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Resting Vagal Tone and Vagal Response to Stress: Associations with Anxiety, Aggression and Perceived Anxiety Control among Youth

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Abstract

This study tested the associations of both resting vagal tone and vagal response to stress with anxiety control beliefs, anxiety, and aggression among 80 youth (aged 11-17 years). Measures included physiological assessments of emotion regulation along with youth self-report of anxiety control beliefs, anxiety, and aggression and caregiver reports of their child's anxiety and aggression. Resting vagal tone was positively related to anxiety control beliefs, but negatively associated with anxiety. Conversely, higher levels of anxiety and aggression were associated with increased vagal tone during a cognitive stress task. Findings suggest associations between physiological and self-report of emotion regulation (anxiety control beliefs) and that anxiety and aggression may have specific and non-specific relations with physiological indices of emotion regulation.

Keywords

vagal tone; heart rate variability; anxiety; aggression; perceived control; emotion regulation

Introduction

The identification of reliable and valid biological correlates of anxiety and aggression is a critical step toward classifying psychopathology based on dimensions of neurobiological function, cognition, and behavior (Cuthbert & Insel, 2013; Insel et al., 2010).

Psychobiological theories have suggested that resting vagal tone and change in vagal tone from resting baseline to stressor may be an important physiological index of emotional dysregulation, which is a characteristic of many emotional and behavioral problems (Porges, 2007, 2011; Thayer & Lane, 2000). For example, resting vagal tone is considered to be a measure of parasympathetic-mediated control of heart rate via the vagus nerve (i.e., tenth cranial nerve) and thought responsible for top-down emotion regulation through neurological structures (e.g., nucleus ambiguus, medial prefrontal cortex; Ochsner & Gross,

2005; Porges, 2007). Research has provided empirical support for using resting vagal tone as an indicator of one's actual ability to regulate emotional states (Butler, Wilhelm, & Gross, 2006; Gottman & Katz, 2002; Vasilev, Crowell, Beauchaine, Mead, & Gatzke-Kopp, 2009; Wetzell, Quigley, Morell, Eves, & Backs, 2006).

In addition to resting vagal tone, Porges (2007; 2011) suggests that individuals with emotional and behavioral problems have difficulty regulating emotional states during stressful events (i.e., change in vagal tone from rest to stress will predict emotional problems). For example, Weems, Zakem, Costa, Cannon, and Watts (2005) found that high anxious youth exhibited faster heart rates than low anxious youth following a mild stressor but there was no difference on heart rate during the resting baseline. Porges (2007) has postulated that vagal withdrawal (or suppression) during times of stress (i.e., decrease in vagal tone from a resting baseline to a stressful event) may be an adaptive response that helps one's biological system to adequately prepare for a challenging or stressful situation (i.e., increased arousal). Blunted vagal withdrawal or perhaps even an increase in vagal tone during stressful events may represent a maladaptive response associated with poor outcomes (e.g., anxiety or aggression). However, relatively little research has tested Porges's (2007; 2011) hypotheses of vagal response to stress using measures of anxiety or aggression among children and adolescents (i.e., ages 6-17 years). Thus, further research is needed to establish whether vagal response to stress is specifically (or non-specifically) related to anxiety- or aggression-related problems in youth. The following sections provide a review of the current state of knowledge about the association of both resting vagal tone and vagal response to stress with anxiety and aggression in youth.

Resting Vagal Tone and Anxiety

Past research has demonstrated that resting vagal tone differs among youth (ages 6-17 years) who suffer from anxiety disorders as compared to peers without an anxiety disorder. In particular, youth with anxiety disorders have been shown to exhibit lower resting vagal tone as compared to relatively non-anxious controls (Blom, Olsson, Serlachius, Ericson, & Ingvar, 2010; Sharma, Balhara, Sagar, Deepak, & Mehta, 2011). However, one drawback of simply comparing youth with and without an anxiety disorder is that the linear relation implied by the dimensional underpinning thesis (Cuthbert & Insel, 2013; Insel et al., 2010) is not established by such group comparisons. In fact, research examining the linear association between resting vagal tone and youths' anxiety among community samples has been inconsistent across studies. For instance, El-Sheikh and colleagues did not find a significant association between resting vagal tone and a measure of general manifest anxiety problems (i.e., Revised Child Manifest Anxiety Scale; RCMAS; Reynolds & Richmond, 1978) in four studies (El-Sheikh, Arsiwalla, Hinnant, & Erath, 2011; El-Sheikh, Harger, & Whitson, 2001; El-Sheikh & Whitson, 2006; Wetter & El-Sheikh, 2012), but did find a negative association between resting vagal tone and anxiety in another study (El-Sheikh et al., 2011, Study 2). Greave-Lord and colleagues (Greaves-Lord et al., 2007; Greaves-Lord et al., 2010) also reported finding a significant negative association between resting vagal tone and a measure of anxiety symptoms based on DSM-IV (APA, 1994) criteria (Revised Child Anxiety and Depression Scale; RCADS-C; Chorpita, Yim, Moffitt, Umemoto, & Francis, 2000) for boys both concurrently and longitudinally, but not for girls, suggesting gender

specificity. These inconsistencies may be largely due to differences in the measure used to assess anxiety. That is, resting vagal tone may be more closely associated with anxiety symptoms that are clinical in nature as opposed to more general anxiety (non-clinical levels) that may be experienced by a greater number of youth. Alternatively, there may be a gender-specific nature of the relationship between resting vagal tone and anxiety problems such that it is more prominent in boys.

