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PROACTIVE AND REACTIVE AGGRESSION, RESPIRATORY SINUS ARRHYTHMIA, AND SLEEP IN ADOLESCENTS

by

ALLISON BRASCH

A master's thesis submitted to the Graduate Faculty in Cognitive Neuroscience in partial fulfillment of the requirements for the degree of Master of Science, The City University of New York

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This manuscript has been read and accepted for the Graduate Faculty in Cognitive Neuroscience for satisfaction of the thesis requirement for the degree of Master of Science.

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THE CITY UNIVERSITY OF NEW YORK

Abstract

Proactive and Reactive Aggression, Respiratory Sinus Arrhythmia, and Sleep in Adolescents

by

Allison Brasch

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Current research evaluating the relationship between proactive and reactive aggression, sleep, and autonomic dysfunction has shown inconsistencies. The unique etiologies, manifestations, and presentation of these two aggressive subtypes have garnered much speculation, and research has shown mixed, and oftentimes conflicting, results. Generally speaking, insufficient sleep has been linked to increased agitation, cognitive impairment, emotional dysregulation, and poorer physical health. Many studies have provided support for an inverse relationship existing between sleep problems and sympathovagal health, implicating hypo- or hyper-autonomic function with proactive and reactive aggression, respectively. Concurrently and conflictingly, additional research has shown support for the exact opposite relationships between sleep problems and sympathovagal health, while some has also suggested that no significant correlations exist at all. The current study aimed to explore this further, investigating if respiratory sinus arrhythmia (RSA), a biomarker for emotion regulation and parasympathetic-mediated cardiac activity, was mediating the relationship between sleep and aggression among a sample of adolescents. The results of the study revealed that although sleep problems were positively associated with both types of aggression, no significant relationship were found between RSA and either sleep or aggression.

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Introduction

Acts of aggression are typically presented in one of two modalities: proactive aggression (PA) or reactive aggression (RA) (Dodge et al., 1997). Proactive aggression is often described as instrumental, goal-oriented, predatory, and cold-tempered (Crick & Dodge, 1996; Vitiello & Stoff, 1997). This type of aggression has been linked to higher risk for conduct disorders, as well as juvenile and adult delinquent behaviors (Vitaro et al., 2002). Reactive aggression, on the other hand, is seen as an intense, uncontrolled, hostile, and hot-tempered response to a perceived threat or provocation (Crick & Dodge, 1996; Vitiello & Stoff, 1997). This type of aggression has been linked to internalizing and externalizing disorders (White, Jarrett, & Ollendick, 2012), as well as emotional dysregulation (Card & Little, 2006), which can last into adulthood. While it may seem trivial to independently assess each subtype of aggression, both PA and RA encompass effectively separate and independent cognitive, affective, and physiological trajectories (Berkowitz, 2008; Fontaine, 2006; Merk et al., 2005). One proposed element contributing to aggressive tendencies is sleep; studies have shown a significant inverse relationship between sleep and aggression, particularly identifying a higher propensity toward reactive aggression in individuals with fractured sleep patterns (Krizan et al. 2006). While the cognitive aspects of sleep deprivation, in the context of aggression, have previously been ascertained by several studies, the psychophysiological components, to date, have yet to be clearly identified. One particular psychophysiological index for measuring emotional and cognitive regulation, according to the polyvagal theory, is respiratory sinus arrhythmia (RSA) (Graziano & Derefinko, 2013). While a reciprocal and bidirectional relationship between RSA and sleep has been established (Dahl, 2006), in this study, we propose that RSA acts as a mediating force between sleep and reactive aggression in particular.

Proactive aggression (PA) is the type of aggression in which an individual acts in a premeditated, calculated way, with the end result of achieving a particular goal beyond that of physical violence toward their victim (Dodge & Coie, 1987). PA is sometimes referred to as 'cold-tempered' because of the lack of emotional arousal, with no discernable overt threat or provocation, and no prior or concurrent arousal of the autonomic nervous system (Meloy, 2005). Simply put, this callous-unemotional type of aggression can manifest without the aggressor actually feeling any type of anger, occurring, for example, in situations like a robbery. It has been suggested that under-arousal of the autonomic nervous system (ANS) may lay the groundwork for PA to occur (Scarpa & Raine, 1997, 2000). As a consequence of this ANS hypo-arousal, the Arousal Theory (van Goozen et al., 2007) proposes that the demonstration of PA is twofold. First, by overcompensating for under-arousal by seeking out hazardous, unsafe, and stimulating situations, individuals can raise arousal from the lower baseline to a higher and more favorable state (Eysenck, 1997; Quay, 1965; Raine et al., 1997). The other component of the Arousal Theory is that in the absence of optimal levels of baseline ANS arousal, individuals may lack the capacity to experience fear in a meaningful way (Raine, 1993, 1997). As a result of these two components, attaining prospective goals or rewards is prioritized over prosocial concerns, and PA is expressed (Scarpa & Raine, 2004). This type of aggression is important to evaluate independently of RA, because in relation to RA, it is rare for adolescents to singularly express PA (Muñoz et al., 2008). Psychopathic traits, such as a lack of empathy and guilt, have been shown to be closely associated with the PA subtype specifically (Cima & Raine, 2009; Frick et al., 2003; Raine et al., 2006). In addition to the aforementioned association of PA with delinquent behaviors and conduct disorders, in one study by Nas, de Castro, and Koops (2005), it was shown that incarcerated juvenile delinquents had significantly higher levels of PA than their non-delinquent peers. Furthermore, PA has also been significantly positively associated with suicidal ideation and suicide attempts in adult males (Conner et al., 2009). Several forensic studies have demonstrated a significantly higher probability of criminal reoffences occurring among those who commit PA crimes (Antonius et al., 2013; Cornell et al., 1996). Clinically and socially, it is of critical importance to understand the cognitive and physiological aspects behind this modality of aggression in order to find successful intervening methodologies, as well as preventative tools.

