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Adolescent RSA Responses during an Anger Discussion Task: Relations to Emotion Regulation and Adjustment

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Abstract

The current study examined associations between adolescent respiratory sinus arrhythmia (RSA) during an angry event discussion task and adolescents' emotion regulation and adjustment. Data were collected from 206 adolescents (10–18 years old, *M* age = 13.37). Electrocardiogram (ECG) and respiration data were collected from adolescents, and RSA values and respiration rates were computed. Adolescents reported on their own emotion regulation, prosocial behavior, and aggressive behavior. Multi-level latent growth modeling was employed to capture RSA responses across time (i.e., linear and quadratic changes; time course approach), and adolescent emotion regulation and adjustment variables were included in the model to test their links to RSA responses. Results indicated that high RSA baseline was associated with more adolescent prosocial behavior. A pattern of initial RSA decreases (RSA suppression) in response to angry event recall and subsequent RSA increases (RSA rebound) were related to better anger and sadness regulation and more prosocial behavior. However, RSA was not significantly linked to adolescent aggressive behavior. We also compared the time course approach with the conventional linear approach and found that the time course approach provided more meaningful and rich information. The implications of adaptive RSA change patterns are discussed.

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Keywords

respiratory sinus arrhythmia; RSA time course; emotion regulation; prosocial behavior; aggressive behavior

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Difficulty managing emotions behaviorally and physiologically plays a critical role in the development of various adjustment problems (Steinberg & Avenevoli, 2000; Thayer, Hansen, Saus-Rose, & Johnsen, 2009), while the ability to regulate emotions has been associated with positive adaptation despite various adverse circumstances (Buckner, Mezzacappa, & Beardslee, 2003; Cicchetti, 2010). Examining factors related to social and emotional development during adolescence is critical because of increases in intense emotions and dynamic fluctuations of emotions that occur during this developmental period (Granic, Hollenstein, Dishion, & Patterson, 2003; Steinberg, 2001; Steinberg & Morris, 2001). In the past few decades, with the development of physiological measurement tools and quantification methods, various studies have investigated the neurophysiological mechanism of cardiac vagal control, focused on respiratory sinus arrhythmia (RSA) as an indicator of parasympathetic regulation linked to both emotion and behavioral regulation, as well as child and adolescent adjustment (e.g., Beauchaine, 2001; Berntson, Cacioppo, & Quigley, 1991; Hastings, et al., 2008; Kreibig, 2010; Porges, 2007; Porges et al., 2007). However, the findings from these studies are often inconsistent and sometimes contradictory (Egizio et al., 2008; Eisenberg et al., 2012; El-Sheikh et al., 2009; Hastings et al., 2008; Obradović, Bush, & Boyce, 2011; De Vries-Bouw et al., 2011). In addition, a number of methodological and research design limitations in the literature have been identified (Dennis, Buss, & Hastings, 2012; Obradović, Bush, Stamperdahl, Adler, & Boyce, 2010; Obradović et al., 2011). For example, recent studies have identified the importance of considering the context (e.g. types of tasks, emotional arousal level) of RSA data collection and focused on the temporal changes in RSA rather than examining simple change or static measures from baseline to task (Brooker & Buss, 2010; Miller et al., 2013; Obradović et al., 2011; Vögele, Sorg, Studtmann, & Weber, 2010). Nevertheless, there have been few published investigations adopting such time course approaches (i.e., temporal changes across time). In response, the current study aimed to examine the associations between time course changes in RSA and adolescent emotion regulation and adjustment in a low-income, ethnically diverse sample during an angry event discussion task in a laboratory setting. In addition, we compared the results using the time course approach and those using conventional approach for analyzing RSA data.

RSA, Baseline RSA and Adjustment

RSA refers to "a rhythmical fluctuation in heart periods (i.e., interbeat interval) at the respiratory frequency that is characterized by a shortening and lengthening of heart periods in a phase relationship with inspiration and expiration, respectively" (Berntson, Cacioppo, & Quigley, 1993, p. 183). It reflects changes in heart rate, at a high respiratory frequency band (about 0.12–0.4 Hz for adolescents in resting state), which is primarily the function of the parasympathetic nervous system (PNS; the Polyvagal theory, Porges, 1995a, 2011). Tonic parasympathetic control of heart is usually quantified as baseline RSA (Diamond, Fagundes,

& Butterworth, 2012; Porges, 1995b) and is assessed when an individual is at rest with paced breathing, or when an individual is shown a calming film (e.g., a film showing dolphins swimming; Fabes & Eisenberg, 1997). It is posited that baseline RSA reflects an individuals' ability to focus attention, engage in social communication (i.e., social engagement), and maintain homeostasis under normal circumstances (El-Sheikh et al., 2009; Porges, 2007). Baseline RSA also may denote physiological regulation of inner resources, potential for emotion regulation capacity, or a trait-like level of arousability (Beauchaine, 2001; Hastings, et al., 2008; Porges, 2007). Empirically, higher baseline RSA has been linked to higher effortful control scores and fewer aggressive behaviors among adolescents (Chapman, Woltering, Lamm, & Lewis, 2010). Likewise, Vögele et al. (2010) found that lower resting high frequency heart rate variability (similar to resting/baseline RSA) was observed among individuals with anger rumination tendencies compared to those with adaptive coping styles. Moreover, lower baseline RSA also has been observed among parasuicidal adolescent girls compared to control group girls (Crowell et al., 2005), and among aggressive adolescents with conduct and ADHD problems (e.g., Beauchaine, Hong, & Marsh, 2008). A longitudinal study also found higher initial baseline RSA was associated with declines in externalizing symptoms, whereas lower initial baseline RSA was associated with increases in externalizing symptoms among boys (El-Sheikh & Hinnant, 2011).

RSA Reactivity and Adjustment

RSA reactivity in response to challenge reflects changes in parasympathetic control of the heart from a resting state to a challenging condition and can be quantified as RSA augmentation (i.e., RSA increases from baseline or resting state to challenging condition) or RSA suppression (i.e., RSA decreases; El-Sheikh et al., 2009). RSA suppression indicates parasympathetic or vagal withdrawal, which generates increases in heart rate. RSA augmentation indicates vagal augmentation, which typically slows heart rate and inhibits sympathetic nervous system input (e.g., El-Sheikh et al., 2009; Obradović & Boyce, 2012). RSA augmentation facilitates the maintenance of an internal equilibrium and social engagement, and RSA suppression signifies the readiness to respond to internal or external threats or challenges (Brooker & Buss, 2010; Porges, 2007). Studies have found that participants with greater RSA suppression during experimental challenges such as star-tracing and watching film clips, showed fewer behavioral problems, higher peer status, higher sociability, higher levels of social skills, and better emotion regulation skills during childhood and adolescence (e.g., Beauchaine, Gatzke-Kopp, & Mead, 2007; El-Sheikh, Hinnant, & Erath, 2011; Gentzler, Santucci, Kovacs, & Fox, 2009; see Graziano & Derefinko, 2013 for a review).

However, other studies have found either no relation between RSA reactivity and emotion and behavior problems during childhood and adolescence (e.g., Eisenberg et al., 2012; Hinnant & El-Sheikh, 2009; Whitson & El-Sheikh, 2003) or contradictory results. For example, greater parasympathetic withdrawal in response to public speaking has been associated with higher rates of antisocial behavior reoffending among adolescent males (e.g., De Vries-Bouw et al., 2011). In contrast, less RSA suppression in response to cognitive challenges was related to better social functioning among older adults (Egizio et al., 2008). Additionally, higher RSA augmentation in response to a social challenge has been linked to fewer internalizing and externalizing problems and better behavior self-regulation among young children (Hastings et al., 2008). Hinnant and El-Sheikh (2009) did not find significant associations between RSA suppression and internalizing and externalizing problems, but greater RSA suppression in conjunction with low baseline RSA predicting higher internalizing problems from middle childhood to early adolescence. Taken together, generally in RSA reactivity empirical studies, both RSA suppression and augmentation have been observed in response to laboratory challenges. Findings of RSA reactivity in relation to adjustment are mixed (see also Hastings & Miller, 2014 for a review). In addition, we concur with other researchers (e.g., Hastings et al., 2008; Obradović et al., 2011; Overbeek, van Boxtel, & Westerink, 2012; Porges, 2007, 2011) that the association between parasympathetic reactivity and adjustment depends on the type and intensity of specific laboratory challenging task used to quantify RSA reactivity.

