04*,* Range = 5.00–5.50*).* Families were locally recruited from hospitals and family-oriented organizations (including daycares, libraries, health clinics, and charitable agencies), and had to have reasonable proficiency in English to understand the consent and assessment procedures. Families of children with developmental disabilities were excluded. Participants were intentionally recruited to create a sample that stratified all income levels based on the 2009/2010 Federal HHS Poverty Guidelines, which uses an income-to-needs ratio based on household size. In our sample, 29% of families were at or near poverty (at or below 150% of the federal poverty threshold), 28% were lower income (below the local median income of $58K), 25% were middle- to upper income (between $58K and $100K), and 18% were upper income (above $100K).

Of the children, 50% were girls. The composition of child race and ethnicity was 2% Native American, 3% Asian American, 9% African American, 10% Hispanic/Latino, 64% European American, and 12% other or multiple backgrounds. Mothers' educational achievement was 3% with some high school, 6% high school graduates, 34% with some college or trade school, 30% college graduates, 27% with postgraduate education. Eighty-one percent of mothers were married or in long-term relationships, 12% were never married, and 7% were divorced, separated, or widowed.

Procedures

Mothers and their children were assessed in offices at the University of Washington where they completed questionnaires, physiological recordings, and observational assessments for each time point

(T1-T4). All components of the study were approved by the University of Washington Institutional Review Board (IRB). Prior to data collection all parents and children completed consent and assent, respectively. To collect electrocardiograph (ECG) data, experimenters assisted children in applying ECG leads and a respiration belt. Once the child was situated, the first ECG baseline (a neutral story read to the child by the experimenter for 3.5 minutes) was collected. After, the child completed a battery of attentional and inhibitory effortful control tasks which were immediately followed by 1-minute RSA recovery recordings. Subsequent to these tasks, children completed the fear eliciting task and the frustration eliciting task, with 1-minute recoveries directly after each. Mothers were read questionnaire instructions and items about family demographics and their child's temperament by trained interviewers in an adjacent room.

Measures

Effortful Control. Effortful control was assessed using several commonly used effortful function tasks to measure attention regulation, inhibitory control, and set shifting. During the Children's Stroop Test (Gerstadt, Hong, & Diamond, 1994) the child was shown a card with a picture of a sun or a card with a picture of a moon and stars. When presented with a sun, the child was instructed to say "night" (inhibiting their prepotent response to say "day") and when presented with a moon and stars they were instructed to say "day". The child's score was calculated as 0 for an incorrect response, and 1 for a correct response, with total scores being the proportion correct out of the number of trials.

During the NEPSY Inhibition task the child was taught only to touch the red circle (on a page containing black, blue, yellow, and red circles) when they heard the word "red". Children listened to a CD which contained 45 words, including color-associated ones, and were scored with a 1 when they correctly touched the red circle after hearing the word "red" or when they did not touch a circle when a word other than "red" was played.

In the Dimensional Change Card Sort Task (Zelazo et al., 2003) children were instructed to first sort cards into a bin based on either the shape on the card (a star or a truck) for the first 6 trials or the color of the card (blue or red) for the second 6 trials. If successful on 50% or more of these trials, children

were advanced to the next set of trials where the shape was colored blue or red on a white background. Children were told to again sort the card based on shape (6 trials) then to sort based on color (6 trials). If successful at this level, children were advanced to a final level where they were presented with 12 new cards with either a border or no border. If the card had a border, the child was told to sort the card by shape. If the card had no border the child was told to sort by color. Total scores were calculated as the total correct out of all 36 possible trials.

The NEPSY Auditory Attention subtest was given as a continuous performance task which measured the child's ability to maintain and shift focus to the target auditory set while ignoring distractors.

Behavioral control was measured by both the Bear-Dragon task (Kochanska et al., 1996) and the Head, Toes, Knees, Shoulders (HTKS) task (Ponitz et al., 2009). During the Bear-Dragon task, children were introduced to two puppets, a "nice monkey" (which replaced the bear in our study) and a "naughty dragon". Children were taught to do what the monkey said, but not to do what the dragon said. During the test trials the children were given 10 command (5 by the monkey and 5 by the dragon in random order). Children received scores ranging from 0 to 3, with 0 = no movement, 1 = wrong movement, 2 = partial correct movement, and 3 = full, correct movement for commands given by the monkey. These scores were reversed for commands given by the dragon. For the HTKS task children were taught to do the opposite of what the experimenter told them to do (e.g. touch their head when told to touch their toes). Children were scored on a scale of 0 to 2, with 0 being touching the wrong body part or not doing anything, 1 being if the child touched the wrong body part, but self-corrected, and 2 being if the child touched the correct (opposite) body part.

A composite score for effortful control was the mean of th e the proportion scores of the individual tasks.