Reactive aggression (RA), is characterized by impulsive, unplanned, and hostile responses to perceived threats, even with marginal provocation (Lake & Stanford, 2011). Conversely to PA, RA is referred to as someone being ‘hot-tempered’ given the contentious and strongly emotionally charged reactions displayed. This type of aggression typically amplifies, or even presents for the first time, during adolescence (Moffitt, 1993; Raine et al., 2006). Reactive aggressive behaviors have been linked to autonomic hyper-arousal (Scarpa & Raine, 1997, 2000). The hyperarousal associated with RA can be measured physiologically through increased activity of the sympathetic nervous system (SNS), which is correlated with aggressive behaviors responsible for the ‘fight or flight’ responses (Lochman et al., 2000; Zillman, 1983), and decreased activity of the parasympathetic nervous system (PNS), which is responsible for the ‘rest and digest’ responses (Pine et al., 1998). In addition to hyper-arousal of the SNS, in children and adolescents, RA is also associated with internalizing and externalizing disorders (White, Jarrett, & Ollendick, 2012) and emotional dysregulation (Card & Little, 2006). Youths who display reactive aggressive behaviors also show more violent aggression (Dodge et al., 1997) and social anxiety (Raine et al., 2006), both at rates higher than PA youths.

As humans spend approximately one-third of their lives asleep, it is clear that the benefits sleep provides are integral to one's physiology and cognitive processes. While the obvious effects of sleep disturbances on cognition, attention, and memory have been well documented (Maquet, 2001; Walker, 2008), positive correlations have also been made between sleep disturbances and emotional instability, such as hostility (Cutler & Cohen, 1979). Mounting evidence has shown that sleep disruption is a transdiagnostic process underpinning many adverse issues; compromised sleep is capable of not only generating but also intensifying emotional and behavioral regulatory problems. One study by Abad and Guillenminault (2005) showed that 80% of those diagnosed with a depressive disorder experience problems in sleep. Additionally, both Borderline Personality Disorder and Antisocial Personality Disorder have been related to sleep as well (Loranger et al., 1997). Furthermore, behavioral and emotional issues have been known to perpetuate erratic sleep cycles, in what appears to be a problematic self-perpetuating cycle (Dahl, 2006).

Taking into account the emotional effects that have been associated with disrupted sleep cycles, it would make sense that emotionally charged RA, and not necessarily callous-unemotional PA, is highly correlated with sleep problems. In fact, one study consisting of children and adolescents showed a significant positive correlation between increased sleep disturbances and parent-reported aggression and conduct issues (Chervin et al., 2003). Furthermore, another study, evaluating violent offenders, showed that a decrease in sleep difficulties was related to a decline in aggressive behaviors (Haynes et al., 2006). Interestingly, it has been shown that even having a false perception of reduced sleep has been shown to lead to an increase in emotional aggression. Barker et al. (2016) demonstrated that by convincing participants they experienced sleep differently than they actually did, cognitive and behavioral functioning was affected. Those who were told they experienced inadequate sleep presented decreased cognitive functioning and behavioral control, and those who were made to believe they experienced satisfactory sleep presented increased cognitive function and behavioral control, regardless of the actual quality and quantity of sleep experienced. Sleep issues among teens, and even adults, is not uncommon; according to the most recent data released by the CDC, in the United States, 72.7% of adolescents between ninth and twelfth grade, and 31.6% of adults over eighteen reported insufficient sleep (Center for Disease Control and Prevention, 2018). Because insomnia and hypersomnia are remarkedly common among adolescents, coupled with the discernable association between compromised sleep and psychopathological symptoms, it is imperative to attempt to further understand the mechanism mediating this dynamic interplay between sleep and aggression.

Investigating further into the ANS functioning correlated with impaired sleep, respiratory sinus arrhythmia (RSA), is widely accepted as a reliable index of PNS functioning, emotional, and cognitive regulation (Graziano & Derefinko, 2018). The PNS sustains continuous control over heart rate, adjusting cardiac activity as needed (Porges, 2007). RSA measures PNS functioning via cardiac activity (heart rate variability) by way of the vagus nerve (Porges, 1995, 2007). A high resting RSA is indicative of higher vagal tone, representing more enhanced control of the heart by the vagus nerve, while a lower resting RSA demonstrates poorer vagal tone, and reduced regulation of cardiac control. The correlation between RSA and behavioral adaptation is well-established; a higher resting RSA is reflective of greater cardiac manipulation via the vagus nerve, allowing for real-time adaptive changes to occur in response to situational fluctuations and environmental stress (Calkins et al., 2013; Porges, 1992, 2007), and a lower resting RSA reveals a decreased ability of the vagus nerve to control cardiac activity, thereby potentially diminishing emotional and behavioral regulation (Porges, 2007). The ANS also has a complex and dynamic relationship with the sleep cycle, whereby different periods of sleep are governed by different aspects of autonomic control. Tobaldini et al. (2013) described how this reciprocal relationship not only allows for dysfunction of ANS activity to moderate and prevent the onset of sleep, as well as fracturing the duration of sleep, but also allows for sleep itself to profoundly disturb vagal regulation.

In the current study, I examined the relationships between sleep quality/quantity and aggressive behavior in a group of adolescents from the community. I aimed to expand on the previous literature that has linked aggression to sleep by testing if sleep problems are particularly associated with the reactive but not proactive type of aggression. More importantly, I aimed to fill a gap by investigating the role of RSA as a potential mediator between sleep and RA.