Resting Vagal Tone and Aggression

While the exact nature of the relationship between resting vagal tone and aggression is still not quite clear, there seems to be accumulating evidence to support a negative association between resting vagal tone and aggression-related behaviors mainly in boys (Gordis, Feres, Oleski, Rabkin, & Trickett, 2010; Mezzacappa et al., 1997; Pine et al., 1998). For example, Mezzacappa et al. (1997) found that resting vagal tone was negatively associated with antisocial behavior in a sample of 15-year-old adolescent boys, and Pine et al. (1998) reported that lower resting vagal tone was associated with externalizing problems among 62 adolescent boys at risk for delinquency (7-11 years of age). Similarly, Gordis et al. (2010) reported that among a sample of 362 mixed gender youth (9-16 years of age) resting vagal tone was associated with aggressive behavior problems for boys (but not girls), even after controlling for a history of maltreatment exposure (boys: $\beta = -.21, p < .05$; girls: $\beta = -.11, p > .05$). Beauchaine, Hong, and Marsh (2008) also found that 8 to 12 year-old boys (but not girls) with conduct problems whose parents reported them as exhibiting high aggression had lower resting vagal tone than boys who exhibited lower aggression.

Vagal Response to Stress: Relations with Anxiety

Relatively little work has investigated whether there is a relationship between vagal response to stress and anxiety or aggression problems in children and adolescents (ages 6-17 years). We found only three studies that have specifically examined the association between vagal response to stress and anxiety in youth when controlling for resting baseline measures of vagal tone and once again the findings are inconsistent across studies. Monk et al. (2001) did not find that anxiety-disordered youth (9-18 years of age) exhibited a change of vagal tone from baseline to CO₂ challenge that was significantly different from healthy controls. El-Sheikh et al. (2011) also did not find a linear association between youth's (8-12 years of age) vagal response to stress and anxiety problems using the RCMAS. However, Greaves-Lord et al. (2010) did report finding a longitudinal association between vagal response to stress (obtained when children were 10-12 years of age) and anxiety symptoms based on DSM-IV criteria using the RCADS-C. They found that low vagal reactivity (i.e., blunted vagal withdrawal from resting baseline to stressor) predicted anxiety symptoms two years later (12-14 years of age) and that the relationship was only significant for girls. As noted, Weems et al. (2005) found that heart rate change in response to stress predicted anxiety levels but that study did not measure change in vagal tone in response to stress. One of the advantages of measuring vagal response to stress is that it provides a more specific index of emotional control whereas change in heart rate may represent either emotional reactivity (sympathetic-mediated) or emotional regulation (parasympathetic-mediated).

Vagal Response to Stress: Relations with Aggression

No studies to our knowledge have examined the association of change in vagal tone with aggression. However, a few studies have examined the association between vagal response to stress and more broad measures of externalizing problems in both children and adolescents. For example, Boyce et al. (2001) found that youth reporting more externalizing problems exhibited less vagal withdrawal (or suppression) than youth with low externalizing problems in a sample of 122 youth (ages 6-7 years). El-Sheikh and colleagues (El-Sheikh et al., 2001; Hinnant & El-Sheikh, 2009) reported a similar finding in that greater vagal withdrawal (or suppression) was associated with less externalizing problems ($\beta = -79.55$, $p < .05$) in 8-12 year-old youth ($n = 75$) and that lower resting vagal tone interacted with vagal response to stress (i.e., less vagal withdrawal) to predict more externalizing symptoms two years after the initial physiological assessment (from third to fifth grade). However, El-Sheikh and colleagues have also reported not finding an association between vagal response to stress and externalizing problems in two independent samples of youth (6-12 years of age; El-Sheikh et al., 2001; El-Sheikh & Whitson, 2006). One possible reason for these inconsistencies may once again lie with the type of measure being used (broad measure of externalizing problems versus aggression). Thus, studies utilizing specific measures of aggression are needed.