Characteristics of Laboratory Stressors and RSA Reactivity

In RSA empirical studies, the context of measurement and methods used to induce emotion may determine which type of RSA reactivity can be observed (Obradović et al., 2011; Overbeek et al., 2012). In particular, under conditions of high stress such as a public speech, it is more likely to observe RSA suppression, which reflects physiological arousal and stress reactivity, and may indicate an individual's higher potential and readiness to cope with the stress. Under conditions of mild stress such as a social interview or social activities such as parent-adolescent interactions, it is more likely to observe RSA augmentation or maintenance, which may reflect an individuals' active regulation to facilitate social engagement/communication (see Porges, 2003, 2007, 2011). Further, the context of measurement and methods used to induce emotion also may determine which of the two types of reactivity is adaptive or maladaptive (Overbeek et al., 2012). For example, the association between parasympathetic regulation and emotional arousal and coping has been found only under conditions of moderate and high stressors (Fabes & Eisenberg, 1997). Its link to major depressive disorder (MDD) was significant only in response to a physical stress (squeezing a handgrip dynamometer) but not to cognitive stress (working memory N-back; Nugent, Bain, Thayer, Sollers, & Drevets, 2011). The characteristics of laboratory stressors are critical in psychophysiological studies (Dickerson & Kemeny, 2004) in that various stressors might evoke levels of social and attentional vigilance or alter affective states differentially (Egizio et al., 2008; El-Sheikh, 2005a, 2005b). RSA suppression and augmentation may represent different processes in response to various lab stressors. For example, Kop and colleagues (2011) found greater parasympathetic withdrawal during a high cognitive load Stroop Color Word Test, but much less suppression during mood induction. However, the characteristics of lab stressors have not been discussed in relation to RSA reactivity. Moreover, a large body of extant literature has focused on physical and cognitive stressors, and studies examining emotional stressors typically use emotion (often fear) eliciting pictures and film clips. None of these stressors reflect adolescents' real-life emotion-charged social experience. The current study used a 3-minute parent-adolescent emotion (i.e., angry) event discussion task with two phases (i.e., phase 1: stressful angry event recalling, and phase 2: regulating anger) and investigated RSA time course changes across the two phases.

The Study of Emotion Regulation and RSA in Real Time

It is widely accepted that emotion and emotion regulation are rapid processes dependent on contextual demands, with individuals displaying fluctuations and flexibilities in emotion responses to unique situational contexts (e.g., Camras & Witherington, 2005; Thompson, 1994). Cole, Martin, and Dennis (2004) suggested more broadly that emotion regulation is "systematic changes associated with activated emotions" (p. 320). The stress-sensitive physiological regulation systems such as the PNS are either acutely or chronically changing over time within individual in accordance with changing internal and external contexts, which is called "allostasis" (Adam, 2012). However, previous RSA studies are variable-centered and typically tap only inter-individual differences, and RSA changes are generally averaged across time. RSA reactivity is often computed by simple change scores (subtracting the averaged scores of RSA levels across a challenging task from baseline RSA), or residualized change scores (regressing the averaged RSA values on baseline RSA; we labeled such methods the conventional approach). These scores do not reflect the temporal emotion and emotion regulation processes, which may be the reason for the inconsistent findings in empirical RSA studies. Butler, Wilhelm, and Gross (2006) posited that within-individual changes in RSA are particularly related to regulatory effort. By the same token, we argue that modeling the intra-individual temporal RSA changes over the processes of a specific laboratory task is a better approach (i.e., the time course approach) allowing researchers to examine the adaptability of RSA reactivity in specific laboratory contexts, as the RSA studies involving social and emotional processes increase (e.g., Brooker & Buss, 2010; Burt & Obradović, 2013; Butler et al., 2006; Miller et al., 2013; Vögele et al., 2010).

To date, some studies have examined PNS regulation processes by specific experimental design such as having a baseline task, a stressful public speech preparation and speech task, and a recovery period (Gunnar, Frenn, Wewerka, & van Ryzin, 2009), a baseline, anger provocation, anger contemplation, and recovery (Vögele et al., 2010), or separating specific components of a task such as breaking up watching a 3-min film clip into 30 second epochs (Crowell et al., 2005). Vögele et al. (2010) found that the pattern of PNS activation in response to anger provocation was observed among anger ruminators, while the pattern of PNS activation during anger contemplation and recovery phases occurred among cognitive reappraisers. These findings suggest that PNS activation may be maladaptive if emotional arousal is expected and may be adaptive if the regulation of negative emotions is required.

Researchers also have investigated the temporal RSA changes within individuals and have linked RSA change patterns to adjustment. For example, longitudinally, researchers have modeled changes in RSA reactivity across three years among adolescents and found that as RSA change scores from baseline to emotional challenge condition increased across the three years, adolescents experienced fewer difficulties with emotion regulation (Vasilev, Crowell, Beauchaine, Mead, & Gatzke-Kopp, 2009). Brooker and Buss (2010) modeled fluctuations (i.e., linear and quadratic changes) in RSA within individual toddlers during a two-and-a-half minute "stranger task" using growth curve models, and found that high fear toddlers showed greater linear increases and more negative quadratic change (RSA augmentation followed by RSA suppression) than non-high fear children. It was not surprising that, the two groups did not differ on simple changes in RSA during the task from baseline. Likewise, Miller and colleagues (2013) used latent growth modeling and captured nonlinear dynamic RSA changes during anger-induction, and found that initial RSA suppression and subsequent RSA recovery to baseline was associated with better regulation of aggression among 4 to 6 year old children, and this pattern of RSA dynamic change was also associated with positive parenting styles. However, less is known about RSA time course changes in response to social and emotional challenges among adolescents, especially adolescents residing in disadvantaged neighborhoods.

The Current Study

The current study considered the context of measurement and utilized a time course approach to examine RSA reactivity (i.e., modeled both adolescent RSA linear and quadratic changes during the angry event discussion with their parent). In particular, adolescents were asked to talk about a time during the last month when they got angry/mad, while they were away from home and their parents were not around. Adolescents were asked to describe where they were, whom they were with, what they were doing, why they got angry, and what they did about it, while parents were asked to listen first and comment or ask questions later. Phase 1 of the task is posited to be quite stressful and may induce quite intensive emotion experience and phase 2 of the task requires regulation during and after the adolescent was recalling the angry event and/or reflects maintaining social engagement in the conversation with parents. An angry task was chosen because anger and anger regulation may be very important for adolescents, particularly in our sample of youth, living in disadvantaged neighborhoods where adolescents are frequently exposed to violence, gang activity, and peer victimization (Cui, Morris, Criss, Houltberg, & Silk, 2014; Houltberg, Henry, & Morris, 2012; Ingoldsby & Shaw, 2002). We aimed to answer the following questions: (1) What are the overall RSA time course responses during an anger discussion task? (2) How do baseline RSA and the RSA time course changes relate to emotion regulation and adjustment outcomes (i.e., anger and sadness regulation, prosocial and aggressive behavior)? (3) Does the time course approach provide richer information (e.g., more associations with adjustment outcomes) compared to the conventional approach?