Method

Participants

The participants for this study consist of a sample of ninety-nine adolescents (51 female, 46 male) between twelve and sixteen years old (mean age = 14.11, SD = 0.80) from the Healthy Childhood Study (HCS). HCS is an ongoing longitudinal study evaluating how neurobiological and psychosocial factors may contribute to childhood behavioral problems. The participants were recruited via phone call or email, and eligibility was determined by previous participation in the HCS. HCS eligibility, assessed by a recruiter phone evaluation with the primary caregiver, included screening for exclusion criteria such as diagnosed psychiatric, behavioral, or intellectual disorders. The recruiters also excluded the participants who engaged in therapy, as well as those on prescription medication. The participants were of varying ethnicities (42.2% African American, 22.4% Caucasian, 14.7% Multiracial, 11.2% Hispanic/Latinx, 2.6% Asian/Pacific Islander, 0.9% Native American, and 6% Other/Decline to Answer), and all lived in or near Brooklyn, New York, during the time of the study. The HCS study required that a parent or legal guardian accompany the participant in the visit to the Psychophysiology Lab at Brooklyn College, as well as provide questionnaire and behavioral data about the participant. Primarily, the caretakers cooperating in the study consisted of the participant's biological mothers (88.9%), but also included biological fathers (9.4%) and grandmothers (1.7%).

Procedure

The participants and their primary caregivers were invited to attend two-hour sessions in the Psychophysiology Lab at Brooklyn College between 2018 and 2020. Each assessment consisted of a behavioral interview, questionnaire data collection, and psychophysiological testing and recording. Some caregivers requested to receive both the parent and child questionnaires in advance, via email, and brought the completed forms in with them. Others opted to complete the questionnaires and demographic data during the session and upon arrival to the lab were provided the questionnaires. Relevant data collected in the questionnaires included the Pittsburgh Sleep Quality Index (PSQI) and the Reactive-Proactive Questionnaire (RPQ). All interview data and psychophysiological data were collected by graduate-level research assistants who had completed training under the supervision of the principal investigator. Child assent and caregiver consent were both obtained at the start of the session. Incentives for their participation in the study, in the form of a monetary compensation, was provided at the end of the assessment. All study procedures and materials were approved by the City University of New York Institutional Review Board.

Measures

Pittsburgh Sleep Quality Index (PSQI; Buyesse et al., 1989)

The Pittsburgh Sleep Quality Index (PSQI), as seen in Appendix A, is widely used as a standardized measure indexing individual's sleep habits, with demonstrated validity of psychometric characteristics among adolescent populations (de la Verga et al., 2015). The PSQI is a self-reported questionnaire consisting of ten questions to assess both the qualitative and quantitative aspects of sleep during the last month. PSQI questions include inquiring into information such as average amount of sleep per night, trouble falling or staying asleep, impaired sleep due to physiological disturbances, medications taken in order to help with poor sleep, daytime dysfunctions caused by poor sleep, and overall sleep quality. Seven components (duration of sleep, sleep disturbance, sleep latency, day dysfunction due to sleepiness, sleep efficiency, sleep latency, need meds to sleep) are used to produce a global score between zero and twenty-one, where a lower global score is associated with a healthier sleep quality, and a higher score indicates increased sleep disturbances. A total composite score less than or equal to five indicates good sleep quality, and a total score greater than five indicates poor sleep quality (Buysse et al., 1989).

Reactive-Proactive Aggression Questionnaire (RPQ; Raine et al., 2006)

The Reactive-Proactive Aggression Questionnaire (RPQ), as seen in Appendix B, is a self-reported questionnaire used to assess reactive and proactive aggressive qualities in children or adolescents (Raine et al., 2006). The RPQ consists of twenty-three questions, twelve relating to proactive aggression (questions such as "I fight others to show who is on top" and "I use force to get others to do what I want") and eleven relating to reactive aggression (questions such as "I hit others to defend myself" and "I damage things when I am mad"). Each answer is ranked on a Likert-type scale: zero (never), one (sometimes), and two (often). The scores from each aggression subtype are summed, creating proactive and reactive scales; higher scores are indicative of increased levels of either subtype of aggression.

Psychophysiological Data

A BIOPAC MP150 system (Biopac Inc., CA) was utilized to obtain all physiological data collected in this study. Resting psychophysiological data were obtained during a two-minute duration at the start of the session, during which participants were advised to sit still while attending to a fixed point shown on the computer screen in front of them.

Respiratory sinus arrhythmia (RSA) was derived from the ECG100C amplifier with a band pass filter of 35 Hz and 1.0 Hz, and a RSP100C respiration amplifier with a band pass filter of 1.0 Hz and 0.05 Hz. Electrocardiography (ECG) information was collected by the ECG100C, via two disposable Ag-AgCl pre-gelled vinyl electrodes. Prior to electrode placement, research assistants used NuPrep gel to clean the areas to which the electrodes would be affixed. The electrodes were then placed in a Lead II configuration. ECG signals were analyzed by a research assistant to identify and correct for anomalies and irregularities. Respiration was measured by fitting the participant with a respiration belt around their abdomen at the point of total exhalation. The AcqKnowledge automated function for RSA analysis was utilized. The well-validated peak-valley method (Grossman et al., 1990) was followed by the software, in which RSA was computed in milliseconds as the difference between the minimum and maximum R-R intervals, the time between heart beats, during respiration. Higher values are reflective of greater PNS activity (Gruber et al., 2009).

Statistical Analysis

All analyses were conducted using SPSS 25.0. Outliers more than three standard deviations from the mean were eliminated from the analysis. Any RSA value that was notated by the research assistant as linked to inconsistencies or errors was also excluded from the analysis. Pearson correlations were conducted to examine the associations among study variables, and hierarchical linear regressions were administered to analyze the relationships between the variables.