Negative Reactivity. To assess fear response, we measured child behavioral fear expression and latency of touch to a fake spider which jumped as the child approached it. Children were prompted three times to touch the spider, and fear was coded by reaction intensity on a scale of 0 (*no observed response*)

to 2 (*obvious, strong response*) based on child vocalizations, facial expressions, and bodily motions. Latency to touch the spider was measured as the seconds between the end of the experimenter prompt and the child's touching the spider. Latency scores ranged from ranged from 0 to 5 seconds. A composite fear response score was computed as the average fear response across the three prompts accounting for latency. At each time point Cronbach's alpha for the scale items was T1=.91 & T4 = .92. The interrater intraclass correlation (ICC) was calculated based on double coding of 20 percent all cases for each timepoint (T1 = .98).

Two tasks, the locked box and knotted sack, were used to induce frustration in children. The use of these tasks was alternated to reduce the likelihood of the child remembering the task from one assessment timepoint to the next. The locked box task was used at Time 1, and during this task children were presented with an attractive toy in a transparent, locked box. Children were given nonworking keys and were told to try and open the box for 2 minutes without the experimenter's help. The knotted sack task was used at Time 4, and during this task children were given a knotted shut sack (that had also previously been sewn closed) and were instructed to open it in order to receive a prize. Children were instructed to work on opening the sack for 2.5 minutes without the experimenter's help. Frustration intensity ranging from 0 (*no observed response*) to 2 (*obvious, strong response*) was coded during 30-second epochs based on observed vocalizations, facial expressions, body motions, and experimenter-directed annoyance. Appropriate child bids to the experimenter for help were included in frustration scores. Composite frustration scores were calculated as the overall rated frustration across all epochs. At each timepoint Cronbach's alpha for the scale items was T1=.83, T4 = .75. The interrater intraclass correlation (ICC) was calculated based on double coding of 20 percent all cases for each timepoint (T1 = .78).

RSA. RSA data was obtained from children through a 2-lead electrocardiograph (ECG) and respiratory band (Biopac PRO Lab 3.7.1, Goleta, CA). Experimenters placed electrodes on the child's lower left abdomen, right clavicle and upper left chest, and helped the child fit the respiratory band around their ribcage. RSA processing was performed in accordance to Porges' methods (1985). ECG and

respiratory data were acquired using AcqKnowledge software (Goleta, CA) and then exported with task start and end time stamps. These data were imported into a custom-purpose Matlab software program and were then overlaid with inter-beat intervals (IBI), defined as the time in milliseconds between R-waves. The software was used to assess the accuracy of AcqKnowledge's beat detection algorithm. Epochs containing mechanical artifacts or electrical interference that obscured the detection of R-waves were excluded from analyses. To apply a high-pass filter, remaining and corrected IBI series were then resampled at 2.8 Hz and filtered with a 21-point, 3rd order polynomial (Litvack et al., 1995). These segments were then converted into coefficients using fast-fourier transformation. This last step of processing produced RSA scores, which account for age-specific respiration frequency (typical range: 0.24 to 1.04 Hz) for children.

Analytic Plan

We first examined correlations among effortful control composite scores, RSA, and negative reactivity across the two emotion induction tasks. In order to evaluate main effects of RSA and effortful control on negative reactivity, as well as their interaction effects, we used a Full Information Maximum Likelihood Estimation (FIMLE) regression approach in Mplus 8.4 (Muthén & Muthén, 2017) which preserves power by including all cases which contain data. Maximum likelihood (ML) is a popular method of statistical estimation due to three properties which increase with sample size 1) ML estimates which move toward the unknown true population parameter values; 2) approximately normal sampling distributions; and 3) smaller standard errors than are produced by other estimation method (Singer & Willett, 2003). Separate regression models were conducted for each outcome, that is, observed fear and frustration at times 1 and 4, and each regression included the linear and quadratic RSA term (either baseline or reactivity), effortful control, and two interaction terms: effortful control x the linear RSA effect and effortful control x the quadratic RSA effect. This resulted in a total of 8 regressions. In all analyses, child sex was included as a covariate and, in models of time 4 outcomes, time 1 measures of those outcomes were also controlled for.

Results

Correlations

Zero-order correlations are presented in Table 1. Baseline RSA was positively related to both effortful control (r = .14) and observed fear (r = .21), but was not related to observed frustration. As would be expected since RSA reactivity scores are derived by subtracting task RSA from baseline RSA, the RSA reactivity scores for fear (r = .39) and frustration (r = .47) tasks were correlated with baseline RSA. Additionally, RSA reactivity scores for fear and frustration were positively associated (r = .29) with each other. Regarding observed emotion, time 1 fear was correlated with time 4 fear (r = .35), however, time 1 and time 4 frustration were not associated with each other.