During the angry task, by design, adolescents were expected (1) to be emotionally aroused with anger (due to retrieving the angry memories during phase 1 of the task, predominantly emotional arousal); and (2) to regulate the corresponding emotions thereafter (due to having the parent's help in dealing with the emotional experience while discussing the event during phase 2 of the task, predominantly emotion regulation) and/or to maintain engaging in the discussion with parents. Therefore, the minute-to-minute temporal changes in RSA were expected to correspond to processes of adolescent emotional arousal (RSA suppression) and regulation (RSA rebound, increases toward baseline). We hypothesized that overall, we would observe RSA suppression (a negative linear coefficient) initially followed by RSA rebound (a positive quadratic coefficient) from the baseline and across the task (e.g., Brooker & Buss, 2010; Vögele et al., 2010). Based on previous empirical findings, we also hypothesized that higher baseline RSA and a pattern of greater RSA suppression followed by greater RSA rebound would be related to better adolescent anger and sadness regulation, more prosocial behavior, and less aggressive behavior.

Based on the literature, we statistically controlled for several variables. For example, Overbeek et al. (2012) found that RSA reactivity to picture series and film fragments for inducing specific basic emotions differed by sex. Research also suggests that baseline RSA develops from infancy to early adolescence (El-Sheikh, 2005a, 2005b; Rigterink, Katz, & Hessler, 2010) and contextual factors affect the development of RSA baseline and reactivity (Katz & Rigterink, 2012). Therefore, controlling for adolescents' sex and age in analyses is important. In addition, it is essential to control for respiration rate (Berntson et al., 1997; Berntson, Quigley, & Lozano, 2007; Kok & Fredrickson, 2010) because of the potential influence of respiration, which may be important when youth are talking during discussion tasks with parents. Talking and dramatic physical movements, which alter respiration, may confound RSA measurement (Butler et al., 2006; Ritz, 2009; Tininenko, Measelle, Ablow, & High, 2012).

Most RSA studies have not examined the effects of SES or income and ethnicity. To our knowledge, no study has found that the associations between RSA baseline and reactivity and adjustment differ by SES or ethnicity. Thus, we expected to find similar patterns in these associations in our low-income sample as has been found in other studies with high SES samples. Given that none of the ethnic groups had big enough sample sizes to warrant ethnic group comparisons, such analyses were not done. We also were interested in comparing the time course approach with the conventional approach. Therefore, we averaged RSA values across the task and ran similar models focusing on linear RSA change slope from baseline to the task overall. We expected that the time course approach would yield richer information compared to the conventional approach since the conventional approach can only tap into simple change.

Method

Participants

The sample consisted of 206 families with adolescents who participated in the Family and Youth Development Project (FYDP; Cui et al., 2014). The purpose of the FYDP was to examine predictors and outcomes of adolescent emotion regulation and parent emotional socialization. Data were collected from urban and rural areas of a southern Midwest region of the United States from adolescents (*M* age = 13.37 years, *SD* = 2.32, Age Range = 10–18 years; 51% female; 32% African American, 29.6% European American, 19.4% Latino American, 19% other ethnic groups) and while interacting with their primary caregivers (83.3% biological mothers, 10.7% biological fathers, 2% grandparents, 4% other primary caregivers). The sample was predominantly comprised of low-income families (*Median* annual income = $40,000, 47.5% of families were receiving welfare or public assistance) with an average of 4.35 people living in each home, and 38.7% headed by single parents.

Procedure

Institutional Review Board (IRB) approval was obtained prior to recruitment and data collection. Participants were recruited from disadvantaged communities with high percentages of ethnic minority and low-income families through fliers distributed at local Boys and Girls Clubs and public facilities, such as the Young Men's Christian Association

(YMCA). A snowball sampling method was also used (had participants give study fliers to friends) although less than 5% of participants were recruited using this method. Interested parent and adolescent dyads were asked to come to a university laboratory to participate in the study. Following the IRB approved procedures, the purpose and procedure of the study were explained to adolescents and their primary caregivers before they signed assent and consent forms, respectively. Next, they were taken to separate rooms where a packet of questionnaires was provided. Research assistants read questions while participants filled in the questionnaires on their own. Parents were taken to the adolescents' room after both finished their questionnaires and completed some interaction tasks.

After completing questionnaires, Biopac MP150 (Biopac Systems, Santa Barbara, CA) cardiovascular (ECG100C) electrodes were attached to the child's shoulder and sides (3-lead) and a respiratory (RSP100C) belt was wrapped around the child's chest while the parent was present. They were then shown a 90-second documentary film clip about dolphins while ECG and respiration signals were recorded to get the baseline RSA (the last 60 seconds were used). Next, parents and adolescents completed several observational tasks. The interaction task used in this investigation was the angry event discussion task. Instructions for the adolescent were explained by the research assistant and stated: "*From time to time, we all feel strong emotions. I'd like you to talk about a time during the last month when you got* ***angry*** *when your parents weren't around. Talk with your [mother] about what you did. Go into as much detail as you like, starting from the beginning and going to the end, describing where you were, why you got angry, and what you did about it*." Instructions for parent: "*[parent's name], please first listen to [target youth's name] and then comment or ask questions about anything you may be interested in*." ECG and respiration signals were recorded during the task, and RSA was calculated minute-to-minute. The laboratory assessment lasted 2 hours on average. The parent and adolescent each received $60 compensation for their time spent in the lab and were debriefed after the research session was completed.

Measures

Adolescent emotion regulation

Adolescents reported on their abilities to regulate their emotions using the Children's Emotion Management Scale: Sadness and Anger scales (CSMS, Zeman, Shipman, & Penza-Clyve, 2001; CAMS, Zeman, Shipman, & Suveg, 2002). The sadness and anger coping scales were used in this study as indicators of adolescent emotion regulation. The sadness subscale includes 5 items such as "When I am feeling sad, I control my crying and carrying on" and "I stay calm and don't let sad things get to me." One item ("When I am sad, I do something totally different until I calm down") was deleted to improve reliability (Cronbach's α was .61 in this study). The anger subscale included 4 items such as, "When I am feeling mad, I control my temper" and "I can stop myself from losing my temper" (Cronbach's α was .74 in this study). The scale ranged from 0 (*Not true*) to 2 (*Very true*). Previous studies have demonstrated adequate internal validity of the scales with a Cronbach's α ranging from .62 to .77 (Sullivan, Helms, Kliewer, & Goodman, 2010; Zeman et al., 2001, 2002). Higher scores indicate better emotion regulation skills.

Adolescent prosocial behavior

Adolescents reported on their prosocial behavior during the past year based on a 3-point scale (0 = *Not true*, 1 = *Sometimes*, 2 = *True*). This measure (from the Strengths and Difficulties Questionnaires, SDQ, Goodman & Scott, 1999) included 5 items such as "I try to be nice to other people, I care about their feelings" and "I usually share with others." Cronbach's α was .81 in the current study. Higher scores indicate more prosocial behavior.

Adolescent aggressive behavior

Adolescent aggressive behavior was obtained using 14 items from the Problem Behavior Frequency Scale (Farrell, Kung, White, & Valois, 2000), which assessed the frequency of physical, relational, and verbal aggression, such as "get in a fight in which someone was hit," "spread a rumor," and "insult someone's family." Adolescents were asked to indicate how frequently they engaged in each behavior during the past year using the following scale: 1 = *never*, 2 = *1–2 times*, 3 = *3–4 times*, 4 = *5–6 times*, 5 = *7 or more times*. Cronbach's α was .88 in the current study. Higher scores indicate more aggressive behavior.