Due to the high correlation between PA and RA, hierarchical multiple regression analyses were conducted in order to control for the effect of the nonfocal type of aggression on the focal type. Separate analyses were done for PA and RA. Within each of the regression models, the effects of the alternate form of aggression were controlled for in the first step. In the second step, the effects of RSA, sleep problem score, and participant gender were examined. Finally, if RSA were associated with sleep and aggression, the PROCESS macro for SPSS (Hayes, 2013) would be conducted to examine the mediating effect of RSA.

Results

Descriptive Statistics

Means for each of the main variables are shown in Table 1. As expected, the PSQI total score was significantly positively correlated with both PA (*r* = .328, $p < .001$) and RA (*r* = .312, $p < .001$), as shown in Table 2, and Figures 1 and 2. Additionally, PA and RA were significantly positively correlated with each other (*r* = .618, $p < .001$), as shown in Figure 3. Within this sample, the correlations between RSA and the other variables were not significant. Additionally, there were no significant correlations between gender and any of the other variables. Due to the lack of significant correlation between RSA and the other variables, running the PROCESS macro for SPSS (Hayes, 2013) for a mediation analyses was determined inappropriate.

Proactive Aggression, RSA, PSQI, and Gender

Results of the hierarchical regression analysis are shown in Table 3. In step one, reactive aggression was significantly linked to proactive aggression, accounting for 42.8% of variation ($R^2 = .428$, $\beta = .654$, *SE* = .037, $t = 8.386$, $p = .000$). After controlling for reactive aggression, the variables in step two accounted for 2.2% of the variation in PA, and none of the effects were significant: for RSA, $\Delta R^2 = .022$, $\beta = -.082$, *SE* = .003, $t = -1.052$, $p = .286$; for PSQI, $\Delta R^2 = .022$, $\beta = .115$, *SE* = .050, $t = 1.383$, $p = .170$; and for gender, $\Delta R^2 = .022$, $\beta = -.073$, *SE* = .291, $t = -.927$, $p = .356$.

Reactive Aggression, RSA, PSQI, and Gender

Results of the hierarchical regression analysis are shown in Table 4. In step one, proactive aggression was significantly linked to reactive aggression, accounting for 42.8% of variation ($R^2 = .428$, $\beta = .654$, *SE* = .163, $t = 8.386$, $p = .000$). After controlling for proactive aggression, step two accounted for 2.9% of the variation on RA, and none of the effects were significant: for RSA, $\Delta R^2 = .029$, $\beta = .077$, *SE* = .006, $t = .997$, $p = .322$; for PSQI, $\Delta R^2 = .029$, β

= .138, *SE* = .104, t = 1.678, p = .097; and for gender, ΔR^2 = .029, β = .070, *SE* = .604, t = .892, p = .375).

Discussion

This study aimed to determine the potential mediating effects that RSA may have on the relationship between more sleep problems and increased reactive aggression in an adolescent sample. It was hypothesized in this study that individuals with higher RA scores would have more sleep problems, and this may be mediated through decreased vagal tone, as indexed by lower RSA. Findings of the current study did not show a significant mediatory effect of RSA on the relationship between PSQI and RA, nor did it reveal any significant correlations between RSA and PSQI directly, or RSA and either aggressive subtype. Thus, the hypothesis was unsupported. In alignment with the previously documented relationship between sleep and aggression, findings did demonstrate significant relationships between increased PSQI score, identifying poorer sleep quality, and increased RA – consistent with the prior assumptions that increased RA is associated with more sleep problems. Interestingly, the analysis additionally revealed a similar relationship between PSQI score and PA, in which increased sleep problems were also correlated with increased PA. Overall, poorer sleep was shown to be significantly correlated with increased aggression. While this study provided further evidence on the relationship between sleep and aggression, findings suggest that the role of RSA in this context is negligible, and additional variables are likely to be impacting the relationship.

Proactive Aggression

The hypoarousal theory of PA, which suggests a significant relationship between under-arousal of SNS (i.e., increased RSA) with increased PA, was not explicitly supported in the current study. The results of this study were indicative of a positive relationship between insufficient sleep and PA, suggesting that overall poorer sleep is associated with higher expressions of the proactive subtype of aggression. While these results were not specifically hypothesized, the concept is not entirely novel considering prior literature. For example, some studies have shown that problems with sleep have been linked to behaviors associated with PA, such as increased risk-taking, as well as delinquency in adolescence (Sadeh et al., 2014). Furthermore, another study showed that children who were reported to experience increased levels of sleepiness during the day had a higher likelihood to be described by their parents as bullies (O’Brien et al., 2011).

Reactive Aggression

Consistent with previous literature, the results of this study supported the established relationship between decreased sleep and increased RA. Although the hyperarousal theory, which posits that excessive arousal of the SNS (i.e., decreased RSA) would be linked to RA as well as undermined sleep, was not explicitly supported. Prior studies have identified associations with autonomic hyperarousal underlying RA. Scarpa and Raine (1997, 2000) identified an increased propensity for RA behaviors among individuals with elevated SNS activity, principally among individuals during times of perceived provocation, or while experiencing acute anger. However, current findings failed to find the link between RSA and RA. In contrast, the manifestation of RA traits, which often emerge in adolescence, and the relationship between RA and insufficient sleep has compelling support from previous literature. One of the major components of RA, the reduced ability to inhibit aggressive responses in the face of perceived threats, is directly associated with diminished sleep quality (Drummond et al., 2006). Additional studies have also linked sleep deficiencies with conduct disorders and other behavioral issues (Vaughan et al., 2015).