Regression Analyses

Baseline RSA Predicting Fear. Sex was a significant predictor of Time 1 (age 3) fear (β = -0.12, p = 0.020) as girls were rated higher in fear than boys (see Table 2). Holding the effects of sex and other covariates constant, Time 1 baseline RSA predicted Time 1 fear (β = 0.18, p = 0.005) such that children with greater baseline RSA also showed greater fear. In addition the interaction of the quadratic baseline RSA term and effortful control (RSA BL^2 x EC), was significant (β = -0.18, p = 0.046). This moderation effect is illustrated in Figure 1 using an application developed by McCabe, Kim, & King (2018), and shows a stronger, curvilinear association between baseline RSA and effortful control at -1 SD effortful control than at either mean levels or at +1 SD of effortful control. When probed, using the Johnson-Neyman approach (Johsnon & Neyman, 1936) visualized using Mplus 8.4 (Muthén & Muthén, 2017), the marginal effects (see Figure 3) show that the slope of baseline RSA on fear was significant and positive for levels of effortful control that were less than or equal to -0.1 SD below the mean. No other main effects or interaction effects in this model were significant.

In predicting relative changes in fear at Time 4, Time 1 fear (β = 0.39, p < 0.001) positively predicted Time 4 fear, showing continuity in average fear from age 3 to age 5. In contrast to the concurrent model of fear, sex was not a significant predictor of changes in fear at Time 4. The moderation effect of EC on baseline RSA^2 (RSA BL^2 x EC) in predicting Time 4 fear was significant (β = 0.16, p =

0.035) and was visualized using the same approach as was noted above. The marginal effects plot shows that the slope of baseline RSA on Time 4 fear was only significant for levels of effortful control between the mean and 1.9 SD above the mean. See Table 3 and Figures 2 & 4.

RSA Reactivity Predicting Fear. Only prior levels of fear at Time 1 predicted fear at Time 4 ($\beta = 0.36$, $p < 0.001$) when including RSA reactivity in the model (see Table 3). There were no other main or interactive effects.

Baseline RSA Predicting Frustration. Males displayed higher levels of frustration than females at both Time 1 ($\beta = 0.11$, $p = 0.052$) and Time 4 ($\beta = 0.13$, $p = 0.035$) (see Table 4). There were no other main or interactive effects in this predicting frustration when baseline RSA was examined.

RSA Reactivity Predicting Frustration. Mirroring the findings using baseline RSA, when RSA reactivity was used as a predictor only sex in the Time 1 ($\beta = 0.11$, $p = 0.057$) and Time 4 ($\beta = 0.13$, $p = 0.032$) models was a significant predictor frustration. Males demonstrated more frustration than females. (See Table 5). There were no other main or interactive effects in this model predicting frustration when baseline RSA was examined.

Discussion

In this study, we tested whether effortful control would moderate the relation between RSA and temperamental fear and frustration reactive behaviors. Given relatively recent work that has highlighted the potential importance of accounting for quadratic effects when examining RSA data (Holzman & Bridgett, 2017) and a plethora of studies with mixed effects (some showing linear effects, quadratic effects, and no effects at all), this study may be of particular import. Additionally, as this study examines emotional reactivity as it relates to both biological and cognitive functioning, it may further elucidate whether there is perceivable parallelism between the functions of distinguishable systems which underlie emotional regulation. Overall, we found partial support for our hypotheses. Though we expected the same pattern of effects for both baseline RSA and RSA reactivity as predictors of fear and frustration respectively, it was only for concurrent fear that we found no relations between baseline RSA and fear at higher levels of EC and a quadratic association between them at lower levels of EC. For prospective fear,

however, we found a positive curvilinear effect (a U-shaped association) of RSA^2 across average and higher than average levels of effortful control. There were no moderation effects of EC when examining the relations of 1) baseline RSA with frustration and 2) RSA reactivity with fear or frustration reactivity. Though these findings should be interpreted with caution given the confluence of null effects across models and the unexpected directionality, these findings may suggest that a possible buffering effect of EC on emotional reactivity may be specific to fear as opposed to frustration reactivity.

There is a robust literature that converges on the idea that parasympathetic activity (as measured by RSA) can be moderated by a number of situational factors (see Beauchaine et al., 2019 for a review) and that it can be an important moderator of the impact of critical areas of support for children (e.g. parenting practices) on indices of child development in multiple domains (Buss et al., 2018; Davis et al., 2016; Peltola et al., 2016). In line with these findings, in our study, age 3 effortful control moderated the effect of baseline RSA^2 on predicting concurrent fear. Specifically, children with poorer effortful control and with average effortful control showed greater levels of fear when they had below or above average levels of baseline RSA (depicted as a U-shaped relation). What is curious about this finding is that, in direct contrast to what we might have expected, at lower levels of effortful control and higher levels of baseline RSA we observed greater fear as opposed to lower fear. Based on the biological sensitivity to context theory (Boyce & Ellis, 2005), we would have thought that, even in cases of low EC, heightened BL RSA, as another regulatory strategy, might have had a protective effect in lowering fear and frustration reactivity. Given that we did not see this pattern of associations, we suggest using care when interpreting these results. It is within the realm of possibility that these results could be false positives, and thus they beg replication in order to test their accuracy. It is also possible that these effects give us some insight into what might be happening in our dataset. Though we controlled for sex in all of our models, we may have seen a clearer picture of what our data may be suggesting had we used separate models for males and females. There are several studies that have found sex differences when analyzing baseline RSA. For example, though Eisenberg et al. (1995) found that high baseline RSA associated with better emotion regulation for boys, for girls, they found an opposite effect such that high baseline RSA

correlated with poorer emotion regulation. It could be that, because we included both males and females in our models, we see increased fear at both extremes of baseline RSA because the low end represents more males and the high end represents more females. In future studies, it may be worthwhile to analyze male and female data separately.