The Present Study

The aim of this study was to test a theoretical model (Porges, 2007, 2011) that postulates two physiological indices of emotion regulation (i.e., resting vagal tone and vagal response to stress) are associated with youths' emotional and behavioral problems. Specifically, we wanted to test this model among a sample of youth who are likely to show wider and more normally distributed levels of anxiety symptoms and aggressive behavior. Theoretically, youth samples that include those who have experienced a traumatic event or a natural disaster (e.g., directly exposed, evacuated and then returned to damaged communities) may show such distributions given youth who experience a natural disaster and/or other traumas often show elevated levels of anxiety and aggression (see Copeland, Keeler, Angold, & Costello, 2007; Scott, Lapre, Marsee, & Weems, 2014; Weems et al., 2007). Moreover, we sought to extend the literature by linking the research on self-reports of perceived control (perceived emotion regulation) with the work on physiological indices of actual emotion regulation. Evidence strongly suggests that low perceptions of control over anxiety may be an underlying risk factor for emotion dysregulation seen in anxiety and aggression (Weems & Silverman, 2006; Weems, Silverman, Rapee, & Pina, 2003). However, the relationship of anxiety control beliefs with biological indices of control (i.e., vagal tone) has not been empirically tested.

Furthermore, research to date has not clearly established if resting vagal tone or vagal response to stress are related to dimensional indices of anxiety or aggression among youth who have reported experiencing a natural disaster or exposed to a traumatic event. Initial findings suggest there may be an association between physiological measures of emotional dysregulation and both anxiety and aggression in these youth (Gordis et al., 2010; Scarpa, Tanaka, & Haden, 2008). For example, Scheeringa and colleagues found that young children with a diagnosis of PTSD or who experienced subclinical symptoms of PTSD had higher

heart rates during recall of their trauma memories than non-traumatized controls (Scheeringa, Zeanah, Myers, & Putnam, 2004). Given seemingly inconsistent findings across studies and few with youth who have experienced a natural disaster or exposed to a traumatic event, we chose to draw heavily on Porges's (2007; 2011) polyvagal theory in formulating our specific hypotheses. We hypothesized that:

1. Anxiety would be negatively associated with resting vagal tone.
2. Aggression would be negatively associated with resting vagal tone but only for boys.
3. Anxiety control beliefs would be positively associated with resting vagal tone.
4. Blunted vagal withdrawal (suppression) or increase in vagal tone from baseline measures to a stress task would be associated with greater anxiety and aggression as well as less perceived control over anxiety.

Method and Materials

Participants

Ninety six caregiver-youth dyads (80 caregivers and 96 youth) from New Orleans and the surrounding area participated in this study. Recruitment procedures entailed (1) distributing flyers in local intermediate and secondary schools, (2) recruiting undergraduate students enrolled in psychology courses at the University of New Orleans to refer caregiver-adolescent dyads, and (3) posting an advertisement via the internet (i.e., Craigslist and Facebook). Sixty percent of participants ($n = 48$) were recruited via internet advertising, 18.75% ($n = 15$) heard about the project from a family member or friend, 8.75% ($n = 7$) heard about it in their psychology course, 5% ($n = 4$) responded to the flyer, and 7.50% ($n = 6$) of families were missing referral information. Families were notified that both the caregiver and youth would be compensated for approximately two and half hours of their time (i.e., total of \$50: parent received \$30 for each adolescent and each adolescent received \$20).

No specific exclusionary criteria were used in recruitment of families, but two children were excluded from analyses due to parent-reported history of a pervasive developmental disorder. Additionally, 15 percent ($n = 14$) of the remaining 94 youth were currently taking a stimulant (e.g., Vyvanse, Adderall, Concerta; $n = 8$), a serotonin reuptake inhibitor (SSRI; e.g., Celexa; $n = 1$), an anti-seizure ($n = 1$), or an anti-psychotic ($n = 1$) medication. Two caregivers also reported that their child was taking multiple types of medications (e.g., stimulant, SSRI, allergy medicine) and another caregiver did not report the medication being used. These fourteen youth were thus also excluded from further analyses given that research shows that these specific types of medication may affect vagal tone indices (Blom et al., 2010).

The final sample consisted of 80 youth (68 child-caregiver dyads) aged 11-17 years ($Mean_{age} = 13.88$, $SD_{age} = 1.95$) with 51 percent being female. Caregivers reported youth's ethnicities as 37.5% African American ($n = 30$), 33.8% Euro-American ($n = 27$), 23.8%

‘other/mixed’ ethnic background ($n = 19$), and 5% Hispanic ($n = 4$). The median family income ($n_{family} = 67$) was between \$20,000 and \$49,999 a year.

