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Relationships between Respiratory Sinus Arrhythmia and Stress in College Students

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Abstract

The purpose of this study was to examine the relationships between university students' respiratory sinus arrhythmia (RSA) profiles and both retrospective and momentary ratings of stress. Participants were undergraduate students enrolled in an introductory health science course (N=64). Participants provided RSA data at rest (tonic) and following an orthostatic challenge (phasic), completed the 10-item Perceived Stress Scale (PSS), and completed 6 daily ecological momentary assessments (EMA) of stress for one week. Higher tonic RSA was associated with lower perceived stress assessed via PSS and average EMA responses. Those with higher tonic RSA did not differ in their experience of stress across the week, whereas those with lower tonic

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RSA experienced increased stress across the week, and these trajectories varied as a function of phasic responses. These findings suggest a need for greater emphasis on behavioral strategies for maintaining and enhancing autonomic nervous system health among college students.

Keywords

Health; Stress; Assessment; Autonomic Nervous System

Introduction

The experience of chronic stress is a profound insult to health and quality of life across the lifespan. Beginning in the 1980s, researchers began to focus on the negative effects of stress among college students; a group of individuals undergoing substantial changes in academic responsibility and social connectivity. Results of this work revealed an association between perceived stress and self-esteem, self-efficacy, and optimism (Saleh, Camart, & Romo, 2017) and a positive association with blood low-density lipoprotein cholesterol concentration (Chaudhuri, Ray, Hazra, Goswami, & Bera, 2016). Academic stress is also a mediator of smartphone addiction and decreased life satisfaction (Samaha & Hawi, 2016). Prolonged exposure to physical or perceived stressors is particularly impactful, as it becomes embodied, altering a number of body systems including the autonomic nervous system (ANS; Porges, 1995). Surprisingly, little research in this population has focused on the relationship between cardiac vagal tone (CVT)—an index of ANS health—and perceived stress (Balzarotti, Biassoni, Colombo, & Ciceri, 2017; Beauchaine & Thayer, 2015; Porges, 2007). In the current study of first year college students, we examine whether or not CVT is related to perceptions of stress assessed with the self-reported 10-item Perceived Stress Scale (PSS-10; Cohen & Williamson, 1988) across the past month, as well as real-time stress perceptions assessed via smartphone-delivered ecological momentary assessments.

The ANS, which is comprised of parasympathetic and sympathetic branches, is responsible for facilitating the response to, and recovery from, a psychological or physiological threat. The sinoatrial (SA) node of the heart, which produces a steady heartbeat via rhythmic electrical impulses, is influenced by both the vagus nerve and sympathetic stimulation (James, 2003). As described in the Polyvagal Theory (Porges, 2007), the vagus nerve is comprised of an unmyelinated branch, which produces bradycardia and freezing behaviors, and a myelinated branch. Output from the myelinated branch to the SA node of the heart varies during respiration, producing an increase in heart rate during inspiration and a decrease during exhalation; a phenomenon termed respiratory sinus arrhythmia (RSA). High myelinated vagal tone slows heart rate, reduces cardiac output, and fosters social connectivity and a state of relaxation and restoration (Porges, 1995); an effect that has been termed the *vagal brake* (Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996). The vagal brake is released when an individual encounters a stressful stimulus, causing reciprocal excitation of the SA node by the sympathetic branch of the ANS. This response leads to an increase in heart rate and cardiac output and a concomitant decrease in heart rate variability (i.e., RSA). This response allows the body to meet the metabolic demands of a given threat (Porges, 1995).

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Much of the early research on RSA focused on RSA measured in a resting state (i.e., tonic RSA), finding that higher tonic RSA is related to better regulation of emotional responses and more flexible coping in response to a stressor (Porges, 1995). It is positively associated with trait resiliency and openness (Lu, Wang, & Hughes, 2016), and negatively associated with anger, hostility, depression symptoms (Ellis, Shumake, & Beevers, 2016), and psychological distress (Gouin, Deschênes, & Dugas, 2014) during cognitive or social stressors. Among college-aged individuals, lower tonic levels of RSA predicted future anger during a computerized stress task (Ellis, Shumake, & Beevers, 2016) as well as significant increases in psychological distress in response to a catastrophizing oriented interview (Gouin, Deschênes, & Dugas, 2014).