Prospectively, the moderation effect of age 3 effortful control on the relation between age 3 baseline RSA^2 and age 5 fear was also significant. Similar to the moderation effect seen on age 3 fear, there was a U-shaped relation between fear and baseline RSA at different levels of effortful control, meaning that children with near average and average levels of baseline RSA showed the least fear. This interaction differs from the interaction we found when predicting concurrent fear, however, in that, at above average levels of EC we still saw a relation between baseline RSA and fear. As we suggested with the effects found for age 3 fear, these finding should be considered with caution. It could be that children at either end of the continuum of baseline RSA have poorer control over their affect, though it could also be the case that these findings are false positives. Confidence in these effects would also benefit from replication.

Though prior research has demonstrated stronger links between frustration (as opposed to fear) and ANS reactivity (Cacioppo et al., 2000), when we examining frustration, sex was the only significant predictor in both the concurrent and predictive models using baseline RSA or RSA reactivity. At both ages 3 and 5, boys showed higher levels of observed frustration than girls. This difference makes good sense given robust findings that suggest that boys typically show greater levels of frustration than girls, especially in the preschool years (VanSchyndel et al., 2017). One possible explanation for the multitude of null effects in our models exploring frustration is that children may have differed in their comfort with showing frustration to our research assistants. Zeman & Shipman (1996) demonstrated that children strategically use emotions to communicate with others and that children express emotion differentially to mothers, fathers, and peers. This study also found that children perceived differences between others in their acceptance of displays of anger. It might have been that, as children only had an unfamiliar research assistant with them during the frustrating tasks, they chose not to show frustration even if they felt it.

Prior work has shown that regulation strategies sometimes result in reductions in frustration, but rarely in reductions of fear (Buss & Goldsmith, 1998), meaning that children may have more inconsistently shown displays of frustration than fear when they felt it.

The confluence of null effects for models using RSA reactivity and assessing concurrent and prospective effects for fear and frustration was surprising given that RSA reactivity was collected simultaneously with observed fear and frustration. Because children's RSA and emotional responses were recorded while they were engaged in the scary and frustrating tasks, we would have thought that there would be a relation between the two, such that children with greater RSA reactivity (and thus more engagement of their ANS) might have better control and show less affect. The fact that this was not the case comes into contrast with literature showing that RSA reactivity can buffer relations between facets of temperament and psychopathology characterized by emotions like fear and frustration (Morales et al., 2015). However, other studies have also found inconsistent associations between autonomic nervous system (ANS) reactivity and affect. Quas et al. (2000) found that it was only among girls with moderate physiological reactivity (as opposed to among boys or children with more extreme physiologic responses) that there was a concurrent relation between physiologic reactivity and negative affect.

This study leveraged a number of strengths. We were careful in our measurement of effortful control and used a composite of multiple indices which assessed abilities in attentional control, inhibitory control, behavioral control, attention shifting, and working memory. We were also thoughtful in our collection of simultaneous affect and physiological data in the hopes of better understanding the complex processes involved in emotional expression. As suggested by recent reviews, (Graziano & Derefinko, 2013; Holzman & Bridgett, 2017) we examined the utility of including a quadratic term for RSA in our analyses and found that it may be important in understanding certain associations. Lastly, our study used an appropriately large sample which was carefully selected to be representative of a wide range of incomes, as income has been associated with effortful control among other critical aspects of child self-regulation (Lengua et al., 2015; Mezzacappa, 2004)

Though this study was conducted using rigorous methods, we acknowledge a number of limitations. We measured emotional and physiological reactivity to the fear- and frustration-inducing tasks, however, we did not measure behavioral regulation strategies. For instance, in the scary spider task, children may have utilized strategies such as physical distancing from the spider, reassurance seeking, and gaze aversion to reduce their fear and, in the locked box and knotted sack tasks, a strategy like disengaging from the task may have provided an alternative means of emotional regulation. However, it is possible that only a small number of children would have used this type of strategy as children more often engage than disengage in fear and frustration-evoking situations (Uhl et al., 2019). Another limitation was that we did not collect subjective measures of fear and frustration after the emotion-induction tasks. Though children's affective and physiological responses were recorded simultaneously, there is evidence to suggest that there is discordance between these types of emotion measurement and subjective experience (Quas et al., 2000). We intentionally used different frustration-inducing tasks at times 1 and 4 to reduce the likelihood of children remembering that the tasks were impossible, however, that may have added additional variance in our data which was not controlled for in these analyses. Finally, a growing literature is suggesting that another potential source of variation in RSA data comes from different task demands which may result in unmeasured effects due to differences in gross motor behavior across tasks (Bush et al., 2011).