Proactive and Reactive Aggression

The results of this study revealed an interesting significant cooccurrence between self-reported PA and RA, as well as a significant correlation between both aggressive subtypes with total PSQI score. This illustrates the significant influential effects that PA and RA have on each other, as well as a substantial positive correlation between PA/RA and sleep dysfunction. While there may be unique cognitive processes and neurobiological underpinnings differentiating the manifestation and demonstration of PA and RA, research has shown that the prevalence of both aggressive subtypes among adolescents is not uncommon (Thompson et al., 2017). While this correlation was not specifically expected, given the cyclic nature of the interaction between sleep and aggression, it is not entirely obscure.

To date, research findings regarding the psychophysiological components differentiating PA and RA subtypes has been largely inconsistent and contradictory. In a review by Fanti (2016), these inconsistencies are showcased; between numerous studies, both high and low physiological arousal were associated with each aggressive subtype, as well as entirely insignificant correlations suggesting no relationship between aggression and physiological indicators. Given the conflicting and irregular data, it remains important to continue to investigate.

Respiratory Sinus Arrhythmia

RSA, which is an index of PNS-linked cardiac activity, has been identified and vastly utilized as a biomarker for emotional dysregulation. Previous research has shown that vagal tone, expressed through vagal augmentation as well as vagal withdrawal, serves a regulatory function in the context of emotional regulation and stress. In a plethora of studies, higher RSA has been identified as an indicator of well-functioning emotional regulation (such as adaptation in the face of stressful events), and lower RSA had been linked to amplified emotional dysregulation (such as increased externalizing behaviors).

In the current study, however, the data did not confirm this relationship, as it would relate to aggression. Similarly, mixed findings regarding the interrelation between RSA and response behaviors have been shown through other research. For example, some studies have shown the opposite correlation between RSA and emotional regulation, indicating lower vagal responsiveness to be associated with appropriate emotional regulation, as well as decreased externalizing issues (Hastings et al., 2008). Moreover, other studies, in conjunction with the current study, have been unable to identify a statistically significant relationship occurring between vagal reactivity and aggression (Zhang & Gao, 2015). While both heightened and lowered PNS reactivity have been identified, in relation to aggressive behaviors, it remains imperative to analyze and consider additional augmenting correlates.

Sleep

Poor sleep quality and diminished sleep quantity are increasingly prevalent issues among adolescents and adults. In the current study, the average PSQI score was approximately 6.7, where any score greater than 5 indicated poor sleep quality. In fact, only 42% of participants scored within the acceptable range indicative of good sleep quality.

As previously discussed, even acute sleep deficiencies have been shown to poorly affect cognitive performance, as well as emotional regulation and aggression. Moreover, sustained sleep problems have been linked to a higher susceptibility to mood disorders (Meerlo et al., 2008). On top of the cognitive and emotional issues linked with sleep, the adverse effects of poor sleep have also been shown to decrease physical components of overall well-being. Dinges et al. (1997) reported that insufficient sleep had a positive correlation with number of headaches, stomach aches, and overall physical discomfort and sensitivity to pain. It is difficult to determine if there is an antecedent/consequent relationship among the variables of disordered sleep, aggression, cognitive, and physiological factors, but research suggests multidirectional relationships in which aggression, cognitive, neurobiological and physiological factors and sleep can be reciprocally shaped by the others.

While mixed findings and inconsistencies have been revealed by previous literature, regarding the relationships between physiological factors and sleep, as well as physiological factors and aggression, most current studies have shown that generally, sleep problems within adolescence are associated with elevated risks of aggressive behaviors, as well as higher risks of psychopathological issues. By examining the psychophysiological attributes correlated with sleep, we are able to further investigate this relationship. Overall, during sleep, vagal activity (PNS) is high, while SNS activity is low. For example, the rapid eye movement (REM) stage of sleep has been associated with increased vagal withdrawal, while non-REM stages are associated with elevated vagal augmentation (Tobaldini et al., 2013). Only approximately 20% of sleep is dominated by REM sleep, while the rest is non-REM. This may be a supplementary informative factor when assessing sleep and autonomic activity. If increased vagal activity (which lowers HR) is moderating 80% of the sleep cycle, it would make sense that in individuals with a sympathovagal imbalance, achieving and maintaining non-REM levels of sleep may be difficult, thus, increasing prevalence of patterns of disordered sleep. This becomes more apparent when evaluating certain aspects of disordered sleep. Chronic insomnia, for example, during times of attempted sleep, is accompanied by sympathetic hyperarousal, reduced PNS activity, and therefore reduced vagal modulation (Fink et al., 2018).

Future Research

Major implications surrounding dysfunctional sleep, aggression, and autonomic arousal have been identified, showcasing the importance of future research within the field. One such example, shown in previous research, is decreased vagal tone participating in the pathogenesis of a multitude of serious and chronic diseases, including diabetes mellitus, hypertension, and congestive heart failure (Masi et al., 2007). Furthermore, due to major hormonal and biological changes associated with adolescence, youths typically experience a greater susceptibility to psychopathological changes (Sadeh et al., 2014). Additionally, research has clearly shown increased risks of suicidal ideations and attempts, mood disorders, and other psychopathologies present among adolescents who experience these subtypes of aggression. Moreover, considering the elevated risk of repeated criminal offenses associated with the aggressive subtypes, it is imperative, clinically and socially, to find successful intervening methodologies and preventative measures.