Researchers quickly recognized the importance of the change in RSA (i.e., phasic RSA) in response to a physical or psychological stressor. Although studies on the relationship between phasic RSA and perceived stress are limited, several studies have examined relationships with related psychosocial outcomes. For instance, greater reductions in RSA in response to a social stressor, which is thought to be the expected ANS response, were found to be associated with the experience of fewer depressive symptoms among college students (Holterman, Murray-Close, & Breslend, 2016). However, there is evidence that the interpretation of phasic RSA responses are dependent upon levels of tonic RSA. Indeed, particularly among those with low tonic RSA, large reductions in RSA in response to a threat appears a common biomarker for psychopathology (Beauchaine & Thayer, 2015; Porges, 1995). For example, individuals that reported higher baseline distress levels were more likely to experience greater and longer-lasting withdrawals of tonic RSA in response to a catastrophizing interview (Gouin, Deschênes, & Dugas, 2014). In a study that measured tonic and phasic RSA, individuals with low tonic RSA who had strong decreases in phasic responses were more likely to experience anger persistence in response to a computerized stress task, and this phenotype was more commonly observed among depressed participants compared to those who were healthy (Ellis, Shumake, & Beevers, 2016). Within the smoking cessation literature, researchers have noted that those with blunted stress-induced vagal reactivity were less able to resist smoking and reported greater craving relief and reinforcement from the act of smoking (Ashare et al., 2012). Importantly, different profiles of tonic and phasic RSA appear to be important for different behaviors. For instance, frequent social drinkers with high tonic RSA and a blunted RSA withdrawal in response to an orthostatic challenge reported greater cravings for alcohol and a greater decrease in craving in response to a drink (Mayhugh et al., 2018) compared to individuals without this RSA profile.

Given that tonic RSA is associated with better emotional regulation and adaptation to stressors—and therefore an individual's ability to react to and recover from individual stressors—we sought to examine whether tonic and phasic RSA were related not only to average self-reported stress, but also to the ways in which students cope with novel challenges on a day-to-day timescale and over the course of one week in the real world via ecological momentary assessment (EMA; Shiffman, Stone, & Hufford, 2008). We selected an orthostatic challenge as it has the advantage of representing a common challenge to the system that is independent of perception. We first hypothesized a main effect for tonic RSA on PSS-10 scores, such that those with higher tonic RSA would have lower scores on the

PSS-10. We also conducted additional exploratory analyses to determine whether or not there was a main effect for phasic RSA or a tonic × phasic RSA interaction on PSS-10 scores. We then replicated these analyses using stress ratings collected via EMA and summarized across one week to reduce recall bias. Finally, we utilized hierarchical linear modeling (HLM) to examine the main effects of tonic and phasic RSA and their interaction on momentary assessments of stress within the day and across the week. We expected that higher resting RSA would be associated with lower levels of stress both within the day and across the week.

Methods

Participants

We recruited undergraduate students from a private university in North Carolina between October and December 2017 using presentations in introductory health classes and university email lists. Inclusion criteria were as follows: (1) at least 18 years of age; (2) own an iPhone or Android smartphone; (3) able to ambulate without assistance; (4) and willing to complete an informed consent. Participants who completed all testing procedures received a gift certificate to a national coffee chain. Participants were excluded if there unable to ambulate or if they were not first year college students.

Procedures

Interested participants received an email providing information about the study. Those who remained interested were contacted by telephone for eligibility before being scheduled for an initial laboratory visit. During the laboratory visit, trained research staff collected height and weight, and then tasked participants with completing the respiratory sinus arrhythmia protocol described below. Additionally, participations provided demographic information and completed the PSS-10, before received orientation on completing ecological momentary assessments.

Beginning on the day following the baseline assessment, participants completed up to 6 daily prompts using a mobile web-app developed by one member of the research team (JF). Participants were asked to complete a survey upon waking up (i.e., an event-contingent survey), and beginning at 10:00 a.m., we delivered prompts at random times within 2-hour windows during the remainder of the day (i.e., 5 signal contingent surveys). Following each prompt, participants had one hour to complete each survey, with reminder prompts delivered at the 30^{th} and 45^{th} minute. At least one hour separated the closure of each assessment window and the start of the next 2-hour window. After seven days, we locked participants' accounts.

Measures

Demographics.—At the initial visit, we collected data on participants' date of birth, sex, race, ethnicity, height, weight and current medication usage. Using height and weight, we computed the body mass index BMI (kg/m^2) for each participant.