Physiological Measurement

Physiological measures (i.e., heart rate, respiration, skin conductance, and temperature) were collected and stored on a Dell Studio XPS, Intel ® Core™, 2.67GHz, 3GB RAM using Biograph Infiniti software, and raw signals from the physiological sensors were received and transmitted to the computer via the ProComp Infiniti encoder (Meyers, 2010). The Biograph Infiniti software was run using a Microsoft Windows 7, 64-bit operating system and output was automatically stored within a designated file (using only the child's unique id number) on the computer. Sensors connected to the ProComp Infiniti encoder were attached to youth via specially designed cables, and fiber optic wiring was used to link the sensors to the computer. The electrocardiogram (EKG) sensors (3-lead system) were attached first using UniGel electrodes (pre-gelled) and were placed on the right (1) and left (1) abdomens (below the rib cage) and at the top of the sternum (1). The respiration band was next strapped around the chest after the participant was asked to fully expand his or her abdomen (i.e., exhale). Lastly, the blood volume pulse (BVP) sensor was placed on the participant's middle finger, the galvanic skin response (GSR) sensors on the index and ring fingers, and the temperature sensor on the baby finger of the child's non-dominant hand. The child then sat in a chair facing a computer monitor while the caregiver was led to another room to complete the parent-reported measures.

The experimenter followed a scripted protocol and each youth was instructed (if all possible) not to eat, drink (water was acceptable), or smoke cigarettes one hour before arriving at the research lab. The first phase of the physiological assessment consisted of the experimenter asking the child to relax and watch a five-minute film clip of the coral reef and undersea fish (i.e., Coral Sea Dreaming Film Clip; adapted from (Piferi, Kline, Younger, & Lawler, 2000)). The purpose of this video baseline was to help youth acclimate to the environment and to standardize collection of baseline physiological data in that all youth were cognitively engaged in the same task. The second phase was a traditional resting baseline procedure in which the experimenter asked the child to relax and breathe normally for five minutes. The third phase (i.e., HR Control Task) consisted of two blocks of one-minute trials (3 trials per block) in which the child was asked to increase (speed up) or decrease (slow down) his or her heart rate and silently read short passages (100 – 110 words) for 30 seconds in between each trial. In the fourth phase the child participated in a non-vocal and developmentally appropriate mental arithmetic task for three minutes (Stroud et al., 2009). The child was asked to subtract a specific number (13 if child's age was 11-14 years; 17 if child's age was 15-17 years) from 500 and continue to subtract that number from each subsequent answer for three minutes. Youth entered their answers on a 10 digit key-pad placed on the desk in front of them. For each correct answer the experimenter said “Right” and the child was allowed to continue with the next number, but for each wrong answer the child was told “Wrong” and was instructed to begin subtracting from the number 500 again.

A repeated measures analysis of variance (ANOVA) indicated that both heart rate and skin conductance differed significantly across the video baseline, resting baseline, and mental

arithmetic task conditions [$F(1, 79) = 11.49, p < .001$ and $F(1, 79) = 202.61, p < .001$, respectively]. Post-hoc probing using repeated measures t-tests revealed that both heart rate and skin conductance increased significantly from the video baseline [$t(79) = 3.74, p < .001$ and $t(79) = 3.40, p = .001$, respectively] and resting baseline [$t(78) = 14.30, p < .001$ and $t(78) = 14.28, p < .001$, respectively] conditions to the mental arithmetic task; and suggested that a physiological stress response was induced (see Figures 1 and 2). In the final phase, youth watched 10 video vignettes (10-20 seconds in length) depicting ambiguous situations youth may have had with their peers and orally answered questions about each vignette.

EKG data from the two baseline conditions (video and resting) and the mental arithmetic task were analyzed for this study using the Kubios HRV 2.1 software (Tarvainen, Niskanen, Lipponen, Ranta-aho, & Karjalainen, 2009). An automatic artifact detection algorithm (medium correction setting) was used to detect IBIs that were .25 seconds above or below the mean inter-beat intervals (i.e., identify missed or extra heart beats in the time series). The identified IBIs were next manually inspected by the first author to ensure that they were actual artifacts that needed to be corrected (not just misidentified). Automatic correction of IBI artifacts was then applied to the data if results were consistent with manual inspection (manual correction was implemented for discrepancies). This method of artifact correction allowed for a standardized procedure of normalizing the IBI data (i.e., without under- or over-correction) and individuals with 10% or more corrupted data were excluded from further analyses.

The artifact-free IBIs were then resampled at .025 Hz and the entire time series was detrended using a second-order polynomial (Porges, Doussard-Roosevelt, & Maiti, 1994) in an effort to remove non-stationary data. The IBIs were then finally subjected to a power spectral analysis using a Fast Fourier Transform algorithm, which produced absolute power (or variance) distributions for low frequency HRV (.04 to .15 Hz) and high-frequency HRV (.15 to .40 Hz; vagal tone) consistent with reported standards for spectral analysis (Electrophysiology, 1996).

Two physiological indices of emotional regulation were derived from this data and included resting vagal tone (for both baseline conditions) and vagal response to stress (Porges, 2007, 2011). *Resting vagal tone* consisted of the high-frequency HRV during the first three minutes of either baseline condition (video or resting) while *vagal response to stress* was the change in vagal tone from either baseline condition to the mental arithmetic task. Multilevel modeling of this repeated measures data (see Statistical Analysis section) provided an alternative measure of youths' emotion regulation in response to a stressful cognitive task.