In the absence of a consistent relationship reported between RSA, sleep, and aggression, other factors that may play a participatory or supplementary role in this interaction must be examined; it is reasonable to consider that aggression, sleep, and autonomic reactivity may be influenced by other variables. For example, when considering the influential nature of low socioeconomic factors, poor familial relationships, and other areas of social adversity, some research has shown a heightened prevalence of aggression and delinquency among adolescents experiencing these variables (Fagan et al., 2017). Adjacent to this, the social-push hypothesis posits that in the absence of these predisposing factors, aggression is exacerbated predominantly via biophysiological factors (Raine, 2002). A further investigation into the biophysiological variables underpinning ANS function, sleep, and aggression leads to a consideration of the potential influential effects of the hypothalamic-pituitary-adrenal (HPA) axis. The HPA axis has a regulatory role governing many processes within the body such as digestion and metabolism, as well as the body's response to stress via the production and secretion of the glucocorticoid, cortisol. Cortisol, which is commonly referred to as the 'stress hormone,' is typically utilized during times of increased stress, during which it raises levels of glucose available within the body. Abnormal expression of cortisol can lead to detrimental physiological impairment, such as metabolic, cardiovascular, and reproductive diseases (Carpenter et al., 2017). Interestingly, irregular cortisol levels have also been linked to chronic fatigue, insomnia, anxiety, and emotional disorders (Carpenter et al., 2017). Examining the role of dysregulated HPA function in conjunction with aggression is not a novel idea. In fact, a review by Józef Haller (2018) proposed the glucocorticoid deficit hypothesis, which posits that the interaction of social adversity and aggressive outcomes are intrinsically correlated via internal circuitry involving the HPA axis. Additionally, consistent with the polyvagal theory concerning the autonomic responsiveness in regard to emotion regulation, the HPA axis response to stress has been shown to be moderated by both sympathetic and parasympathetic activity (Rotenberg & McGrath, 2016). Future studies into the role of the HPA axis and aggression may consider testing cortisol levels along with other measures, in order to attempt to identify a potential modulatory effect.

Limitations

Although the population for the current study was initially part of an ongoing longitudinal study, the current analysis included only a cross-sectional subset of the larger group. Because of this, it was not possible to track the variables over time, which would have provided a richer breadth of data. Future research should focus on including longitudinal capabilities encompassing these measures over time. Additionally, the questionnaires indexing sleep quality, as well as reactive and proactive aggression, were self-reported measures. Inclusion of more direct measures of these components in future studies could potentially provide more accurate data. Although, as previously mentioned, both RPQ and PSQI have been shown in other research to be valid measures.

Conclusion

This study provides some support into the complex, and often conflicting, understanding of sleep, aggression, and autonomic functioning within adolescents. While the initial expectations regarding the potential mediatory effects of RSA within the context of sleep and aggression were not supported, the study revealed the significant correlations between sleep problems and both proactive and reactive aggression. Additionally, the study was able to expand on the existing inconsistencies within the current literature, dispelling the belief that RSA may serve a mediatory role. Further studies are necessary to provide a more expansive understanding of the role that autonomic imbalances may play in relation to sleep and aggression.

Tables

Table 1.

Demographics

		Count	Mean
Age Range	12 - 16	97	14.11
Gender	Female	51	
	Male	46	
PSQI		99	6.84
RSA		98	101.77
Race	African American	42.2%	
	Caucasian	22.4%	
	Multiracial	14.7%	
	Hispanic/Latinx	11.2%	
	Asian/Pacific Islander	2.6%	
	Native American	0.9%	
	Other/Decline to Answer	6%	

Table 2.

Pearson Correlations Between Variables

		RSA	**RA**	**PA**	**PSQI**	**Gender**
RSA	r	1				
	N	98				
RA	r	0.051	1			
	N	98	98			
PA	r	-0.055	.618**	1		
	N	98	99	99		
PSQI	r	-0.013	.312**	.328**	1	
	N	98	99	99	99	
Gender	r	-0.073	0.076	-0.014	0.098	1
	N	97	97	97	97	97

Note. ** $p < .001$.

Table 3.

Hierarchical Regression Analysis between Proactive Aggression, Reactive Aggression, Gender, Respiratory Sinus Arrhythmia, and PSQI Score

Proactive Aggression

		β	*SE*	*t*	*p*	ΔR^2
Step 1	RA	0.654	0.037	8.386	0.000	0.428
Step 2	RA	0.623	0.040	7.519	0.000	0.022
	Gender	-0.073	0.291	-0.927	0.356	
	PSQI	0.115	0.050	1.383	0.170	
	RSA	-0.082	0.003	-1.052	0.296	

Table 4.

Hierarchical Regression Analysis between Reactive Aggression, Proactive Aggression, Gender, Respiratory Sinus Arrhythmia, and PSQI Score

Reactive Aggression

		β	*SE*	*t*	*p*	ΔR^2
Step 1	PA	0.654	0.163	8.386	0.000	0.428
Step 2	PA	0.615	0.17	7.519	0.000	0.029
	Gender	0.070	0.604	0.892	0.375	
	PSQI	0.138	0.014	1.678	0.097	
	RSA	0.077	0.006	0.997	0.322	

Figures

Figure 1.