RSA and respiration rate

Adolescent electrocardiogram (ECG) and respiration pneumogram were recorded using Biopac MP150 system. The sampling frequency was 2 kHz for both ECG and respiration signals. ECG and respiration data were imported to MindWare HRV 3.0.9 (MindWare Technologies, Ltd., 2010) to calculate RSA values and respiration rate (e.g., Rash & Prkachin, 2013. We used power spectral analysis method and employed Hamming spectral window in calculating RSA for our short-term recordings of ECG (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, [Task Force], 1996). RSA values in ms^2 and respiration rate were calculated during the neutral film baseline task and the 3-minute angry task. ECG data were analyzed minute by minute for high frequency component of HRV (Task Force, 1996) and ECG artifacts were edited (including visual checks and manual corrections) in the MindWare HRV 3.0.9 program to obtain reliable measures of RSA. In data preparation and analyses, we controlled for respiration in two ways: (1) computing respiration peak frequency in MindWare HRV 3.0.9, we discarded unreliable RSA values when respiration frequency was out of the high frequency 0.12–0.40 Hz range (Berntson, Norman, Hawkley, & Cacioppo, 2008); (2) including respiration rates in Level 1 of multilevel models as covariates. Twenty-two adolescents' physiological data during the discussion task were not usable due to technical issues or research assistant errors and unreliable RSA values were treated as randomly missing across the 3 minutes (about 14%). Missing data were handled in HLM 7 (Raudenbush, Bryk, & Congdon, 2011) using full information maximum likelihood (FIML) estimation during multilevel modeling.

Results

Descriptive Statistics

Means and standard deviations of all study variables are presented in Table 1. As indicated in Table 1, the zero-order bivariate correlations showed that during the baseline and the second minute of the anger task, higher respiration rate was significantly associated with lower RSA levels, suggesting that respiratory activities may influence RSA and we should control for respiration rate in statistical analyses. Neither respiration rate nor RSA was significantly related to adolescent sex or age (Tables 1). RSA levels were correlated with each other across baseline and the 3-minute anger task, but were not significantly associated with adolescent emotion regulation, prosocial behavior, or aggressive behavior. Adolescent sadness and anger regulation abilities were positively associated with prosocial behavior, and negatively related to aggressive behavior. Adolescent prosocial behavior was negatively associated with aggressive behavior. Adolescent age was positively related to aggressive behavior (Table 1). Finally, adolescent girls had higher levels of prosocial behavior, $t(204) = 4.30$, $p < .001$, and lower levels of aggressive behavior than boys, $t(204) = -1.99$, $p = .048$.

RSA Reactivity in Response to Anger Event Discussion

The time course approach—To answer the first research question about the overall RSA time course changes across time, we first implemented the time course approach using multilevel modeling in HLM 7 by incorporating both linear and quadratic effects of Time (across all 4 time points, 1-min baseline and 3-minute task) while controlling for respiration rate, so that the coefficients of linear and quadratic terms represent RSA reactivity. At second level, adolescent sex and age were controlled. The results of this model without further predictors showed that there was a significant initial decrease in RSA, $b_2 = -0.44$, $p < .001$, followed by a significant increase in RSA, $b_3 = 0.10$, $p = .002$, indicating a pattern of initial RSA suppression and subsequent RSA rebound. No age or sex differences in RSA baseline, respiration effects, RSA suppression and rebound were found.

The conventional approach—Next, we implemented the conventional approach by computing a single slope (linear change) from baseline to the discussion task overall. RSA reactivity was then the mean RSA change from the baseline to the 3-minute task overall. In the multi-level model, time was dummy coded (0 for the RSA baseline; 1 for each minute of the anger task), so that the intercept represents RSA baseline (time =0), and the coefficient for time represents the mean change from baseline to the anger task. Likewise, adolescent concurrent respiration rates were controlled for at level 1 and adolescent age and sex were controlled for at level 2. The results of this model showed that there was a significant decrease in adolescent RSA from baseline to the anger task, $b_2 = -0.42$, $p = .001$, indicating significant RSA suppression from baseline to the anger task. No age or sex differences were found.

Baseline RSA, RSA Reactivity and Emotion Regulation and Adjustment[1]

The time course approach—To answer the second research question regarding the associations between baseline RSA, RSA reactivity and adolescent emotion regulation and

[1]Parent-reported adolescent emotion regulation and adjustment data were also collected and tested in relation to RSA variables and but no significant effects were identified. This suggests that adolescents' physiological regulation was related to their own perceptions of emotion regulation and adjustment, but not to their parents' perceptions. It should be noted that there is growing recognition that discrepancies in findings across reporters is not a flaw or limitation. Rather the discrepancies provide essential insight into the nuances and contextualization of our understanding of an individual's regulation functioning and development within complex social relationships involving multiple perspectives.

adjustment, based on the previous model, adolescent anger and sadness regulation, and prosocial and aggressive behavior were entered separately to predict RSA baseline (b_0), and RSA linear change (b_2) and quadratic change (b_3) in the following model (four separate models were tested):

$$\mathrm{RSA}=\mathrm{b}_0+\mathrm{b}_1\mathrm{RR}+\mathrm{b}_2\mathrm{Time}+\mathrm{b}_3\mathrm{Time}^2+\varepsilon \quad \text{Level 1}$$

$$\begin{array}{c}\mathrm{b}_0=\gamma_{00}+\gamma_{01}\mathrm{Predictor}+\gamma_{02}\mathrm{Sex}+\gamma_{03}\mathrm{Age}+\upsilon_0\\ \mathrm{b}_1=\gamma_{10}+\gamma_{11}\mathrm{Predictor}+\gamma_{12}\mathrm{Sex}+\gamma_{13}\mathrm{Age}+(\upsilon_1)\\ \mathrm{b}_2=\gamma_{20}+\gamma_{21}\mathrm{Predictor}+\gamma_{22}\mathrm{Sex}+\gamma_{23}\mathrm{Age}+\upsilon_2\\ \mathrm{b}_3=\gamma_{30}+\gamma_{31}\mathrm{Predictor}+\gamma_{32}\mathrm{Sex}+\gamma_{33}\mathrm{Age}+\upsilon_3\end{array} \quad \text{Level 2}$$

Respiration rates (RR_t) were grand-mean centered at level 1. Time was coded as "0" (RSA baseline) and "1", "2", "3" (first-, second-, and third-minute RSA during the anger task). Predictors (i.e., sadness and anger regulation, prosocial and aggressive behavior) were tested separately. Predictor and adolescent age and sex were grand-mean centered at level 2. Error term in parentheses (υ_1) was trimmed in final models since it was not significant.

As shown in Table 2, the results showed that adolescents with high sadness regulation had greater initial RSA suppression, $\gamma_{21} = -0.48$, $p = .04$, and greater subsequent RSA rebound, $\gamma_{31} = 0.15$, $p = .03$ (Figure 1). Likewise, adolescents with high anger regulation showed greater initial RSA suppression, $\gamma_{21} = -0.74$, $p < .001$, and greater subsequent RSA rebound, $\gamma_{31} = 0.20$, $p < .001$ (Figure 2). Adolescents with high anger regulation also demonstrated marginally high baseline RSA, $\gamma_{01} = 0.33$, $p = .08$. Adolescents with high prosocial behavior showed high RSA baseline, $\gamma_{01} = 0.68$, $p = .01$, greater initial RSA suppression, $\gamma_{21} = -1.02$, $p < .001$, and greater subsequent RSA rebound, $\gamma_{31} = 0.30$, $p < .001$ (Figure 3). We did not find significant results for aggressive behavior (Table 2). Taken together, these results suggest that a pattern of initial RSA suppression and subsequent RSA rebound was associated with better sadness and anger regulation, and more prosocial behavior. Further, higher RSA baseline was related to more prosocial behavior.