Assessment of Anxiety Control Beliefs, Anxiety Symptoms, and Aggressive Behavior

Youth were administered the *Anxiety Control Questionnaire for Children (ACQ-C)*; (Weems *et al.*, 2003) in order to assess their perception of control over anxiety-related symptoms. In addition, both children and parents completed the *Revised Child Anxiety and Depression Scale (RCADS-Child version and RCADS-Parent version)* (Chorpita *et al.*, 2000) to assess anxiety symptoms based on DSM-IV (APA, 1994) criteria and the *Peer Conflict Scale (PCS-C and PCS-P)* (Marsee & Frick, 2007) to measure aggressive behavior based upon the forms and functions of aggression (overt, relational, proactive, and reactive). Youth also

completed the *Revised Child Manifest Anxiety Scale (RCMAS*; Reynolds & Richmond, 1978) to provide a more generalized measure of anxious emotion given the discrepant findings between studies using the RCADS and RCMAS. Each of these measures has demonstrated reliability and validity estimates with their respective theoretical constructs among youth (Chorpita et al., 2000; Marsee & Frick, 2007; Reynolds & Richmond, 1978; Weems et al., 2003).

Other Measurements

Caregivers reported their child's age, gender, ethnicity, and family income, as well as any known medications currently being administered to the child. Exposure to natural disaster events was assessed via a child-report survey of exposure to hurricanes and their aftermath that was based on the work of La Greca and colleagues (La Greca, Silverman, Vernberg, & Prinstein, 1996; La Greca, Silverman, & Wasserstein, 1998; Vernberg, La Greca, Silverman, & Prinstein, 1996). Youth specifically were asked to report whether they had experienced Hurricane Katrina, Hurricane Gustav, Hurricane Isaac, and/or the BP Oil Spill and which one was the most scary or upsetting for them. In addition, they completed a measure of hurricane exposure events in which they reported their experiences during and after their respective most upsetting or scary hurricane. Youth were also asked to report if they had experienced any other traumatic, scary, or upsetting event besides the aforementioned natural disasters.

Statistical Analysis

In order to test the linear associations between vagal tone indices (video, resting, and mental arithmetic task) and youths' anxiety control beliefs, anxiety, and aggression, bivariate correlations were calculated. Multilevel modeling using HLM 7.0 (Bryk & Raudenbush, 1992; Raudenbush, Bryk, Cheong, Congdon, & du Toit, 2011) was used to examine youths' overall change in vagal tone from the baseline conditions (video and resting) to the mental arithmetic task (level 1) and to determine whether anxiety symptoms or aggression (level 2) moderated this change. A random slopes model was conducted with the criterion variable as vagal tone index scores. Time [coded 0 = baseline measure (video or resting baseline) or 1 = mental arithmetic task] was entered as a level 1 predictor and age, gender (coded 0 = boy and 1 = girl), and anxiety or aggressive behavior symptoms were entered as level-2 predictors. All continuous predictors at level 2 were grand-mean centered to reduce multicollinearity (Tabachnick & Fidell, 2007). We further illustrated all cross-level interactions (e.g., anxiety symptoms by change in vagal tone from resting baseline to stress task) by plotting graphs for youth one standard deviation below or above the mean on anxiety or aggression problems.

The mean, standard deviation, range, and skewness of each study variable is presented in Table 1. Preliminary examination of the data indicated that there were no missing data. However, further inspection of the distributions for each variable revealed one univariate outlier in terms of the video and resting baseline vagal tone, one for the RCADS-C Total Anxiety, one for the PCS-C Total Aggression, and one for the PCS-P Total Aggression score (i.e., +3 standard deviations above the mean). Pairwise deletion of each case was used to handle each univariate outlier given that there were different variables for each analysis

and thus each case had usable data for other analyses. Evaluation of multivariate outliers using multiple regression techniques (i.e., Mahalanobis distances; Tabachnick & Fidell, 2007) found no evidence of multivariate outliers. Vagal tone during both the video and resting baselines, parent-reported anxiety (RCADS-P) and both child- and caregiver-reported aggressive behavior (PSC-C and PSC-P) scores were severely positively skewed in this sample and thus were transformed using a log-10 base.

Results

Hurricane and Trauma-related Experiences

Seventy-six youth reported being exposed to at least one hurricane (i.e., Hurricane Katrina, Hurricane Rita, Hurricane Gustav, and/or Hurricane Isaac; 28 of these youth also reported experiencing another scary or traumatic event), one youth reported experiencing only the BP Oil Spill (i.e., no hurricane exposure), and three youth who did not experience a natural disaster reported being exposed to another traumatic or scary event in their lifetime. On average, youth with hurricane exposure reported 4.74 of 16 possible hurricane exposure events for the most upsetting or scary hurricane, with the most commonly reported disaster-related experiences being: thought someone might be hurt badly (73%), thought someone might die (60.8%), hard to see friends because of moving (56.8%), home damaged or badly destroyed (47.3%), moved to a new place (44.6%), saw someone get hurt during the storm (29.7%), and windows or doors broke in the place you stayed (16.2%).