Scatterplot of RA by PSQI

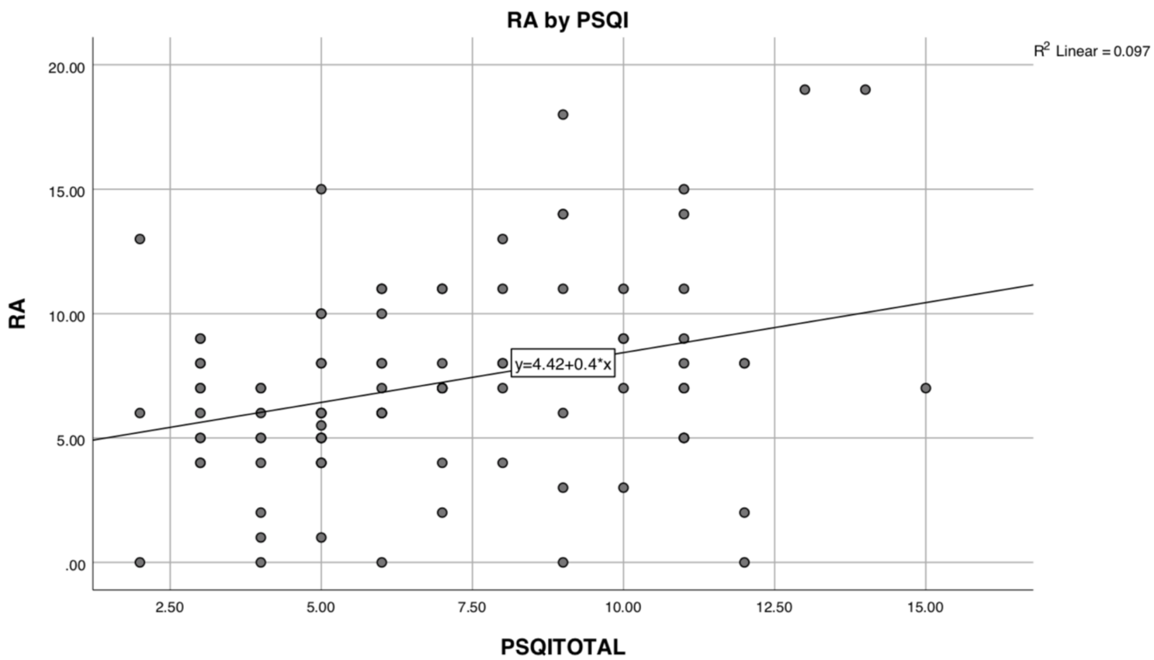


Figure 2.

Scatterplot of PA by PSQI

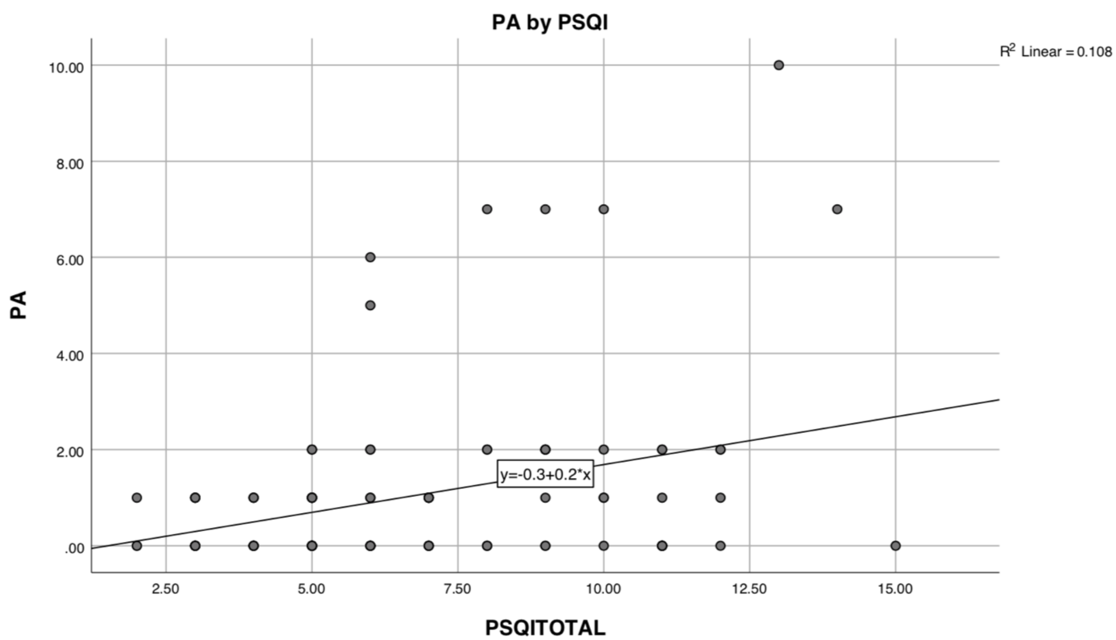
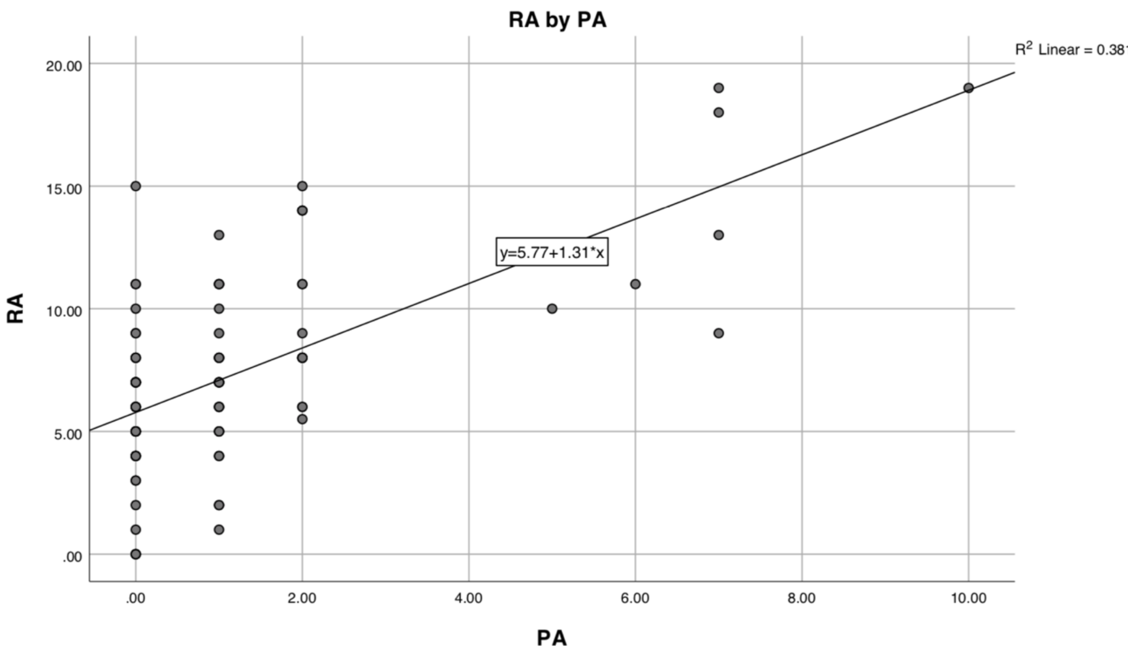


Figure 3.