The conventional approach—Next, we again implemented the conventional approach, similarly based on the previous model, adolescent anger and sadness regulation, and adolescent prosocial and aggressive behavior scores were entered at level 2 separately to predict baseline RSA (b_0) and RSA suppression (b_2) in the following model (four separate models were tested):

$$\mathrm{RSA}=\mathrm{b}_0+\mathrm{b}_1\mathrm{RR}+\mathrm{b}_2\mathrm{Time}+\varepsilon \quad \text{Level 1}$$

$$\begin{array}{c}\mathrm{b}_0=\gamma_{00}+\gamma_{01}\mathrm{Predictor}+\gamma_{02}\mathrm{Sex}+\gamma_{03}\mathrm{Age}+\upsilon_0\\ \mathrm{b}_1=\gamma_{10}+\gamma_{11}\mathrm{Predictor}+\gamma_{12}\mathrm{Sex}+\gamma_{13}\mathrm{Age}+(\upsilon_1)\\ \mathrm{b}_2=\gamma_{20}+\gamma_{21}\mathrm{Predictor}+\gamma_{22}\mathrm{Sex}+\gamma_{23}\mathrm{Age}+\upsilon_2\end{array} \quad \text{Level 2}$$

Respiration rates (RR_t) were grand-mean centered at level 1. Time was coded as "0" at RSA baseline and as "1" during each of the other 3 minutes. Predictors including sadness and anger regulation, prosocial and aggressive behaviors were tested separately, one at a time. Predictor and adolescent age and sex were grand-mean centered at level 2. Error term in parentheses (υ_1) was trimmed in final models since it was not significant. The results indicated that adolescents with high anger regulation showed greater RSA suppression from baseline to the anger task, $\gamma_{21} = -0.65$, $p = .001$, also marginally high baseline RSA, $\gamma_{01} = 0.41$, $p = .05$. The other three predictors were not significantly linked to either RSA baseline or RSA suppression. Adolescents with high prosocial behavior demonstrated high RSA baseline, $\gamma_{01} = 0.77$, $p = .004$, greater RSA suppression, $\gamma_{21} = -0.78$, $p = .001$.

Discussion

To shed light on methodological issues in empirical RSA research, the current study adopted a process view of physiological regulation of emotion, and focused on adolescent RSA time course changes during an interpersonal challenging context. We also controlled for respiration parameters, and adolescent sex and age. Our findings indicated that an adaptive RSA change pattern was initial RSA suppression and subsequent RSA rebound, which was related to better anger and sadness regulation and more prosocial behavior among adolescents. These findings suggest that in response to emotional challenge, a pattern of parasympathetic withdrawal and subsequent parasympathetic activation may be more adaptive, which may facilitate better adolescent emotion regulation skills and positive development. We also compared the time course approach of capturing RSA linear and quadratic changes with the conventional approach of using simple RSA reactivity scores. We found that the time course approach yielded richer information by adding a rebound component of RSA change and more relations to emotion regulation outcomes, indicating that using simple RSA reactivity scores may be one main reason for null or inconsistent findings of previous RSA empirical studies (Burt & Obradović, 2013; Graziano & Derefinko, 2013; Hastings & Miller, 2014).

RSA Responses and Emotion Regulation, and Adjustment

Adopting a time course approach to model RSA temporal changes during an emotion event discussion task, we found a pattern of initial RSA suppression followed by RSA rebound from baseline across the task. Further, greater RSA suppression and rebound were associated with better anger and sadness regulation skills and more prosocial behavior. These results suggest that in the context of interpersonal challenge, such as talking about an actual anger-charged event, a pattern of initial RSA suppression followed by RSA rebound may reflect adaptive emotion regulation abilities, which in turn, may be related to more positive behavior among adolescents. These findings support the notion that RSA suppression in response to challenges may imply a readiness to respond to social stress (Brooker & Buss, 2010; Porges, 2007). Findings are also in line with recent empirical studies that found adaptive function of RSA suppression (e.g., Beauchaine et al., 2007; El-Sheikh et al., 2011; Gentzler et al., 2009). Further, these results are consistent with other investigations using similar time course approaches and support the notion that initial RSA suppression and subsequent RSA increases may be adaptive RSA reactivity in response to social and emotional challenges (e.g., Brooker & Buss, 2010; Miller et al., 2013). In adolescents' daily life, RSA suppression observed when individuals are exposed to stressful or challenging social environment may be advantageous as adolescents are probably emotionally aroused and RSA suppression allows them to react and respond to stressors. In addition, subsequent RSA rebound observed thereafter may be adaptive as individuals are probably actively regulating their intense negative emotions and trying to maintain a calming state to engage in the social activities (Hastings et al., 2008; Porges, 2007; Vögele et al., 2010).

Following the conventional approach of focusing on the overall change from baseline to the anger task, we found significant RSA suppression from baseline to the task overall, and significant associations between RSA suppression and anger regulation and prosocial behavior. Compared to the conventional approach of analyzing RSA data, the time course approach added a rebound component to RSA changes across time, which better matched with actual behavioral and emotional processes (Burt & Obradović, 2013) and provided richer information as it revealed meaningful associations to anger regulation, prosocial behavior, and also sadness regulation. The time course approach is an emerging approach in psychophysiological studies that researchers have started to utilize, and our findings are consistent with previous investigations utilizing similar temporal approaches and suggest the promise of such methods (e.g., Brooker & Buss, 2010; Gunnar et al., 2009; Miller et al., 2013).

This time course view of RSA suppression and rebound also aligns with a process view of emotion regulation. Emotion regulation has been defined in the literature as the internal and external processes by which the individual manages the occurrence, intensity, and expression of emotions to reach goals or situational demands (Eisenberg & Morris, 2003; Thompson, 1994). Cole et al. (2004) argued that researchers must examine emotion regulation in the context of emotional arousal where emotions are activated for there to be evidence of emotion regulation. Likewise, it may be essential for researchers to examine physiological regulation of emotion in process and in the context of emotional arousal for RSA suppression to be observed. Subsequent RSA rebound likely indicates emotion down regulation of the arousal.

Our findings also highlight the importance of considering the context of RSA measurement (Obradović et al., 2011). It is possible that the degree to which RSA reactivity to stress is adaptive depends on the context in which RSA is assessed (Obradović, 2012). We used an anger event recall and discussion task and examined RSA processes across the discussion. In such a social and emotional challenge context, individuals may be relatively emotionally aroused resulting in sympathetic activation and parasympathetic inhibition which would allow RSA suppression to be observed (El-Sheikh et al., 2009; Obradović & Boyce, 2012). This was what we found for the first phase of the task as adolescents were generally recalling and reliving the anger event. During this phase, RSA suppression is adaptive as the youth are emotionally aroused and getting ready to cope or deal with the negative emotion. The subsequent RSA rebound by the end of the anger event conversation in this study may reflect adolescents' regulation efforts while they were responding to parents' questions and engaging in the calming conversation. RSA rebound is adaptive in the second phase of the task. By considering RSA change processes, corresponding to internal and external needs of emotion regulation, our data afford critical information on the adaptability of RSA reactivity.

Note that, we did not find significant associations between the pattern of RSA suppression and rebound and adolescent aggressive behavior. Instead, links to prosocial behavior were evident. According to Polyvagal theory (Porges, 2007), RSA suppression reflects an individual's responses to threatening and challenging stimuli, and RSA augmentation is an indicator of active regulation to support calm engagement and form social bonds (Porges, 2011). Thus, the parasympathetic regulation of emotion may facilitate an individual's proficiency for cooperative, caring, and helping behaviors during social interactions (Hastings & Miller, 2014). For our assessment of parasympathetic activity, it may be more likely that RSA is linked to prosocial behavior rather than aggressive behavior. Indeed, studies have found greater RSA suppression in response to challenges associated with more empathic concern and prosocial behavior (e.g., Graziano, Keane, & Calkins, 2007; Hastings & Miller, 2014; Liew et al., 2011). Our lack of findings for aggression is in contrast to findings of Miller et al. (2013)'s study among young children who used an anger-induction film watching approach (i.e., observing other's anger). These authors found initial RSA suppression followed by RSA recovery pattern was related to children's better control of aggression. It is possible that how children react to others' anger (compared to their own anger) may be more strongly linked to aggression as indicated by the results of Miller et al. (2013) study. In addition, it should be noted that their temporal RSA changes were assessed across neutral, anger and positive emotion film watching, and their measure of control of aggression may have tapped anger regulation. Another possible reason of our lack of findings may be that during the second phase of the anger event discussion, adolescents may choose to talk with their parents rather than attempt to self-regulate. As such, the RSA rebound may not have been sufficiently robust to be linked to aggression.