Conclusion

The ability to regulate one's emotions relies on the complex integration of biologically-based predispositions for experiencing certain emotions above others (reactive temperament), cognitive capacities (effortful control), and biological regulation (ANS activity). This study sought to better understand the contributions of some of these processes in determining emotional expression through analyzing potential interactive effects. We found that, for younger children, there may be a buffering effect of effortful control such that, for children of high effortful control, having low RSA is not related with showing greater fear. As the findings of this study were somewhat surprising given prior literature, the field would benefit from replication studies. Future studies may also look to advance our

understanding of these complex systems which serve emotional regulation by assessing both emotion and RSA using a dynamics approach where both the rises and falls of emotional and RSA reactivity are analyzed in synchrony so as to provide a finer understanding of the sequences of these reactions (Miller et al., 2013). There should also be support for additional work aimed at explicating how reciprocal activation of the parasympathetic (RSA) and sympathetic (measured as pre-ejection period, "PEP") systems contribute to our conceptualization of emotional processing (Stifter, Dollar, & Cipriano, 2011) given individual differences in effortful control and temperament. Though the findings from this study should be interpreted with care, they add to a growing literature that continues to provide support for the utility of understanding for what types of children (considering temperament and age) what types of interventions may be most beneficial.

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Table 1. Descriptive Statistics and Correlations for Study Variables

	Variable	*M(SD) or %*	*1*	2	3	4	5	6	7	8	9
1	Sex (1 = male)	*50%*	*1*								
2	T1 EC	0.29 (0.02)	-0.07	1							
3	T1 RSA BL	5.91 (1.40)	-0.06	**0.14**	1						
4	T1 RSA-R Fear	0.03 (1.00)	-0.04	-0.01	**0.39**	1					
5	T1 RSA-R Frustration	0.27 (0.74)	-0.04	0.02	**0.47**	**0.29**	1				
6	T1 Obs Fear	0.36 (0.08)	-0.12	-0.01	**0.21**	-0.03	-0.15	1			
7	T1 Obs Frustration	0.27 (0.02)	0.11	0.01	0.1	-0.02	-0.05	0.07	1		
8	T4 Obs Fear	0.46 (0.30)	-0.07	-0.10	0.01	-0.01	-0.14	**0.35**	0.01	1	
9	T4 Obs Frustration	0.25 (0.16)	0.11	-0.05	-0.02	0.15	-0.13	-0.05	0.05	0.11	1

Note: Boldface indicates p < 05. M represents mean and SD represents standard deviation.

Table 2. RSA BL Regression Analyses Predicting Fear

	Concurrent (T1) Observed Fear			**Prospective (T4) Observed Fear**		
	β	SE	p	β	SE	p
T1 Observed Fear				**0.39**	**0.06**	**<0.000**
Sex (1 = male)	**-0.12**	**0.06**	**0.020**	-0.04	0.06	0.487
T1 EC	0.07	0.08	0.480	**-0.18**	**0.07**	**0.009**
T1 RSA BL	**0.18**	**0.07**	**0.005**	-0.09	0.06	0.149
RSA BL x EC	-0.12	0.07	0.078	0.06	0.6	0.415
RSA-BL^2	0.13	0.07	0.052	**0.15**	**0.06**	**0.023**
RSA BL^2 x EC	**-0.18**	**0.09**	**0.046**	**0.16**	**0.08**	**0.035**

Note: Boldface indicates p < 05.

Table 3. RSA-R Regression Analyses Predicting Fear

	Concurrent (T1) Observed Fear			**Prospective (T4) Observed Fear**		
	β	SE	p	β	SE	p
T1 Observed Fear				**0.36**	**0.05**	**<0.001**
Sex (1 = male)	**-0.12**	**0.06**	**0.042**	-0.05	0.06	0.380
T1 EC	-0.06	0.08	0.419	-0.12	0.07	0.109
T1 (RSA-R) Fear	0.02	0.07	0.779	-0.08	0.08	0.262
RSA-R x EC	-0.05	0.08	0.492	0.05	0.08	0.556
RSA-R^2	0.04	0.07	0.585	0.02	0.08	0.830
RSA-R^2 x EC	0.04	0.09	0.626	0.02	0.09	0.864

Note: Boldface indicates p < 05.

Table 4. RSA BL Regression Analyses Predicting Frustration

	Concurrent (T1) Observed Frustration			**Prospective (T4) Observed Frustration**		
	β	SE	p	*β*	SE	p
T1 Observed Frustration				0.06	0.06	0.303
Sex (1 = male)	*0.11*	*0.06*	*0.052*	**0.13**	**0.06**	**0.035**
T1 EC	-0.01	0.08	0.922	-0.09	0.08	0.231
T1 RSA BL	-0.08	0.07	0.272	-0.04	0.07	0.568
RSA BL x EC	-0.12	0.08	0.134	0.03	0.07	0.726
RSA BL^2	-0.02	0.07	0.790	0.02	0.07	0.826
RSA BL^2 x EC	0.02	0.10	0.862	0.06	0.09	0.465

