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Lower catecholamine activity is associated with greater levels of anger in adults☆

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ABSTRACT

Previous research has revealed a consistent association between heart rate at rest and during stress and behavioral problems, potentially implicating autonomic nervous system (ANS) functioning in the etiological development of antisocial behavior. A complementary line of research has focused on the potential independent and interactive role of the two subsystems that comprise the ANS, the parasympathetic nervous system (PNS) and the sympathetic nervous system (SNS), on behavioral problems. The current study aims to contribute to the existing literature by examining the influence of heart rate (HR) reactivity, high-frequency heart rate variability (HF-HRV) reactivity, and catecholamine activity on a comprehensive measure of anger in a large, nationally-representative sample of adults from the United States. Results from a series of structural equation models (SEMs) revealed that catecholamine activity was most consistently linked to anger, while associations involving HR and HF-HRV reactivity were nonsignificant. Additional analyses revealed that HF-HRV did not significantly moderate the association between catecholamine activity and anger. These findings highlight the importance of SNS activity in the development of more reactive forms of aggression such as anger.

1. Introduction

An impressive line of research has consistently demonstrated a significant and robust association between resting heart rate (HR) and various mental disorders including personality disorders (Lorber, 2004; Raine et al., 2000), internalizing problems such as depression (Stein et al., 2000), and lower overall levels of empathic response (Muñoz and Anastassiou-Hadjicharalambous, 2011). Perhaps the largest segment of the extant literature has been devoted to examining the potential association between resting HR and various externalizing behavior problems including delinquent and criminal behavior (Lorber, 2004; Ortiz and Raine, 2004; Portnoy and Farrington, 2015). Studies also find decreased heart rate in response to stressors in individuals with high levels of antisocial behavior (Ortiz and Raine, 2004; Popma et al., 2006; van Goozen et al., 2000). Taken together, findings flowing from this line of research have provided evidence indicating a significant association between lower HR at rest and during stress and greater levels of externalizing behavior problems. The results of a recent systematic review examining 114 studies and 115 independent effect sizes revealed a summary effect size of $d = -0.20$, indicating lower resting HR was associated with greater levels of antisocial behavior (Portnoy and Farrington, 2015). Importantly, this association persisted even after controlling for a host of study characteristics and across multiple measures of antisocial behavior, indicating a robust association.

Previous studies have indicated that HR is an indirect indicator of autonomic nervous system (ANS) activity, indicating that the reduced activity of the ANS may result in an increased predisposition toward externalizing behavior problems. While a significant number of studies have reported results that support this general hypothesis (Beauchaine, 2001; El-Sheikh et al., 2009), this particular line of research has continued to develop, identifying more details of the association between ANS activity and behavioral problems. For example, recent studies have examined the potential role of ANS activity in the development of more specific forms of behavioral problems (Hubbard et al., 2002; Pitts, 1997; Raine et al., 2014). The results of this line of research are decidedly mixed with some studies indicating that lower resting HR was significantly associated with both proactive and reactive forms of aggression (Pitts, 1997), while other studies have reported more

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consistent associations between resting HR and proactive forms of aggression (Hubbard et al., 2002; Raine et al., 2014). These findings suggest that heart rate may be differentially associated with reactive forms of aggression compared to proactive forms. Directly in line with this possibility, anger represents one particular facet of reactive aggression that may be differentially associated with resting HR, as previous studies have indicated that individuals with higher overall levels of anger are more likely to experience behavior problems including delinquent and criminal behavior (Carmichael and Piquero, 2004; Mazerolle et al., 2000).

Sympathetic nervous system (SNS) and parasympathetic nervous system (PNS) activity have also been independently implicated in the development of behavioral problems (Beauchaine, 2001; de Vries-Bouw et al., 2012; El-Sheikh et al., 2009; Ortiz and Raine, 2004). Studies have identified significant associations between behavioral problems and a host of indirect indicators of SNS activity including lower electrodermal response (EDR) to stress tasks (Gao et al., 2010), lower pre-ejection period (PEP) reactivity (Hinnant et al., 2016), attenuated salivary alpha-amylase responsivity (Glenn et al., 2015), and lower overall levels of plasma or urinary catecholamine activity (McCaffery et al., 2000). Similarly, studies have implicated PNS activity as a significant risk factor for the development of behavioral problems (Grossman and Taylor, 2007; Beauchaine, 2001, 2015; El-Sheikh et al., 2009; Porges, 2007). For example, cardiac vagal control (typically operationalized by high frequency-heart rate variability [HF-HRV] and previously recognized as an indirect indicator of PNS activity) has been found to be significantly associated with behavioral problems (Beauchaine, 2015; Berntson et al., 2007; Porges, 2007). High baseline cardiac vagal control is thought to index appropriate emotional regulation (Beauchaine, 2001), and reduced cardiac vagal control at rest in response to emotional stimuli has been found to predict externalizing behavior problems in selected samples (Beauchaine, 2015; Porges, 2007).