RSA Baseline and Emotion Regulation and Adjustment

We also found that adolescent baseline RSA, measured when watching a neutral film clip, was linked to positive development (i.e., prosocial behavior) and (at trend level) to better anger regulation. Higher baseline RSA may reflect emotion regulation potentiality, and it has been linked to fewer behavior problems, such as internalizing and externalizing problems (Beauchaine et al., 2008; Crowell et al., 2005; El-Sheikh & Hinnant, 2011). Our findings add to the empirical evidence that higher baseline RSA is associated with positive developmental outcomes. However, the association between RSA baseline and emotion regulation was relatively weak. Several other studies of baseline RSA have not found significant correlates of vagal tone or baseline RSA with child and adolescent adjustment (e.g., Diamond et al., 2012; Egizio et al., 2008; El-Sheikh et al., 2009; Hinnant & El-Sheikh, 2009). Our findings of RSA baseline emerged after controlling for respiration rate, adolescent sex and age.

Despite our significant findings using a time course approach, the effects of RSA baseline were still relatively weak in the current study. It is possible that laboratory baseline measures do not accurately capture the actual baseline RSA of each individual. In particular, the laboratory setting may be novel and thus be moderately stressful to some participants, despite the fact that they typically have spent some time in the laboratory before the baseline measure. Another reason for a lack of findings may be because our baseline measure was relatively short (only one minute) and it was measured while adolescents were passively watching a neutral film clip. Third, there may be interaction effects between baseline RSA and the environmental contexts in which adolescents live. Some empirical studies support the notion that high baseline RSA may buffer the negative effects of adverse contexts, instead of manifesting main effects (e.g., El-Sheikh & Hinnant, 2011; El-Sheikh et al., 2011). Multiple and longer baselines under different conditions such as pure resting, paced breathing, and in supine position should be explored in future studies. Importantly, a more comparable talking baseline may work better as a better baseline (see Tininenko et al., 2012).

Strengths and Limitations

One of the strengths of the current study was that we modeled both the linear and quadratic RSA changes across a challenging task, which allowed us to capture the processes of emotional arousal and regulation that correspond to RSA reactivity. A second strength was that we accounted for respiration parameters (e.g., respiration rate) in all analyses. RSA is usually confounded with respiratory parameters, and previous studies typically have not corrected the respiratory confounds. Controlling for respiration parameters allowed us to obtain a better measure of RSA, particularly in our study where adolescents were talking from time-to-time and had some physical movement while sitting in the chair. A third strength was that we focused on interpersonal challenging social settings (i.e., parent-adolescent discussion of a real anger event), which represent typical adolescent daily stressors and may demonstrate strong ecological validity. In previous RSA reactivity studies, participants have been passively exposed to lab stressors such as physical (e.g., receiving special stimuli such as lemon juice on the tongue or squeezing handgrip dynamometer), cognitive (e.g., tracing stars or digit span recitation), social (e.g., structured interview), or emotional (e.g., watching film clips) challenges (Butler et al., 2006; Chapman et al., 2010; Ellis, Essex, & Boyce, 2005; El-Sheikh et al., 2011; Kreibig, 2010; Obradović et al., 2010; Nugent et al., 2011). However, in “real life,” most of the everyday stress that makes children and adolescents vulnerable to adjustment problems are related to *social* issues. In the current study, we used an angry event discussion task in which participants played an active role in choosing the topic and leading the discussion. Another strength was that our sample was a particularly low-income ethnically diverse sample as there have been few published RSA reactivity studies utilizing such samples. However, caution should be taken when generalizing our findings to other populations.

We also had some limitations in the current study. One limitation was that the baseline measure of RSA was not immediately preceding the anger task and the anger task did not have a specific clear recovery period by design. Although it may not have influenced the current findings, it would have been ideal to have a baseline right before the challenging task. A second limitation was that we only focused on measures of parasympathetic nervous system (PNS) functioning and did not have pure measures of sympathetic nervous system functioning such as pre-ejection period (PEP). PNS functioning has been found to be inconsistent across situations (e.g., Bertsch, Hagemann, Naumann, Schachinger, & Schulz,

2012) and is not always in concordance with reactivity in other physiological systems (e.g., Bauer, Quas, & Boyce, 2002; Cacioppo, Uchino, & Berntson, 1994). It would be helpful to investigate various systems simultaneously to better understand physiological response to stress in the future. Recent calls for integrative approaches to studying physiology and emotion across autonomic nervous systems, across multiple biological systems, and even across biological systems and contexts (El-Sheikh et al., 2009; Hastings, Buss, & Dennis, 2012; Kreibig, 2010) point out the need to consider the functioning of different systems. It may be beneficial for future studies that only focused on one physiological system to adopt a process perspective in data analyses and indeed, our findings suggest the advantages of the time course approach. A third limitation was that emotion regulation and adjustment variables were all self-reports. It is possible that adolescents with more adaptive RSA responses report more positive adjustment due to differences in physiological reactivity rather than actual behaviors. Future work should explore such issues using longitudinal data and other outcome measures.

Conclusions and Implications

The current study findings suggest that a pattern of initial RSA suppression followed by RSA rebound may be adaptive in response to interpersonal stress, especially to promote positive development among adolescents. Methodologically, the current study contributes to the field of RSA research by adopting a time course approach to illustrate the temporal processes of physiological regulation of emotion. The new generation of research on physiology and emotion would benefit from treating physiological regulation of emotion as processes. In addition, much can be gained from the use of multilevel modeling analysis to better understand the complex patterns of physiology of emotion.

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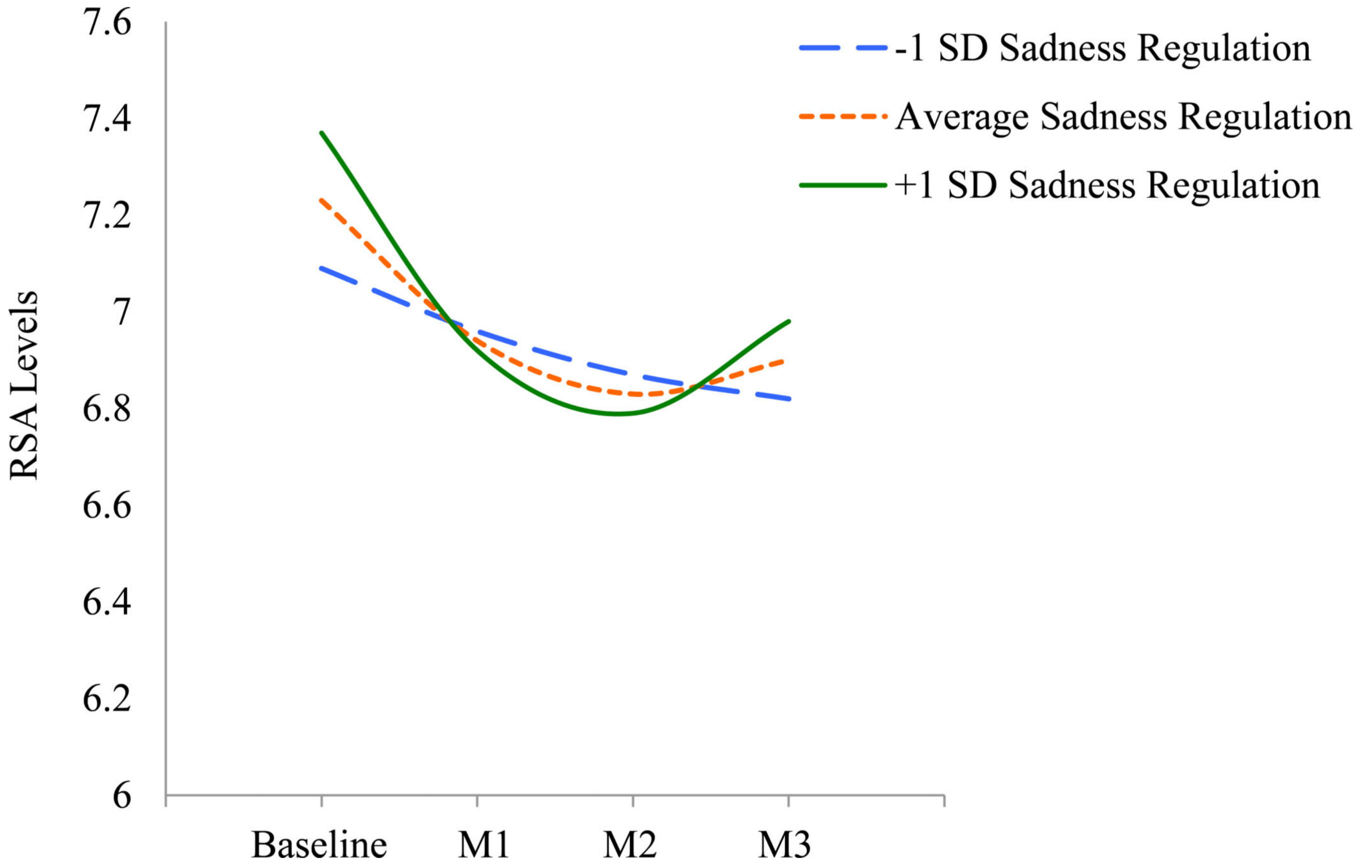