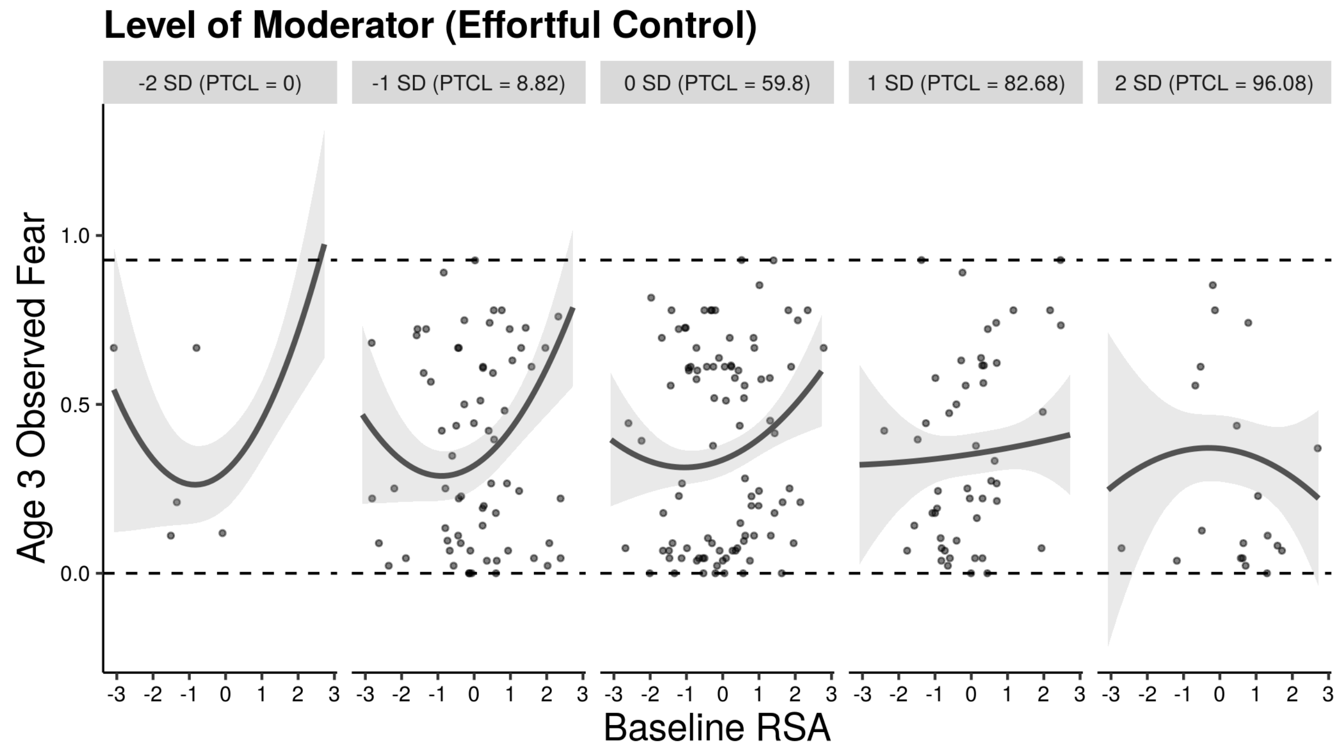
Note: Boldface indicates p < 05. Italics indicate p < .10.

Table 5. RSA-R Regression Analyses Predicting Frustration

	Concurrent (T1) Observed Frustration			**Prospective (T4) Observed Frustration**		
	β	SE	p	*β*	SE	p
T1 Observed Frustration				0.04	0.06	0.483
Sex (1 = male)	*0.11*	*0.06*	*0.057*	**0.13**	**0.06**	**0.032**
T1 EC	0.04	0.07	0.604	-0.06	0.07	0.419
T1 (RSA-R) Frustration	0.04	0.08	0.629	-0.04	0.08	0.679
RSA-R x EC	-0.07	0.08	0.397	-0.08	0.08	0.321
RSA-R^2	-0.03	0.08	0.752	-0.07	0.08	0.404
RSA-R^2 x EC	-0.08	0.09	0.352	0.03	0.09	0.743