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Respiratory Sinus Arrhythmia (RSA).—We collected heart rate data using a BIOPAC MP160, with three electrodes at the following locations: right iliac crest, medial left clavicle, and the 5th intercostal space on the left side. Data were collected during seated rest (3 minutes) and moving from a seated position to a standing position, while standing (3 minutes), and again while seated (1 minute). These data were processed by Dr. Porges' laboratory in the Department of Psychiatry at the University of North Carolina to yield measures of tonic RSA and phasic RSA (i.e., RSA measured while standing, residualized on the individual's resting RSA score). Heart rate data were visually inspected and edited off-line using CardioEdit software (Brain-Body Center, University of Illinois at Chicago, 2007). Editing consisted of integer arithmetic (i.e., dividing intervals when R-peak detections were missed and adding intervals when spuriously invalid R-peak detections occurred) or manual insertion/deletion of missing/spurious R-peak detections based on the ECG recording. RSA was quantified using CardioBatch Plus software (Brain-Body Center for Psychophysiology and Bioengineering, University of North Carolina, Chapel Hill, 2016) consistent with the procedures developed by Porges (1985). CardioBatch Plus quantifies the amplitude of RSA using age-specific parameters that are sensitive to the maturational shifts in the frequency of spontaneous breathing. The method includes the following steps: 1) timing sequential R-R intervals to the nearest millisecond to produce sequential heart rate periods; 2) producing time-base data by resampling the sequential R-R intervals into 500 ms intervals; 3) detrending the time-based series with a 21-point cubic moving polynomial (Porges & Bohrer, 1990) to produce a template that is subtracted from the original time-based series to generate a detrended residual series; 5) bandpass filtering the detrended time series to extract the variance in the heart period pattern associated with spontaneous breathing in adults (.12 – .40 Hz); 6) transforming the variance estimates with a natural logarithm to normalize the distribution of RSA estimates (Riniolo & Porges, 1997). RSA was quantified during sequential 30-sec epochs during each of the conditions. The average RSA of the epochs within each of the conditions was used for analyses.

Perceived Stress Scale (PSS).—The 10-item Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983) is a widely used assessment of perceived stress. It measures the extent to which an individual appraises situations in their life as stressful (e.g., "In the last month, how often have you been upset because of something that happened unexpectedly?"). Participants indicate the frequency of their response on a 0 (Never) to 4 (Very Often) scale. Higher scores indicate higher levels off perceived stress.

Ecological Momentary Assessment.—Each ecological momentary assessment took no more than 90 seconds to complete. Of relevance to this study was one item meant to assess perceived stress on an 11-point visual analogue scale wherein 0 represented no stress and 10 represented high stress.

Analyses

Descriptive statistics related to EMA prompt completion were computed for each prompt, while descriptive statistics for demographic characteristics and PSS-10 scores were computed with the individual as the unit of analysis. To determine whether or not retrospective ratings of stress differed by tonic or phasic RSA, we partitioned participants

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into tertiles based upon phasic and tonic RSA scores, and compared PSS-10 scores between the top and bottom tertiles using a series of independent samples t-tests. We replicated this analysis utilizing an individual's EMA-reported stress averaged across the assessment week. For both sets of tests, normality was assessed using the Shapiro-Wilk test, equality of variances examined with Levene's test, and boxplots were used to identify extreme outliers. These analyses were conducted in SPSS version 25 (IBM Corp, Armonk, NY).

We examined relationships between momentary assessments of stress and RSA profiles using hierarchical linear modeling, performed with the Hierarchical Linear and nonlinear Modeling software package (HLM version 7.03, Scientific Software International, Chicago, IL). This approach adjusts the standard errors for clustering of the ecological momentary responses within the individual. Two-level models were fit, nesting within-day assessments (level 1) within the individual (level 2). Analyses followed a step up hierarchical approach wherein a null model was first fit to estimate within-person and between-person sources of variation and to compute intraclass correlation coefficients (ICC). Next, models were fit accounting for time of day, day of the week, and day of the study. Finally, to examine the relationship between RSA profile and stress reports, a median split was applied to both tonic and phasic RSA variables to identify 4 different groups corresponding to the 4 quadrants of the 2 × 2 median split, and four dummy variables were created. *High-typical* represents an individual with higher tonic RSA and greater reduction in RSA following the orthostatic challenge. *High-atypical* represents an individual with higher tonic RSA and a blunted or positive change in RSA in response to the standing task. This is reversed among those with lower RSA. Specifically, an individual with low tonic RSA and a still further withdrawal of RSA in response to the orthostatic challenge is atypical (i.e., *low-atypical*) when compared with an individual with low tonic RSA and a blunted phasic RSA response (i.e., *low-typical; see* Table 1). *High-typical* was treated as the reference condition and the associated dummy variable was omitted from models. It should be noted that tonic and phasic RSA exhibited a low correlation (ρ=.01), allowing for the creation of these four groups. The remaining dummy variables were entered into models in stepwise fashion, initially examining main effects and then interactions with time of day, day of the week, and day in the study. Finally, age and BMI were entered as a covariates. All continuous predictors were grand mean centered prior to entry in the model whereas dummy variables were entered uncentered. Statistical significance was established at $p \leq .05$, and variables were retained in the model at $p < .10$. For each model, visual inspection of scatterplots was used to determine linearity between included variables and momentary stress, as well as between residuals and predicted values. Visual inspection of the distribution of errors was used to establish normality of errors. Initial inspection of the outcome variable (i.e., momentary stress reports) indicated a strong positive skew that could not be meaningfully reduced via transformation. Moreover, the in-built homogeneity of level-1 variances test within the HLM package indicated heterogeneity in level-1 errors. As such, we investigated models allowing for heterogeneous level-1 variances. Given the skewed distribution of outcome values we also performed analyses using a non-linear (i.e., Poisson) distribution.