Figure 1.
RSA changes across time for adolescents with different levels of sadness regulation.

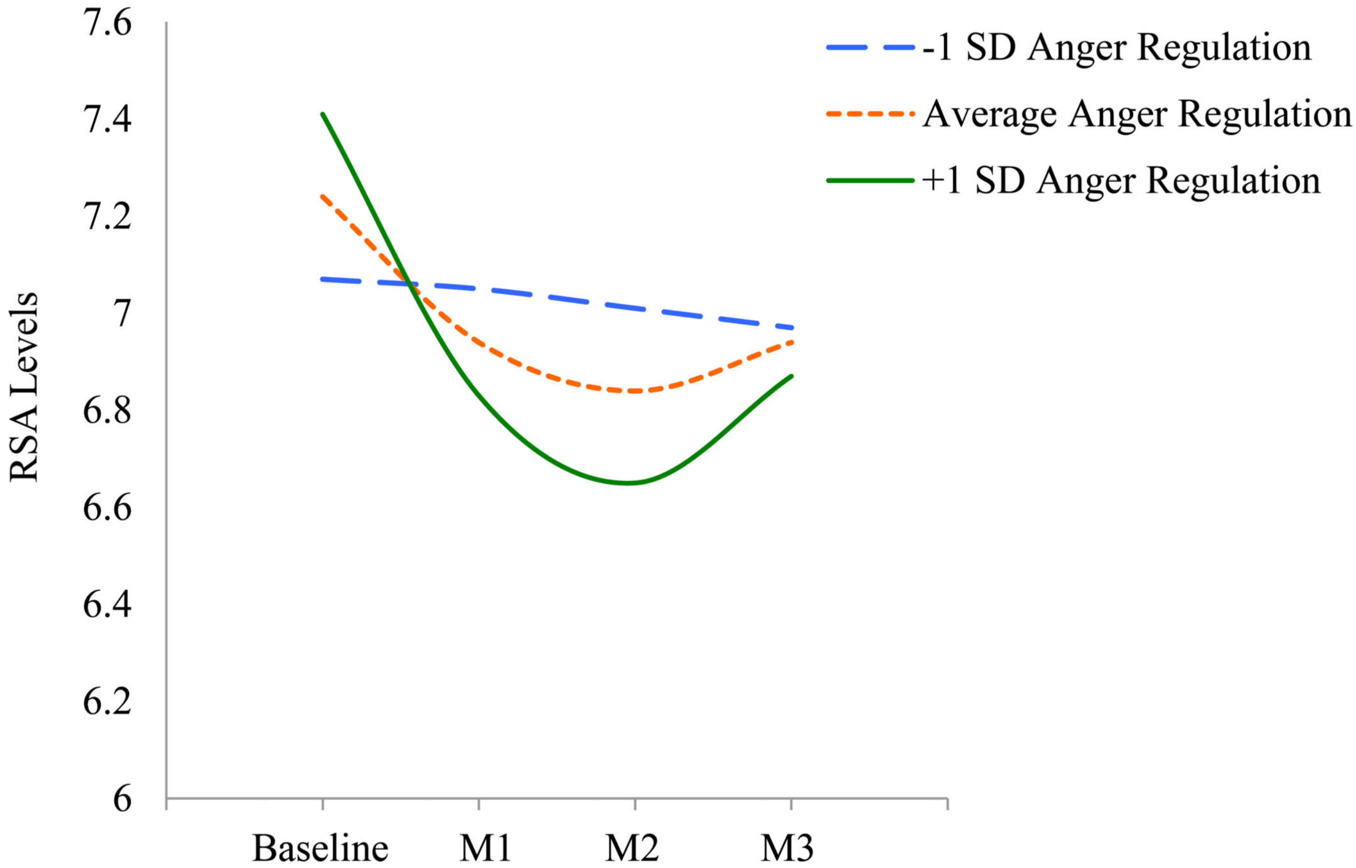

Figure 2.

RSA changes across time for adolescents with different levels of anger regulation.