Based on the differential responsibilities in the regulation of homeostatic reactions to stress-inducing stimuli of each subsystem, and in line with the concept of autonomic determinism (Berntson et al., 1991), previous studies have also examined whether the manner in which the PNS and SNS respond to one another also contributes to behavioral problems. More specifically, due to the reciprocal contributions of the PNS and SNS, previous studies have postulated that as activity in indicators of one subsystem increases, activity in indicators of the other should decrease (Berntson et al., 1994). However, other studies have found that concurrently low activity in both the PNS and SNS is associated with behavior problems in juveniles (Beauchaine et al., 2007; de Vries-Bouw et al., 2012; El-Sheikh et al., 2009). While previous studies have found preliminary evidence for both conditions (i.e., asymmetrical activity or concurrently low activity), the resulting limited literature remains decidedly mixed, leaving the potential moderating effects of one subsystem on the other unclear.

Additional methodological limitations exist within the current literature examining the association between indirect indicators of the SNS and PNS and behavioral problems. First, few studies focused on behavioral problems have simultaneously examined HF-HRV and catecholamine activity, with the majority of the existing literature focused on indicators of overall ANS activity, such as HR (Lorber, 2004; Ortiz and Raine, 2004; Portnoy and Farrington, 2015). Second, the majority of previous studies examining ANS activity and behavioral problems have focused almost exclusively on earlier stages of the life course such as childhood and adolescence (e.g., Crowell et al., 2006; de Vries-Bouw et al., 2012; El-Sheikh et al., 2009), with few studies examining the association during adulthood (but see Chiang et al., 2001; Hansen et al., 2007; Lobbestael et al., 2009). Third, many of the existing studies that do examine indicators of PNS and SNS activity in the development of externalizing behavior problems seem to be underpowered and rely on relatively small convenience samples (for an overview of studies examining externalizing behavior problems among children and adolescents, see van Goozen et al., 2007). Finally, many existing studies rely on bivariate correlations or multivariate statistical models with a limited number of covariates (for a comprehensive summary, see Portnoy and Farrington, 2015), effectively increasing the likelihood of detecting a spurious association.

In light of the status of the existing literature examining the associations involving HR, HF-HRV, catecholamine activity, and behavioral problems, the current study aims to accomplish two related objectives. First, the current study aims to examine the potential associations between HR reactivity, HF-HRV reactivity, catecholamine activity and anger in a large, nationally-representative sample of adults from the Survey of Midlife Development in the United States (MIDUS). This particular aspect of the current study is aimed at more directly examining the external validity of previous studies, while also increasing overall levels of statistical power in an effort to detect potentially smaller effects. Second, the current study also examines the potential interaction between HF-HRV and catecholamine activity in predicting anger. Previous simulation studies have revealed that within smaller samples ($N < 120$) even moderate to large moderating effects can be difficult to detect (Stone-Romero and Anderson, 1994). Since the current study employs a sufficiently powered sample (ranging between 682 and 742, depending on the estimated model), the likelihood of detecting a small, or even moderately sized, moderating effect increases significantly.

2. Methods

2.1. Data

The current study analyzes data from the MIDUS, a prospective, two-wave study consisting of a nationally representative sample of adults and funded by the National Institute on Aging (Brim et al., 1996). The first wave was carried out between 1995 and 1996 and included over 7000 adults from the United States, ranging in age from 25 to 74 years old ($M = 46.38$, $SD = 13.00$). Participants were selected using random-digit dialing sampling procedures and were asked to participate in a 30-minute telephone interview and complete two self-administered questionnaires (Brim et al., 2004). The final sample was comprised of slightly more females (51.69%) than males (48.31%) and was predominantly Caucasian (90.67%). The second wave of data collection was carried out between 2004 and 2006, when respondents were between 32 and 84 years old ($M = 55.43$, $SD = 12.45$). A total of 4963 respondents who participated in the first wave of the study were contacted a second time (70 percent retention rate; Love et al., 2010; Radler and Ryff, 2010). Participants were asked to complete a brief telephone interview and two self-administered questionnaires with an overall response rate of approximately 81%.

During the second wave of data collection, a subsample of participants was also asked to participate in the Biomarker Project, an extensive physical and mental health assessment carried out over two days (Love et al., 2010). Inclusion criteria for the Biomarker Project included the completion of the Wave 2 telephone interview and self-administered questionnaires, as well as existing health information indicating that the participant would be able to travel to one of three General Clinical Research Centers: University of California, Los Angeles (UCLA), University of Wisconsin, or Georgetown University. The resulting sample ($n = 1255$) did not significantly differ from the larger, nationally representative sample across age ($M_{Full} = 55.50$; $M_{Biomarker} = 55.26$; $t = 0.57$, $p = 0.57$) and sex (full sample = 47.06% males; biomarker sample = 45.26% males; $\chi^2 = 1.08$, $p = 0.30$), but was comprised of significantly more Caucasian participants (full sample = 89.97% Caucasian; biomarker sample = 93.05% Caucasian; $\chi^2 = 9.27$, $p = 0.002$) and participants with significantly higher socioeconomic status ($M_{Full} = 41.71$; $M_{Biomarker} = 43.40$; $t = 2.84$, $p = 0.01$). Medical professionals collected information related to a wide variety of factors related to medical history, medication use, sleep quality, and psychosocial experiences over a 24-hour period.