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Results

Participant Characteristics

In total, 123 undergraduates expressed interest in participating in the study, and 95 completed an initial telephone screening. Of these, 16 were eligible but failed to schedule or to attend the baseline testing visit. Therefore, baseline assessment data were collected on 74 individuals, and 64 had sufficient data for inclusion (i.e., with valid tonic and phasic RSA data). Participants had mean age of 18.24±0 .47 years with a healthy body mass index (22.96±3.76 kg/m). Participants were predominantly white (85.5%) and female (80.6%). Participant characteristics are displayed in Table 2, and study flow is depicted in Figure 1.

Prompt Characteristics

The 64 individuals included in the analysis provided a total of 2336 stress ratings from the ecological momentary assessments. The average response rate was 87.83%, with an average of 36.69 of 42 prompts answered per person. Regarding day in the study, the second day had the highest completion rate (91.67%), while the final day had the lowest completion rate (85.25%). With regard to day of the week, Friday had the highest completion rate (91.91%) while Sunday had the lowest (80.28%). Of the signal-contingent surveys, the fourth survey of the day (i.e., the "after dinner" prompt) had the greatest response rate (94.59%) while the first and last (i.e., late-morning prompt and before-bed) had the lowest (both 87.78%). Of all the daily surveys, the event-contingent prompt that were to be completed upon waking had the lowest response rate (73.08%).

Relationships between Stress as Assessed via PSS-10 and RSA

Scores on the PSS-10 were normally distributed (Shapiro-Wilk $p = 0.09$) and without extreme outliers, and the Levene's Test indicted equality of variances (tonic RSA $p = 0.50$, phasic RSA $p = 0.36$). The t test comparing PSS-10 scores between the top and bottom tertiles for tonic RSA was significant ($p = 0.031$) whereby individuals with higher tonic RSA reported lower perceived stress, a response supporting the hypothesis that participants with higher tonic RSA experienced lower levels of stress over the past month than those with lower tonic RSA (15.00±6.18 vs 18.95±5.44; $d = 0.68$). There was no significant relationship between the upper and lower tertiles of phasic RSA and PSS-10 scores (p =0.91).

Relationships between Stress averaged across Ecological Momentary Assessments and RSA

As with scores on the PSS-10, prospective person-averaged momentary stress scores on the 11-point visual analogue scale were normally distributed (Shapiro-Wilk $p = 0.11$), without extreme outliers, and Leven's Test indicated quality of variances (tonic RSA $p = 0.60$, phasic RSA $p = 0.28$). Once again, the t test comparing stress scores between the top and bottom tonic RSA tertiles was significant ($p = 0.050$) such that higher tonic RSA was associated with lower momentary reports of stress (3.05±1.51 vs 4.05±1.73; d=0.62). The t test for phasic RSA was not significant ($p = 0.71$).

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Relationships between Momentary Stress Responses and RSA