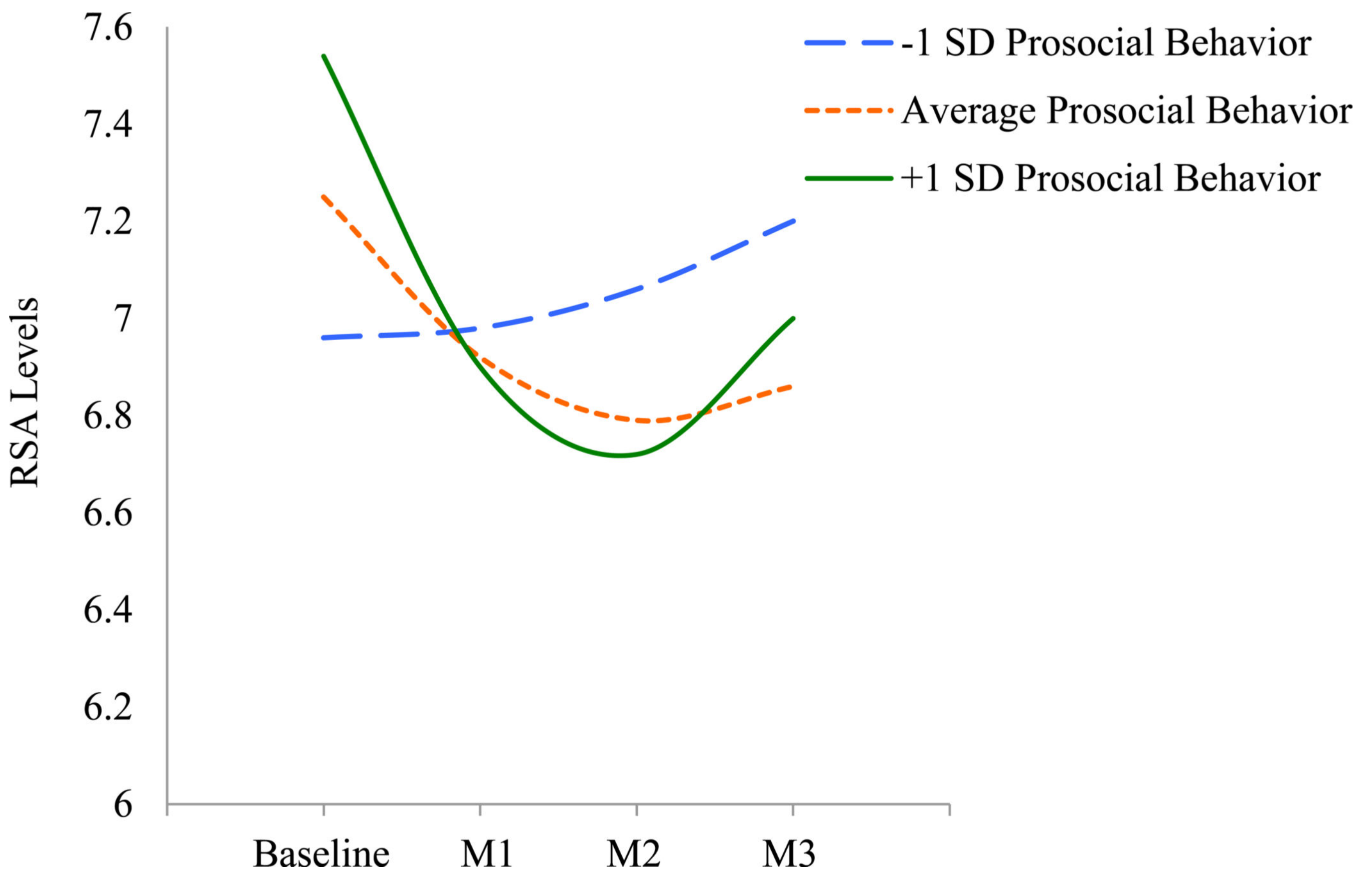

Figure 3.
RSA changes across time for adolescents with different levels of prosocial behavior.

Table 1

Means, Standard Deviations and Correlations of Major Variables

	N	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Sex	206	0.49	0.50	--												
2. Age	206	13.37	2.32	−.01	--											
3. RSA Baseline	188	7.09	1.32	−.03	−.12	--										
4. RR Baseline	188	18.70	4.99	−.04	−.02	−.15*	--									
5. RSA M1	155	7.01	1.17	.03	−.10	.65***	.04	--								
6. RR M1	155	21.64	6.28	−.03	−.01	−.04	.08	−.05	--							
7. RSA M2	155	6.90	1.23	.10	−.07	.73***	−.04	.81***	−.003	--						
8. RR M2	155	21.63	5.37	.01	−.03	−.01	.03	−.03	.12	−.16*	--					
9. RSA M3	154	6.95	1.10	.05	−.11	.64***	.11	.77***	−.08	.78***	−.13	--				
10. RR M3	154	21.50	5.59	−.07	−.12	−.02	.17*	−.004	.19*	.04	.27***	.04	--			
11. SR	205	1.26	0.47	−.01	.02	.03	−.06	.06	.05	.03	.04	.10	−.12	--		
12. AR	206	1.19	0.52	−.02	−.03	−.003	.004	−.04	.04	− .05	.02	.07	.05	.40***	--	
13. Prosocial	206	1.57	0.43	−.29***	−.06	.14†	−.02	−.03	.11	.01	.02	.10	.04	.28***	.45***	--
14. AB	206	1.43	0.52	.14*	.18**	−.08	.09	−.09	−.16*	−.09	.03	−.03	−.12	−.12†	−.43***	−.28***

Note. RR = Respiration Rate; M1 = First minute of anger task; M2 = Second minute of anger task; M3 = Third minute of anger task; SR = Sadness Regulation; AR = Anger Regulation; AB = Aggressive Behavior. Adolescent sex was coded as 0 (female) and 1 (male).

† $p < .10$.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 2

Four Multi-level Models of Whether Dynamic RSA Changes were Associated with Adolescent Emotion Regulation and Adjustment (Level 2 Results)

Fixed Effect	Model 1 Sadness Regulation			Model 2 Anger Regulation			Model 3 Prosocial Behavior			Model 4 Aggressive Behavior		
	Coefficient	***SE***	***t***	**Coefficient**	***SE***	***t***	**Coefficient**	***SE***	***t***	**Coefficient**	***SE***	***t***
b_0 (RSA Baseline)												
γ_{00} (Intercept)	7.23^{***}	0.11	67.99	7.24^{***}	0.10	69.35	7.25^{***}	0.10	69.52	7.27^{***}	0.11	66.59
γ_{01} (Predictor)	0.30	0.19	1.57	$0.33^{\dagger}$	0.18	1.79	0.68^{**}	0.24	1.99	−0.33	0.22	−1.47
γ_{02} (Sex)	−0.001	0.21	−0.01	−0.02	0.21	−0.11	0.17	0.21	0.81	0.004	0.21	0.02
γ_{03} (Age)	−0.08	0.05	−1.65	$-0.08^{\dagger}$	0.04	−1.74	−0.07	0.04	−1.69	−0.05	0.05	−1.04
b_1 (Respiration Rate)												
γ_{10} (Intercept)	-0.01^{*}	0.006	−2.13	-0.01^{**}	0.01	−2.53	-0.02^{*}	0.01	−2.37	-0.02^{*}	0.006	−2.57
γ_{11} (Predictor)	$-0.02^{\dagger}$	0.01	−1.94	-0.03^{**}	0.01	−3.27	-0.03^{*}	0.01	−2.35	0.02	0.01	1.53
γ_{12} (Sex)	−0.01	0.01	−0.52	−0.004	0.01	−0.40	−0.01	0.01	−1.15	−0.01	0.01	−0.44
γ_{13} (Age)	0.001	0.003	0.46	0.001	0.002	0.55	0.001	0.003	0.51	−0.00	0.003	−0.08
b_2 (RSA Linear Change)												
γ_{20} (Intercept)	-0.38^{**}	0.12	−3.21	-0.40^{***}	0.11	−3.56	-0.43^{***}	0.12	−3.67	-0.44^{**}	0.13	−3.48
γ_{21} (Predictor)	-0.48^{*}	0.24	−2.04	-0.74^{**}	0.17	−4.32	-1.02^{*}	0.27	−3.82	0.16	0.27	0.60
γ_{22} (Sex)	0.18	0.24	0.74	0.21	0.23	0.92	−0.10	0.25	−0.40	0.24	0.25	0.97
γ_{23} (Age)	0.04	0.05	0.80	0.05	0.05	0.91	0.04	0.05	0.82	0.03	0.06	0.44
b_3 (RSA Quadratic Change)												
γ_{30} (Intercept)	0.09^{**}	0.03	2.77	0.10^{**}	0.03	3.09	0.10^{**}	0.03	3.26	0.10^{**}	0.03	3.04
γ_{31} (Predictor)	0.15^{*}	0.07	2.19	0.20^{**}	0.05	4.35	0.30^{***}	0.07	4.03	−0.03	0.08	−0.42
γ_{32} (Sex)	−0.05	0.06	−0.76	−0.06	0.06	−0.93	0.03	0.07	0.47	−0.07	0.07	−1.02
γ_{33} (Age)	−0.01	0.01	−0.62	−0.01	0.01	−0.72	−0.01	0.01	−0.58	−0.01	0.02	−0.38
Random Effect	Variance Component	χ^2 (df)	*p*	Variance Component	χ^2 (df)	*p*	Variance Component	χ^2 (df)	*p*	Variance Component	χ^2 (df)	*p*
υ_0 (RSA Baseline)	1.35	860.69 (159)	.000	1.36	874.41 (159)	.000	1.33	876.90 (159)	.000	1.34	846.59 (159)	.000

Fixed Effect	Model 1 Sadness Regulation			Model 2 Anger Regulation			Model 3 Prosocial Behavior			Model 4 Aggressive Behavior		
	Coefficient	***SE***	***t***	**Coefficient**	***SE***	***t***	**Coefficient**	***SE***	***t***	**Coefficient**	***SE***	***t***
υ_2 (RSA Linear Change)	0.40	234.16 (159)	.000	0.38	231.10 (159)	.000	0.39	233.26 (159)	.000	0.39	231.86 (159)	.000
υ_3 (RSA Quadratic Change)	0.02	202.27 (159)	.012	0.02	200.69 (159)	.014	0.02	200.24 (159)	.015	0.02	202.18 (159)	.012
Level-1 error, ε_t	0.32			0.32			0.32			0.32		

†*Note*. $p < .10$.

* $p < .05$.

** $p < .01$.

*** $p < .001$.