Scatterplot of RA by PA



Appendices

Appendix A

Pittsburgh Sleep Quality Index

Instructions:
The following questions relate to your usual sleep habits during the past month *only*. Your answers should indicate the most accurate reply for the *majority* of days and nights in the past month.
Please answer all questions.

1. During the past month, when have you usually gone to bed at night?
   USUAL BED TIME _________________

2. During the past month, how long (in minutes) has it usually take you to fall asleep each night?
   NUMBER OF MINUTES _________________

3. During the past month, when have you usually gotten up in the morning?
   USUAL GETTING UP TIME _________________

4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spend in bed.)
   HOURS OF SLEEP PER NIGHT _________________

For each of the remaining questions, check the one best response. Please answer *all* questions.

5. During the past month, how often have you had trouble sleeping because you…

(a) Cannot get to sleep within 30 minutes
Not during the past month _____ Less than once a week _____ Once or twice a week _____ Three or more times a week _____

(b) Wake up in the middle of the night or early morning
Not during the past month _____ Less than once a week _____ Once or twice a week _____ Three or more times a week _____

(c) Have to get up to use the bathroom
Not during the past month _____ Less than once a week _____ Once or twice a week _____ Three or more times a week _____

(d) Cannot breathe comfortably
Not during the past month _____ Less than once a week _____ Once or twice a week _____ Three or more times a week _____

(e) Cough or snore loudly
Not during the past month _____ Less than once a week _____ Once or twice a week _____ Three or more times a week _____

(f) Feel too cold
Not during the past month _____ Less than once a week _____ Once or twice a week _____ Three or more times a week _____

(g) Feel too hot
Not during the past month _____ Less than once a week _____ Once or twice a week _____ Three or more times a week _____

(h) Had bad dreams
Not during the past month _____ Less than once a week _____ Once or twice a week _____ Three or more times a week _____

(i) Have pain
Not during the past month _____ Less than once a week _____ Once or twice a week _____ Three or more times a week _____

(j) Other reason(s), please describe
____
____

6. During the past month, how would you rate your sleep quality overall?
Very good _______
Fairly good _______
Fairly bad _______
Very bad _______

7. During the past month, how often have you taken medicine (prescribed or "over the counter") to help you sleep?
Not during the past month _____ Less than once a week _____ Once or twice a week _____ Three or more times a week _____

8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?
Not during the past month _____ Less than once a week _____ Once or twice a week _____ Three or more times a week _____

9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?
No problem at all _______
Only a very slight problem _______
Somewhat of a problem _______
A very big problem _______

10. Do you have a bed partner or roommate?
No bed partner or roommate _______
Partner/roommate in other room _______
Partner in same room, but not same bed _______
Partner in same bed _______

If you have a roommate or bed partner, ask him/her how often in the past month you have had…

(a) Loud snoring

Not during the past month _____	Less than once a week _____	Once or twice a week _____	Three or more times a week _____

(b) Long pauses between breaths while asleep

Not during the past month _____	Less than once a week _____	Once or twice a week _____	Three or more times a week _____

(c) Legs twitching or jerking while you sleep

Not during the past month _____	Less than once a week _____	Once or twice a week _____	Three or more times a week _____

(d) Episodes of disorientation or confusion during sleep

Not during the past month _____	Less than once a week _____	Once or twice a week _____	Three or more times a week _____

(e) Other restlessness while you sleep; please describe______________________________________

____

Not during the past month _____	Less than once a week _____	Once or twice a week _____	Three or more times a week _____

Appendix B

Reactive-Proactive Questionnaire

RPQ (youth version)

There are times when most of us feel angry, or have done things we should not have done. Rate each of the items below by putting a circle around either 0 (never), 1 (sometimes), or 2 (often). Don't spend a lot of time thinking about the items - just give your first response. Make sure you answer all the items.

0 = NEVER

1 = SOMETIMES

2 = OFTEN

1	I yell at others when they annoy me	0	1	2
2	I fight others to show who is on top	0	1	2
3	I get angry when others annoy me	0	1	2
4	I take things from other kids	0	1	2
5	I get angry when frustrated	0	1	2
6	I damage or break things for fun	0	1	2
7	I have temper tantrums	0	1	2
8	I damage things when I am mad	0	1	2
9	I get into fights to be cool	0	1	2
10	I hurt others to win a game	0	1	2
11	I get angry or mad when I don't get my way	0	1	2
12	I use force to get others to do what I want	0	1	2
13	I get angry or mad when I lose a game	0	1	2
14	I get angry when others threaten me	0	1	2
15	I use force to get money or things from others	0	1	2
16	I feel better after hitting or yelling at someone	0	1	2
17	I threatened and bully other kids	0	1	2
18	I make prank phone calls just for fun	0	1	2
19	I hit others to defend myself	0	1	2
20	I get others to gang up on other kids	0	1	2
21	I carry a weapon to use in a fight	0	1	2
22	I get mad or hit other others when they tease me	0	1	2
23	I yell at others so they will do things for me	0	1	2

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