Resting Vagal Tone

Anxiety and anxiety control beliefs—As shown in Table 2, the results indicated that resting vagal tone measured in both the video and resting baseline conditions were negatively associated with both child-reported general anxiety problems (RCMAS) and anxiety symptoms based on DSM-IV criteria (RCADS-C). In addition, resting vagal tone measured in both the video and resting baseline conditions were also negatively correlated with parent-reported anxiety symptoms based on DSM-IV criteria (RCADS-P). Conversely, resting vagal tone measuring in both the video and resting baseline conditions was positively associated with anxiety control beliefs (ACQ-C).

Aggression—As shown in Table 2, the results also indicated that resting vagal tone measured in both the video and resting baseline conditions was not associated with child- or parent-reported aggression.

Vagal Response to Stress

Child-reported anxiety and anxiety control beliefs—The results indicated there was a significant effect of child-reported general anxiety symptoms (RCMAS) on the change from both video and resting baseline [coefficient = 0.01, $t(76) = 2.22$, $p = .03$ and coefficient = 0.01, $t(76) = 2.27$, $p = .03$, respectively]. Examination of the former interaction (i.e., anxiety problems by change in vagal tone from video baseline to the stress task) suggested there was an increase in vagal tone for all youth who were one standard deviation above the mean on RCMAS anxiety symptoms and a decrease in vagal tone (vagal withdrawal) for those youth one standard deviation below the mean (see Figure 3A). Similarly, examination

of the latter interaction (i.e., anxiety problems by change in vagal tone from resting baseline to the stress task) suggested there was an increase in vagal tone for all youth who were one standard deviation above the mean on RCMAS anxiety problems. However, the slope of change from resting baseline to the stressor task for those youth with low anxiety symptoms (-1 standard deviation) seemed to vary across gender with a blunted vagal response seen in boys and vagal withdrawal in girls (see Figures 3B and 3C, respectively). There was no significant effect of child-reported anxiety control beliefs (ACQ-C) on change in vagal tone from either the video or resting baseline to the stress task [coefficient = 0.001, $t(76) = -.78$, $p = .44$ and coefficient = 0.0008, $t(76) = -.48$, $p = .63$, respectively].

Additionally, there was a significant effect of child-reported anxiety symptoms (RCADS-C) on change in vagal tone from the video baseline to the stress task [see Figure 3D; coefficient = 0.005, $t(75) = 2.07$, $p = .04$]. Once again, examination of the interaction (i.e., anxiety symptoms by change in vagal tone from video baseline to the stress task) revealed that vagal tone increased from the video baseline to the stress task for those youth one standard deviation above the mean on RCADS-C anxiety symptoms and decreased for those youth one standard deviation below the mean vagal withdrawal). Conversely, no significant effect was found for child-reported anxiety symptoms (RCADS-C) on change in vagal tone from the resting baseline to the stress task [coefficient = 0.003, $t(75) = 1.84$, $p = .07$].

Parent-reported anxiety—There was no significant effect of parent-reported anxiety symptoms (RCADS-P) on change in vagal tone from either the video or resting baseline to the stress task [coefficient = 0.44, $t(76) = .99$, $p = .33$ and coefficient = 0.20, $t(76) = .51$, $p = .61$, respectively].

Child-reported aggression—The results revealed that there was a significant effect of child-reported aggression (PCS-C) on change in vagal tone from the video and resting baseline to the stress task [coefficient = 0.13, $t(75) = 1.97$, $p = .05$ and coefficient = 0.16, $t(75) = 2.23$, $p = .03$, respectively]. Examination of the former interaction (i.e., aggression by change in vagal tone from video baseline to the stress task) suggested there was an increase in vagal tone for all youth who were one standard deviation above the mean on PCS-C aggression scores and a decrease in vagal tone (vagal withdrawal) for those youth one standard deviation below the mean (see Figure 4A). Similarly, examination of the latter interaction (i.e., aggression by change in vagal tone from resting baseline to the stress task) suggested there was an increase in vagal tone for all youth who were one standard deviation above the mean on PCS-C aggression scores and a decrease in vagal tone (vagal withdrawal) for those youth one standard deviation below the mean (see Figure 4B).