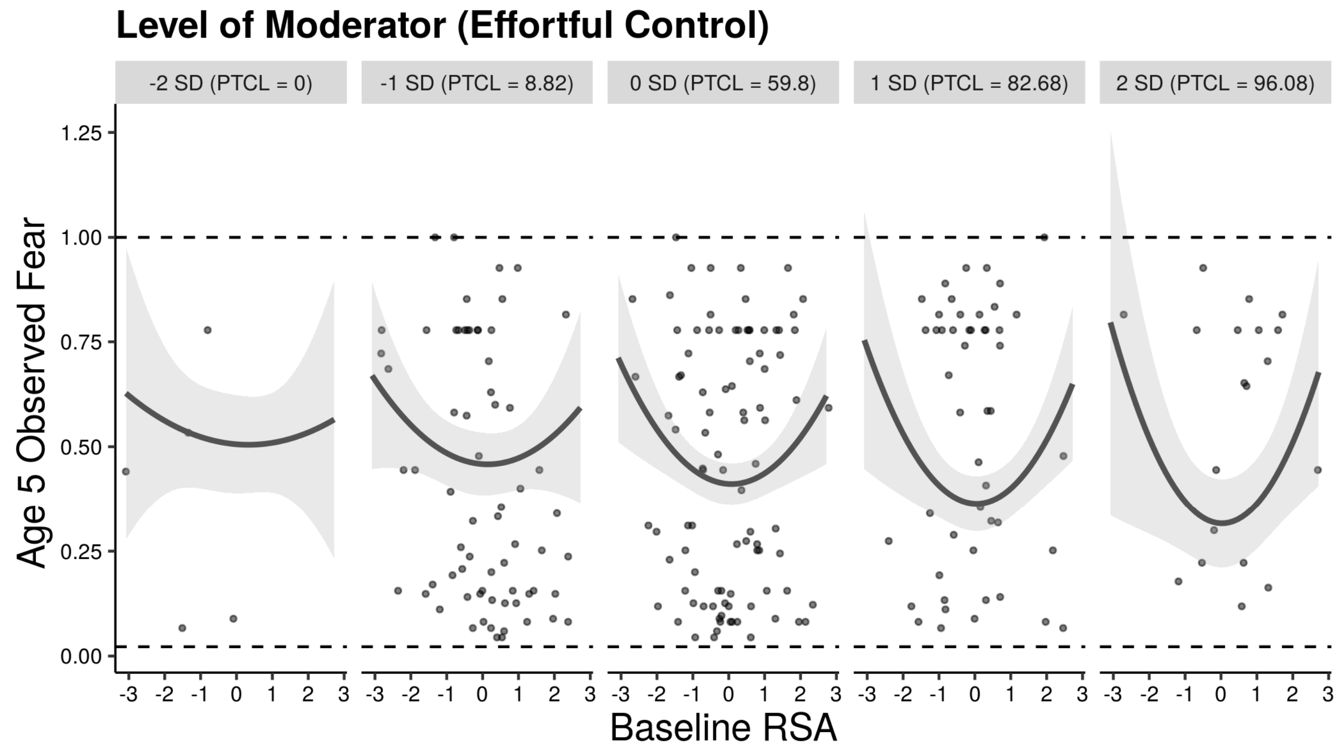
Note: Boldface indicates p < 05. Italics indicate p < .10.

Figure 1. Quadratic moderation effect of effortful control on baseline RSA and Age 3 Fear



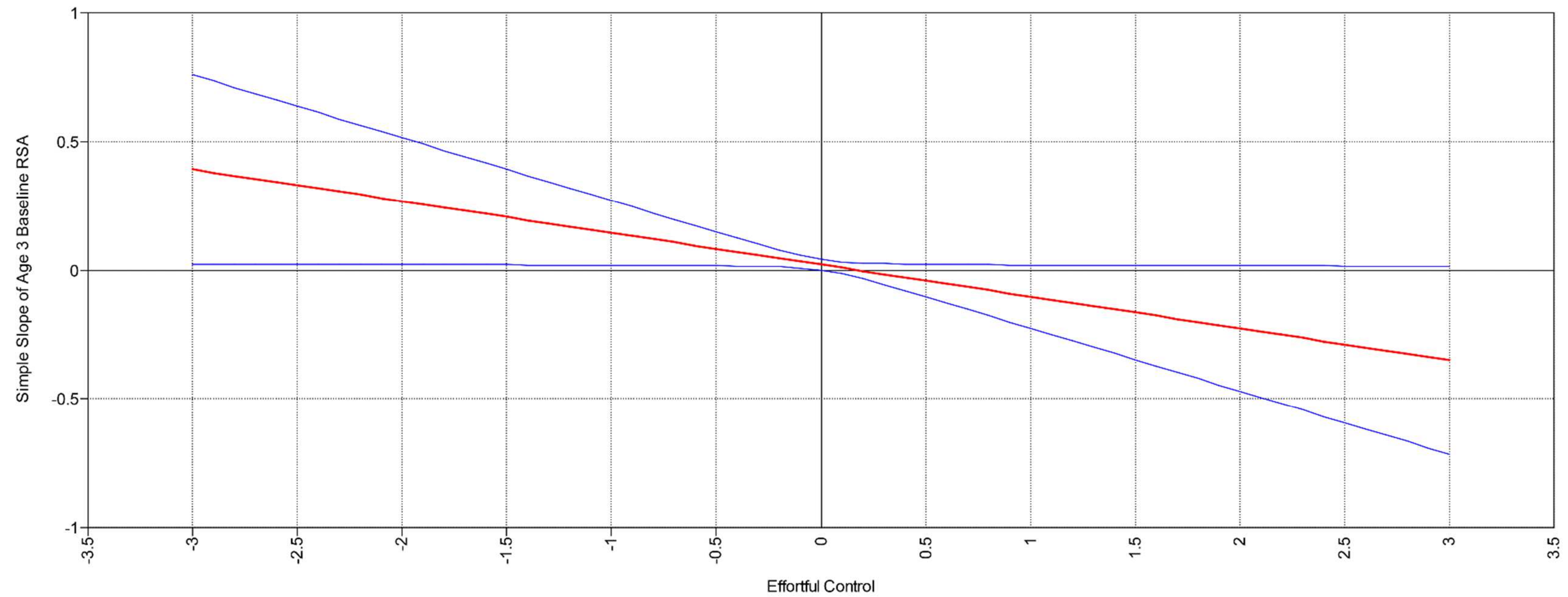
The solid, dark lines indicate the model estimates for fear and the light grey band represents the 95% confidence interval of those estimates. SD = standard deviation, PTCL = percentile.