The null model produced an ICC of 0.409 indicating that approximately 41% of variance in stress was between individuals, and 59% was within-person (i.e., variations in stress occurring throughout the study week). There were no significant relationships between RSA profiles and patterns of stress accumulation within the day, or by day of the week; thus, these interactions were removed from the final model (Table 3). Similarly, there were no significant main effects or interactions with within-day prompt number so this effect was also removed from the final model. The model revealed a linear main effect for day of the week ($\beta = -0.25$, $p < 0.001$), suggesting a general reduction in stress responses in the group across the calendar week. There was also a quadratic main effect for day in the study ($\beta = 0.03$ $p = 0.011$) whereby individuals reported the lowest levels of stress at the mid-point of the study week. Compared with the reference condition (i.e., *high-typical*), there was no significant interaction effect for day of the study × *high-atypical*. There were, however, significant interactions for *low-typical* ($\beta = 0.18$, $p = 0.005$), and *low-atypical* ($\beta = 0.30$, $p = <0.001$). Additional post-hoc contrasts indicated significant differences in patterns of stress across days of the study between *high-atypical* and both *low-typical* ($\chi^2 = 6.22$, $p =0.01$) and *low-atypical* ($\chi^2 = 20.88$, $p < 0.001$) profiles. The difference between *low tonic* profiles was marginally significant ($\chi^2 = 3.62$, $p = 0.054$). Predicted stress values across the study week are depicted in Figure 2, and values are collapsed within *high* vs *low* tonic RSA in Figure 3. Investigation of Figure 3 highlights a general trend toward elevated or increasing stress across the study period in those with low tonic RSA, and lower or decreasing stress among those with high tonic RSA. Of note, those with low tonic RSA who experience a further decrease in RSA in response to the orthostatic challenge demonstrate a more substantial increase in stress across the week, albeit from a lower initial level, as depicted in Figure 2. We ran additional models to investigate factors contributing to heterogeneity in level-1 variances. Both day of the week (β=–0.05; $p = 0.004$) and BMI (β= 0.05; $p < 0.001$) accounted for significant level-1 variance. This suggests that stress reports were less variable on later days of the week, while individuals with higher BMI tended to have greater variability in stress reports. However, this model did not meaningfully alter the study findings. Likewise, the use of a non-linear distribution did not meaningfully affect the results.

Discussion

Herein we examined the relationship between both tonic and phasic RSA profiles and perceived stress ratings among college students. As expected, individuals with lower levels of tonic RSA had significantly higher perceived stress as assessed via questionnaire in the laboratory context, and these results were replicated using averaged momentary stress responses across the week. Investigation of momentary stress ratings revealed unique profiles of stress accumulation differentiating individuals with *high* and *low* tonic RSA, and these relationships are depicted in Figures 2 and 3. Among these students, higher tonic RSA was associated with the tendency to report a general decrease in perceived stress across the seven days of the study, with no significant difference between phasic RSA conditions. Among those with low tonic RSA, perceived stress scores generally increased across the study period; a finding in line with a strong body of research suggesting that low tonic RSA

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is associated with poorer psychological health and more difficulty with emotional regulation and flexible recovery from a stressor (Porges, 1995; Thayer, Hansen, Saus-Rose, & Johnsen, 2009). One potential explanation for this stress trajectory may be reactivity to the EMA prompts among those with low tonic RSA. Given the frequency with which adults now receive digital prompts (e.g., text messages, push notifications) via person smartphones and wearable devices, additional research capturing reactions to this type of minor stressor may highlight an important source of daily stress for some individuals.

The findings related to phasic RSA were more limited. Within the retrospective questionnaire data, there were no relationships between phasic RSA and perceived stress. Among those with high tonic RSA, there were no meaningful differences in momentary stress reports between phasic RSA profiles. Interestingly, whereas *low-typical* individuals maintained an elevated but stable level of stress across the study period, *low-atypical* individuals demonstrated marked increase in stress responses, albeit beginning from a lower initial level of stress. An interesting area for additional research lies in studying whether this instability, which may reflect a tendency to view stressors as “piling up” across the week or a difficulty recovering from day-to-day threats, is associated with poorer health and academic outcomes. Likewise, individuals with higher BMI demonstrated greater variability in stress responses. Emerging EMA research suggests that above and beyond typical levels of stress or affective valence, within-person variability may be indicative of poorer psychological health (Smyth et al., 2007; Trull et al., 2008). Others have found that individuals exhibiting the *low-atypical* RSA profile are more likely to seek out behaviors such as tobacco and alcohol use to aid in regulating their ANS in response to daily stressors (Mayhugh et al., 2018).

These results were observed from a fairly homogenous group of undergraduate students, but they extend prior work on the interaction between tonic and phasic RSA and hold several implications for addressing pressing student mental health challenges. First, it appears as though tonic RSA is related to one’s tendency to accumulate stress from day to day. Thayer and Lane (2000) suggest that higher tonic RSA is representative of better cognitive control of emotions that allows one to more appropriately process negative affect. Conversely, low tonic RSA may be indicative of hypervigilance to threat and an inability to inhibit the allocation of attention to imagined or innocuous stimuli, contributing to rumination and worry (Thayer & Lane, 2000). For students, (a) parental and personal expectations, (b) a looming transition away from student life and into the workforce, (c) along with academic, social, and extracurricular time commitments pose sometimes-overwhelming “threats” that place the individual at risk for depressed ANS functioning, further increasing their susceptibility to daily stressors (Kim, Cheon, Bai, Lee, & Koo, 2018). Fortunately, several behavioral therapies, including mindfulness meditation and biofeedback training (Lehrer & Gevirtz, 2014), have shown promise for restoring ANS functioning and improving measures of tonic RSA (Thayer et al., 2009). Bearing this in mind, administration at institutions of higher education may consider the inclusion of tonic RSA assessment on entry into the university and throughout a student’s tenure, with the option to receive behavioral treatment for those with abnormally low levels. Given the large increase in student mental health counseling utilization in recent years (Oswalt et al., 2018), it is apparent that many students are receptive to, and in need of, such support.