Parent-reported aggression—The results indicated that there was no significant effect of parent-reported aggression (PCS-P) on change in vagal tone from the video baseline to the stress task [coefficient = 0.11, $t(75) = 1.42$, $p = .16$]. However, there was a significant effect of parent-reported aggression (PCS-P) on change in vagal tone from resting baseline to the stress task [coefficient = 0.15, $t(75) = 2.47$, $p = .02$]. Examination of the interaction (i.e., aggression by change in vagal tone from resting baseline to the stress task) suggested there was an increase in vagal tone for all youth who were one standard deviation above the

mean on PCS-P aggression scores and a decrease in vagal tone (vagal withdrawal) for those youth one standard deviation below the mean (see Figure 4C).

Age and gender effects—Overall, there were no cross-level age or gender effects on change in vagal tone from the video or resting baseline conditions to the stress task for any analyses.

Discussion

The identification of reliable biological correlates of anxious ‘flight’ and aggressive ‘fight’ expressions of youth who are at-risk for mental health problems is a critical first step towards the dimensional classification of disorders and may better inform researchers of their specific and non-specific biological underpinnings. The present study provides evidence for the importance of examining linear associations in samples of youth who may have a wider and more normal distribution of psychopathology in that biological indices of emotion dysregulation were both similarly and differentially related to youths’ anxiety and aggressive behavior symptoms. First and as expected, the results revealed a negative linear association between resting vagal tone and both child- and caregiver-reported anxiety symptoms. In addition, both child- and parent-reported anxiety and aggression problems (two measures of child-reported anxiety) were associated with an increase in vagal tone from baseline conditions to a cognitive stress task. These findings are not only consistent with neurobiological theories of emotion regulation (Beauchaine et al., 2008; Porges, 2007) and past research findings from community samples (El-Sheikh et al., 2011; Greaves-Lord et al., 2007), but also provide strong evidence for two distinct emotionally-based biological correlates of anxiety symptoms and a specific biological correlate of aggression among youth at greater risk for mental health problems.

The present study made an important contribution to knowledge about the relation between cognitive dimensions underlying anxiety problems in youth (i.e., perceived control over anxiety) and actual emotion regulation deficits. More specifically, anxiety control beliefs were positively related with resting vagal tone. While the correlational nature of this finding precludes causal inferences, it does suggest that anxiety control beliefs may be a critical dimension underlying the fight or flight response system. Furthermore, this appears to be the first time that a measure of perceived control over anxiety has been empirically linked with an index of actual emotional control in youth. Theoretically, this finding suggests perceived control over anxiety may, to some degree, correspond to one’s actual ability to regulate anxious emotion (Weems & Silverman, 2006), though the size of the effect suggests this was not true for everyone. Research that further explores the unique and interactive role of perceived regulation (anxiety control beliefs) and actual regulation (vagal tone) during times of stress further the understanding of the interplay of cognition and physiology in emotional dysregulation (Scott & Weems, 2010; Weems & Silverman, 2006). Given that over half of this sample experienced events involving Hurricane Katrina or were exposed to a traumatic event and that exposure to an uncontrollable event may change cognitive appraisal of controllability (i.e., exposure to an uncontrollable event may lead to poor perceived control; Weems & Overstreet, 2008), future studies will need to further explore this relationship in samples of youth who have not experienced a natural disaster or other trauma.

The results of this study also suggest that both child- and caregiver-reported aggressive behavior were associated with an increase in vagal tone from the resting baseline to the stress task. This finding expands upon previous research findings of more general externalizing problems being related to increases in vagal tone in response to stress in both at-risk and not-at-risk community samples of youth (Boyce et al., 2001; El-Sheikh et al., 2001; Hinnant & El-Sheikh, 2009). Conversely, the findings did not support our hypothesis that aggression would be negatively associated with resting vagal tone or that gender would moderate this association (Beauchaine et al., 2008; Gordis et al., 2010; Mezzacappa et al., 1997). One possibility for these inconsistent findings is that resting vagal tone may not capture the exact nature of the emotional dysregulation process associated with aggression. That is, youth who were more aggressive in this sample may display biological dysregulation during times of stress (but not rest) and thus, in this case, vagal response to stress may be the better measure of emotional dysregulation (Porges, 2007).

Finally, the present study also made a potential methodological contribution with the use of a cognitive-based method to measure resting vagal tone. More specifically, the findings revealed that the association between less vagal withdrawal or increase in vagal tone from the two baseline conditions (video and resting) to the stress task and greater anxiety symptoms were only significant when using resting vagal tone derived from the video baseline condition. It is plausible that the video baseline condition may have produced a less variable index of youth's resting vagal tone for use in examining change to a cognitive stress task (in this case the Mental Arithmetic Task), due to it 1) helping standardize the physiological state of the individuals (Piferi et al., 2000) and 2) obtaining a resting vagal tone while using similar attentional processes produced in the cognitive stress task. That is, all youth who participated in the study watched the same film clip and in contrast to the resting baseline with no stimuli, youths' attention may have turned to the atypical nature of the situation (i.e., sit blankly for five minutes) during which thinking or worrying about different things may have ensued.