Figure 2. Quadratic moderation effect of effortful control on baseline RSA and Age 5 Fear



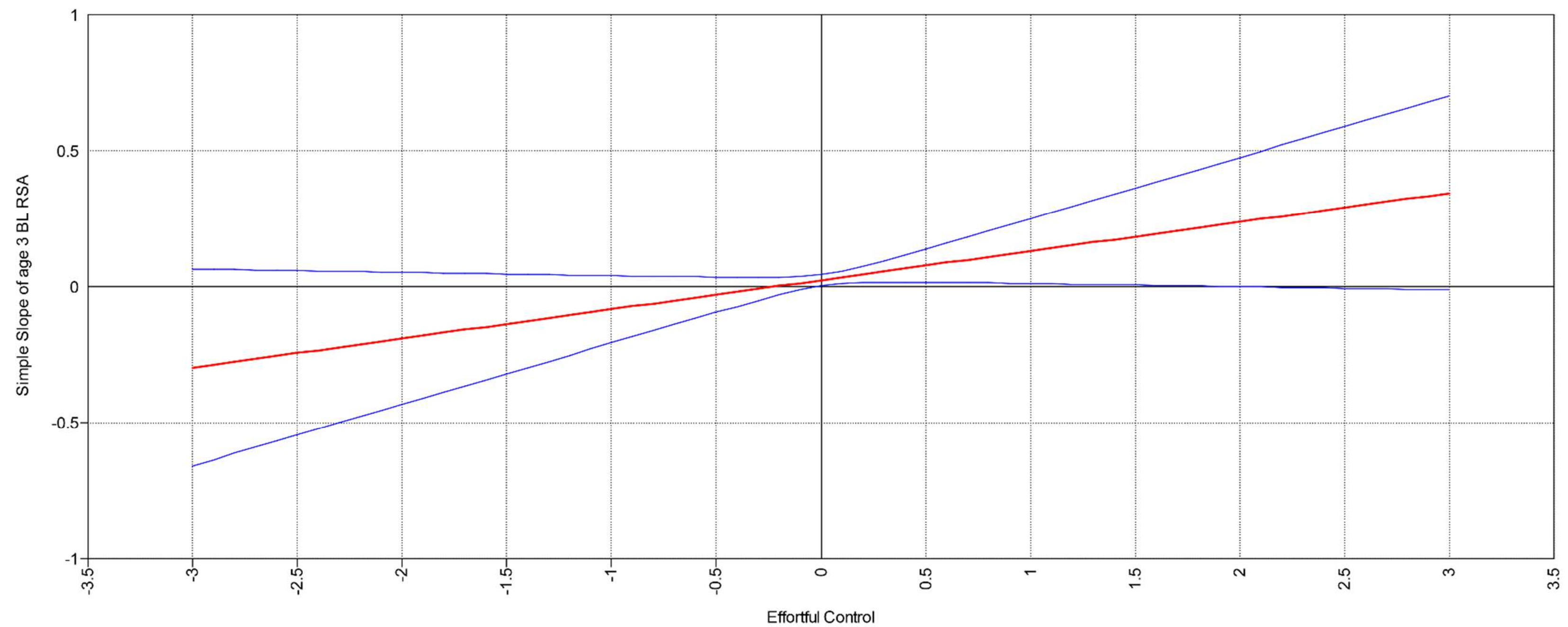
The solid, dark lines indicate the model estimates for fear and the light grey band represents the 95% confidence interval of those estimates. SD = standard deviation, PTCL = percentile.

Figure 3. Marginal effects plot for the interaction between BL RSA and EC predicting Age 3 Fear



The simple slope of baseline RSA is significant and positive for children who have fear scores of -0.10 standard deviations below the mean and below. The red line depicts slope values of baseline RSA and the lower and upper blue lines represent the upper and lower bounds of the 95% confidence interval, respectively.

Figure 4. Marginal effects plot for the interaction between BL RSA and EC predicting Age 5 Fear



The simple slope of baseline RSA is significant and positive for children who have fear scores between the mean and 1.9 standard deviations above the mean. The red line depicts slope values of baseline RSA and the lower and upper blue lines represent the upper and lower bounds of the 95% confidence interval, respectively.