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A primary limitation of this study lies in the narrow scope of recruitment. Namely, students were recruited from within a small age range at a single liberal arts college. This is illustrated by slightly lower levels of perceived stress (16.71 ±5.96) relative to other studies of stress in university students. For instance, Saleh and colleagues (2017) reported PSS-10 scores of 20.23±1.99 in a sample of 483 students aged 18–24, while Roberti, Harrington, and Storch (2006) noted scores of 18.4±6.5 and 17.4±6.1 among 285 female and male undergraduate students, respectively. Future research would benefit from the inclusion of students encompassing a wider age range (Byrne, Fleg, Vaitkevicius, Wright, & Porges, 1996), and from institutions with varied academic expectations in order to capture wider variability in retrospective and momentary stress responses. Moreover, providing technology to assess RSA throughout the day would provide rich data on the synchronicity between EMA-assessed stress and affect and RSA reactivity in response to real-world challenges. Additionally, we leveraged median splits on tonic and phasic RSA to mirror previous literature (Mayhugh et al., 2018) and to leverage our fairly small sample size; however, additional research with larger sample sizes would benefit from analytic approaches that use continuous RSA scores. Finally, an interesting area of research would be examining how RSA profiles are related to coping with daily stressors, as research suggests that individuals with low tonic RSA and further RSA withdrawal to a stressor (i.e., the *low-atypical* group) also tend to find greater relief in substances such as alcohol (Mayhugh et al., 2018) and tobacco (Ashare et al., 2012).

Conclusion

In sum, this study represents the first attempt to relate tonic and phasic RSA profiles to both retrospective and real-world assessments of perceived stress among college students. Tonic RSA was related to retrospectively reported stress, averaged momentary stress ratings, and the accumulation of stress across the week. Lower phasic RSA appeared to be related to greater change in stress during the week, but these results were less robust than those related to tonic RSA. These findings suggest a need for greater emphasis on behavioral strategies for maintaining and enhancing ANS health among college students.

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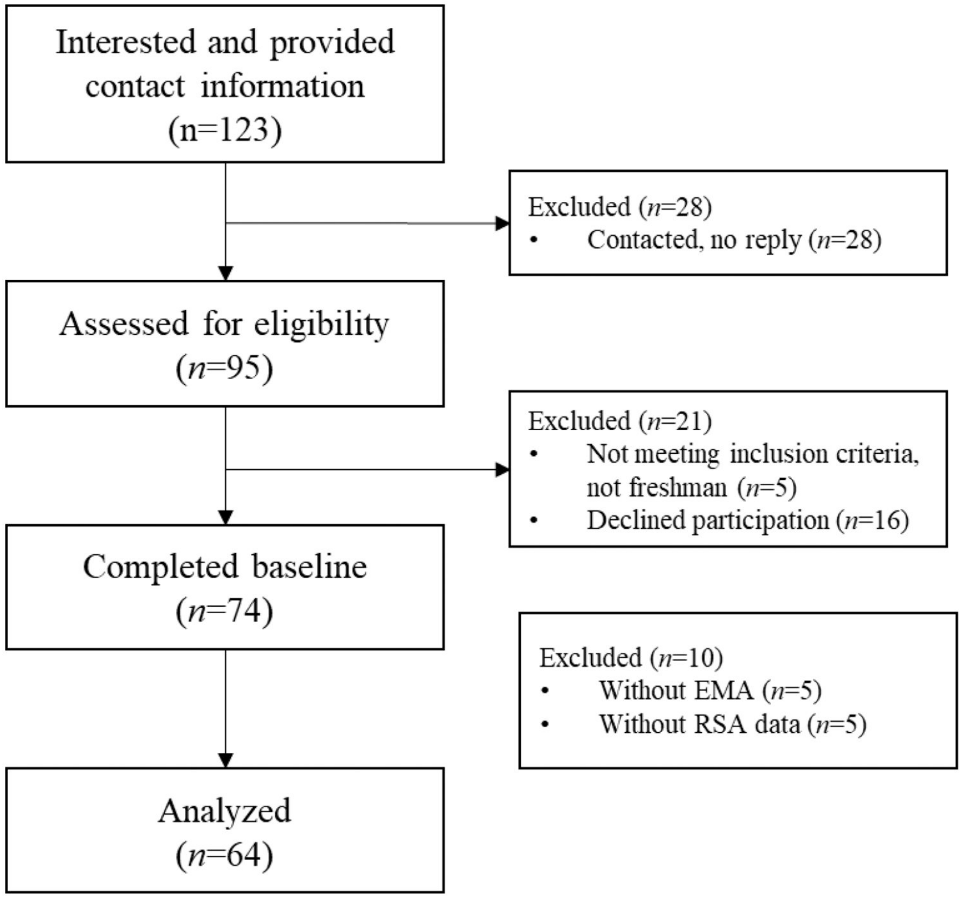