Though the present study makes several contributions to the anxiety, aggression, and emotion regulation literature, it was not without its limitations. One limitation is that the cross-sectional design of the study precludes directional or causal interpretations of the findings. For example, it is impossible to rule out that the experience of chronic anxiety symptoms over the youths' lifetimes may have resulted in the low resting vagal tone or the blunted or increased vagal response to stressful events. Another limitation is that exclusion of those youth who were currently taking medications may have lessened the generalizability of the findings to those youth who suffer from more severe physical, emotional, and behavioral problems. Nevertheless, it is an important area for future research to determine whether the current findings would generalize to children suffering from greater psychopathology and/or clinical populations.

In summary, the findings add to our understanding about the associations of resting vagal tone and vagal change in response to stress with anxiety control beliefs, anxiety, and aggression in youth. Theoretically, the findings are in line with Porges's views (Porges, 2007; 2011) and suggest that lower resting vagal tone may be a reliable and valid biological correlate of anxious emotion in youth. However, of even more theoretical importance is that

these findings point towards vagal response to stress as a plausible non-specific index of emotion dysregulation across anxiety and aggressive behavior problems. Finally, these findings support the need for further investigation of the linear associations between underlying biological correlates of emotional and behavioral disorders and the manifested symptoms that are theoretically and empirically linked with such disorders.

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Figure 1.
Mean change in heart rate from video and resting baseline conditions to stress task.

Figure 2.
Mean change in skin conductance from video and resting baseline conditions to stress task.

Figure 3. Change in vagal tone from baseline to stress task for low anxious (-1 SD below the mean), average anxious (Mean), and high anxious (+1 SD above the mean) youth. Predicted vagal tone reported in non-transformed units. Figure 3A: High anxiety associated with increased vagal tone from video baseline to stress task; Figure 3B: High anxiety associated with increased vagal tone from resting baseline to stress task for boys; Figure 3C: High anxiety associated with blunted vagal withdrawal from resting baseline to stress task for girls; Figure 3D: High anxiety symptoms associated with increased vagal tone from video baseline to stress task. RCMAS = Revised Child Manifest Anxiety Scale; RCADS-C = Revised Child Anxiety and Depression Scale - Child Version.

Figure 4.

Change in vagal tone from baseline to stress task for low aggressive (-1 SD below the mean), average aggressive (Mean), and high aggressive (+1 SD above the mean) youth. Predicted vagal tone is reported in non-transformed units. Figure 4A: High aggression associated with increased vagal tone from resting baseline to stress task; Figure 4B: High aggression associated with increased vagal tone from video baseline to stress task; Figure 4C: High aggression associated with increased vagal tone from resting baseline to stress task. PCS-C = Peer Conflict Scale – Child Version; PCS-P = Peer Conflict Scale – Parent Version.

Table 1
Means, Standard Deviations, Ranges, and Skew for Child- and Caregiver-Reported Measures

	<i>N</i>	<i>M</i>	<i>SD</i>	<i>Min - Max</i>	<i>Skew</i>
Child Report					
ACQ-C Control Beliefs	80	73.63	19.49	21 – 120	-.08
RCMAS Total Anxiety	80	10.97	5.83	1 – 23	.15
RCADS Total Anxiety	79	61.88	14.53	38 – 104	.76
PCS Total Aggression	79	10.28	10.44	0 – 49.23	1.74
Parent Report					
RCADS Total Anxiety	80	51.99	10.04	38 – 92	1.54
PCS Total Aggression	79	6.00	7.11	0 – 31	1.40

ACQ-C = Anxiety Control Questionnaire for Children; RCMAS = Revised Child Manifest Anxiety Scale; RCADS = Revised Child Anxiety and Depression Scale; PCS = Peer Conflict Scale.

Table 2
Correlations between Child- and Caregiver-reported Anxiety, Aggression, and Resting Vagal Tone during Baseline Conditions

	Video Baseline Vagal Tone	Resting Baseline Vagal Tone
<u>Child Report</u>		
ACQ-C Control Beliefs (<i>n</i> = 79)	.29**	.25**
RCMAS Total Anxiety (<i>n</i> = 79)	-.27**	-.25**
RCADS Total Anxiety (<i>n</i> = 78)	-.28**	-.22*
PCS Total Aggression (<i>n</i> = 78)	.05	-.10
<u>Parent Report</u>		
RCADS Total Anxiety (<i>n</i> = 79)	-.28**	-.25**
PCS Total Aggression (<i>n</i> = 78)	-.03	-.08

Note:

**
p < .05;

*
p = .05;

ACQ-C = Anxiety Control Questionnaire for Children; RCMAS = Revised Child Manifest Anxiety Scale; RCADS = Revised Child Anxiety and Depression Scale; PCS-C = Peer Conflict Scale.