Figure 1.
Study Flow. Notes: EMA=ecological momentary assessment; RSA=respiratory sinus arrhythmia

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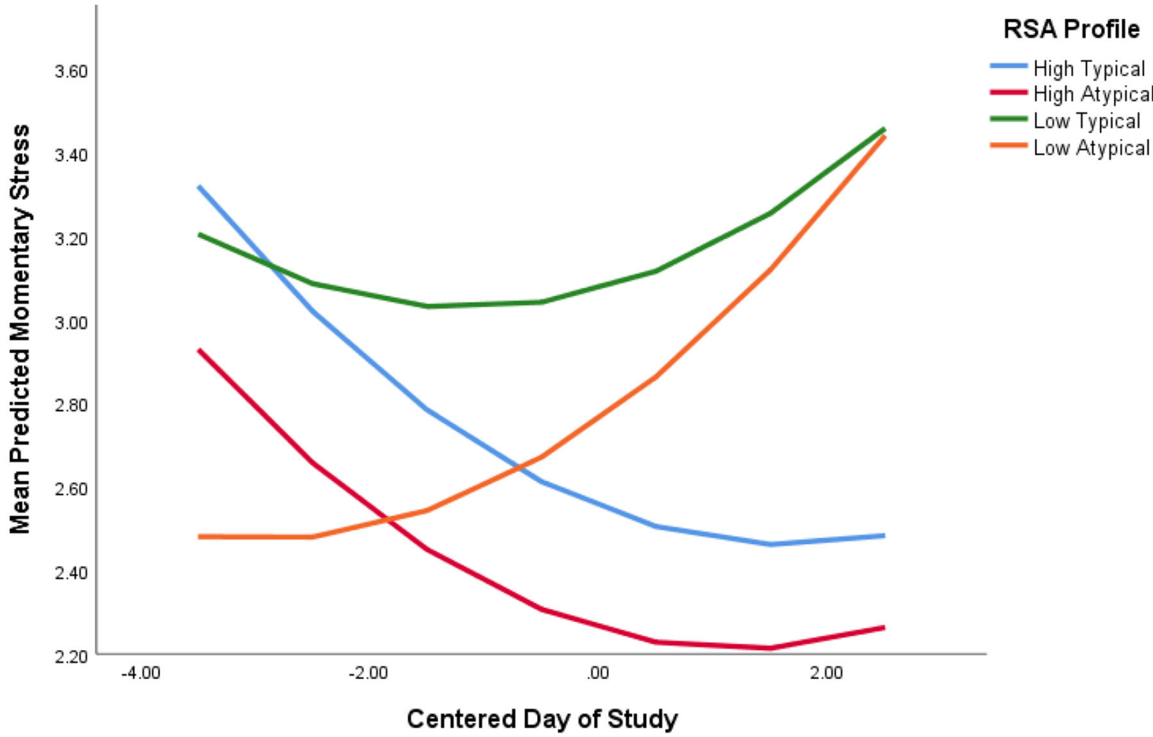

Figure 2.

Predicted daily stress across the week-long study period from final hierarchical linear model. Notes: RSA=Respiratory Sinus Arrhythmia

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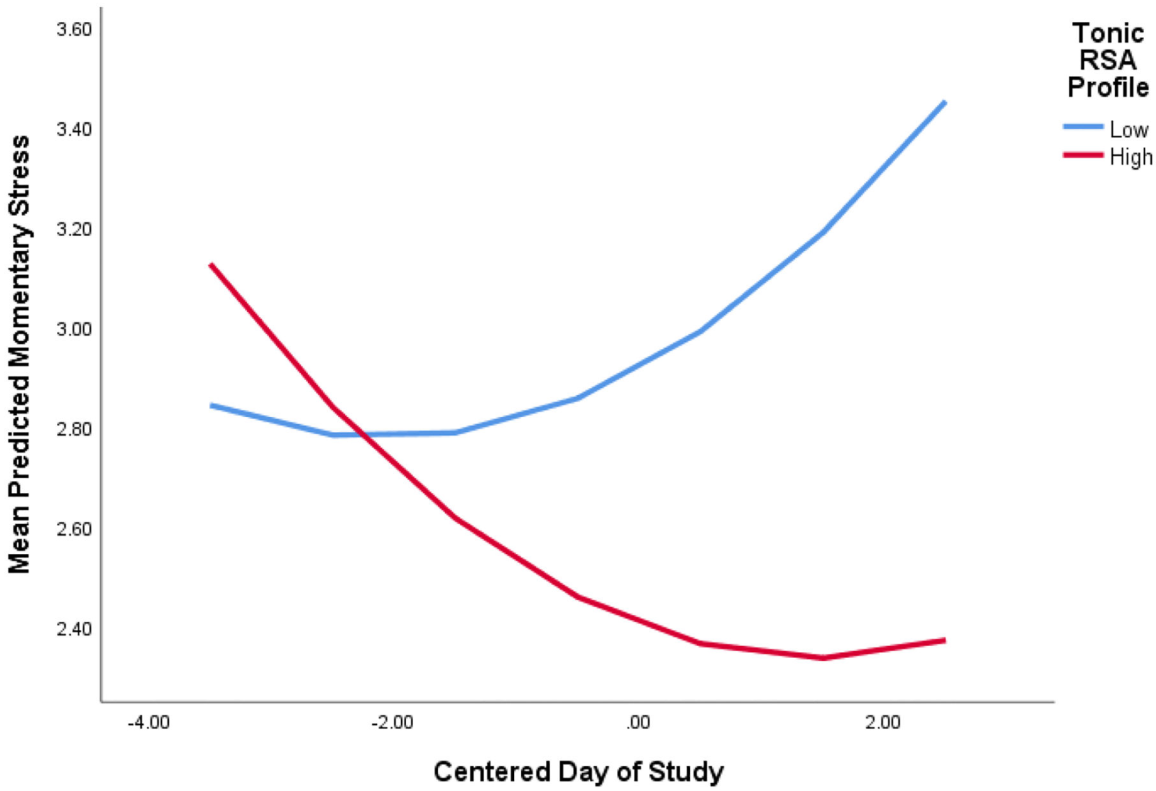

Figure 3.

Predicted daily stress across the week-long study period from final hierarchical linear model, collapsed across tonic RSA profiles. Notes: RSA=Respiratory Sinus Arrhythmia

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Table 2.

Participant characteristics.

Characteristic	
Sex, N (%)	
Male	15 (23.4)
Female	49 (76.6)
BMI, mean (SD)	23.15 (3.64)
Age, mean (SD)	18.23 (0.46)
Race, N (%)	
White	56 (87.5)
Non-White	8 (12.5)
Ethnicity, N (%)	
European	39 (60.9)
Hispanic	6 (9.4)
Asian	5 (7.8)
Other	5 (7.8)
Declined	9 (14.1)
Medication Use, N (%)	
Anxiety/Depression	2 (3.1)
Sleep	2 (3.1)
ADHD	3 (4.7)
PSS-10, mean (SD)	16.71 (5.96)

Notes: BMI=body mass index; SD=standard deviation; ADHD=attention-deficit/hyperactivity disorder; PSS-10=10-item Perceived Stress Scale

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Table 1:

Tonic x Phasic Respiratory Arrhythmia Interaction

Tonic RSA	Phasic RSA	
	High Withdrawal	**Blunted Withdrawal**
High Resting	High-Typical	High-Atypical
Low Resting	Low-Atypical	Low-Typical

Notes: this table describes four groups created by the interaction of a median split on tonic respiratory sinus arrhythmia (RSA) and median split on phasic RSA.

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Table 3.

Final hierarchical linear model results

Effect in Multilevel Model	Unstandardized Coefficient (SE)	Significance
Intercept	2.43	<0.001
High Atypical	−0.29 (.69)	0.674
Low Typical	0.52 (.71)	0.466
Low Atypical	0.21 (.67)	0.757
Day of Week*	−0.25 (.02)	<0.001
Day of Study*	−0.11 (.05)	0.027
Day of Study (quadratic)	0.03 (.01)	0.011
Day of Study × High Atypical	0.03 (.06)	0.646
Day of Study × Low Typical	0.18 (.06)	0.005
Day of Study × Low Atypical	0.30 (.06)	<0.001

Notes: BMI = Body Mass Index; HH=High Tonic-High Phasic Respiratory Sinus Arrhythmia (RSA); HL=High Tonic-Low Phasic RSA; LH=Low Tonic-High Phasic RSA; LL=Low Tonic-Low Phasic RSA; *=mean centered; ref = reference group; Adjusted for age*, BMI, and sex*