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The longitudinal association between resting heart rate and psychopathic traits from a normative personality perspective

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Abstract

A large body of research has accumulated investigating the possibility of an association between resting heart rate and psychopathic traits, with meta-analysis suggesting a modest, negative association. Some recent research suggests that prior findings of an association between heart rate and psychopathy may be influenced by inclusion of antisocial behavior in the assessment of psychopathic traits. The current study explores this possibility in a longitudinal sample of British males by comparing resting heart rate at age 18 to psychopathy assessed from a Five Factor Model perspective and from the Psychopathy Checklist: Screening Version (PCL:SV) at age 48. Our psychopathic personality scale, created using the Big Five Inventory (BFI), was significantly correlated with the PCL:SV and was most related to the antisocial factor. In correlation analyses, resting heart rate at age 18 was not significantly related to BFI psychopathy, but was positively related to BFI Openness and Conscientiousness, and these associations held up after controlling for childhood SES, BMI at 18, and whether the participant smoked during the age 18 assessment. Additional analyses controlling for smoking status were conducted to address the biasing effect of smoking on heart rate during the age 18 assessment and a significant negative association between resting heart rate and BFI psychopathy emerged. Future research should replicate these results using other normative personality approaches to assess psychopathic traits.

Owing to its translational, clinical, and forensic relevance, the topic of psychopathy has elicited a large amount of attention from scholars across the psychological sciences for decades (Cleckley, 1941; Hare, 1991/2003; Patrick, Fowles, & Krueger, 2009). There have been various lines of research on the topic, including how best to conceive of and measure the construct, including its attendant factor structure (i.e., psychometric debates: see Cooke & Michie, 2001; Hare, 1991; 2003; Skeem & Cooke, 2010) and core features (i.e., debates about the relevance of boldness/fearless dominance: see Lilienfeld et al., 2012; Miller and Lynam, 2012), as well as on the relative contributions of genetic and non-genetic factors to trait variance (Henry et al., 2018; Tuvblad et al., 2018). Consistent evidence suggests that variation in psychopathic tendencies is partly heritable—just like most quantitative human traits (Polderman et al., 2015). While parsing the heritable and environmental components is interesting, further clarifying phenotypic pathways that may contribute to the development of psychopathic traits is just as important if not more so (see Mitchell, 2018). Unfortunately, the evidence base for many of these pathways remains inconsistent.

Psychophysiological studies of psychopathic traits have been of some interest to researchers since the 1970s (e.g., Hare, Frazelle, & Cox, 1978; Glenn, Raine, Venables, & Mednick, 2007; Mawson & Mawson, 1977; Williamson, Harpur, & Hare, 1991). A body of research has explored possible physiological correlates of the construct—resting heart rate (RHR) in particular (e.g., Bergstrøm & Farrington, 2018; Portnoy & Farrington, 2015; Kavish et al., 2017; 2018; 2019). The reasoning that would lead one to suspect such an association seems clear, considering the rather persistent correlations that have emerged between resting heart rate and various incarnations of crime, violence, aggression, and other forms of antisocial behavior (Jennings et al., 2013; Ortiz & Raine, 2004; Piquero et al., 2012; Portnoy & Farrington, 2015;

Raine, 2002). Given the behavioral component present in many psychopathy measures, it seems plausible that an association between the variables (resting heart rate and psychopathy) may exist. In addition to this indirect evidence, there is also theoretical reasoning why autonomic functioning (which resting heart rate is an indicator of) might be related to psychopathic traits. For example, the sensation-seeking theory (Eysenck, 1977; Raine et al., 1998) suggests that those with low heart rates experience their low arousal as uncomfortable and impulsively seek out situations which raise their arousal to a more comfortable level. Alternatively, the fearlessness hypothesis (e.g., Raine, 1993) suggests a lower arousal level results in a higher threshold for experiencing fear and anxiety, reducing concerns about consequences and conditioning to punishment.

However, as we noted earlier, direct empirical findings to date have been mixed. In the most recent meta-analysis on the subject, Portnoy and Farrington (2015) found a statistically significant negative association between resting heart rate and psychopathy in two out of three meta-analytic models tested (d = -.19). The research available for inclusion in the meta-analysis had several limitations however, that preclude drawing strong conclusions. Much of the early research in this area relied on very small samples and categorized their participants into "psychopaths" and "non-psychopaths." Reliance on underpowered samples introduces a variety of concerns, chief among them being the possibility of statistical artifacts emerging in the data (see Button et al., 2013). Furthermore, the taxometric literature on psychopathy has strongly supported viewing psychopathy as a dimensional, rather than a categorical construct (e.g., Guay et al., 2007; Murrie et al., 2007; Walters et al., 2007), indicating that heart rate research that has dichotomized participants into "psychopaths" and controls may have obscured important variability in their samples.

More recent research has begun to address some of the limitations of prior research, but with interesting and inconsistent results. For example, in the only known longitudinal exploration of resting heart rate and psychopathy, Bergstrøm and Farrington (2018) reported a negative correlation between heart rate at age 18 and PCL-R scores at age 48 in a sample of British males. Using a nationally representative sample of American respondents, however, Kavish and colleagues (2018) reported no association between resting heart rate and a measure of psychopathic tendencies derived from classical Big Five personality constructs using a cross-sectional analysis and controlling for age, gender, and race. The psychopathy measure used by Kavish et al. (2018) was not a traditional psychopathy measure, nor has its convergent validity with traditional measures been assessed, so it is possible that the failure to replicate the relationship between heart rate and psychopathy was due to limitations in the psychopathy measure.

More recently, Kavish and colleagues (2019) examined the associations between four indicators of autonomic functioning, including heart rate, and two traditional measures of psychopathic traits and found little evidence supporting an association. Importantly, Kavish et al. (2019) used the Inventory of Callous-Unemotional traits (ICU; Frick, 2004) and the Levenson Self-Report Psychopathy scale (LSRP; Levenson, Kiehl, & Fitzpatrick, 1995). The ICU strictly assesses the affective component of psychopathy, and the LSRP, although it includes some behavioral items, does not appear to measure antisocial behavior as explicitly as the PCL-R, which includes ratings of items such as juvenile delinquency, early behavioral problems, revocation of conditional release, and criminal versatility.

This raises an interesting question concerning why findings might diverge. Several possibilities exist, including that some of the studies just mentioned represent false positives.

Another important possible reason revolves around the measurement of psychopathy as a construct. Much of the etiological work done on psychopathy has relied on clinically inclined measurements, the Hare Psychopathy Checklist being chief among them (Hare, 1993; 2003), which are saturated with measurement of antisocial behavior and potential item response issues (Tsang et al., 2014). Other scholars have argued that psychopathy is also appropriately conceived of as a multifaceted personality construct, the measurement of which can be derived from existing valid and reliable classic personality measures (e.g., the Big Five and personality psychopathology analogues such as the Personality Inventory for DSM-5; Kavish, Sellbom, & Anderson, 2018; Lee & Ashton, 2005; Miller & Lynam, 2003; Miller, Lynam, Widiger, & Leukefeld, 2001). An increasingly large and consistent body of research suggests that five factor model traits, particularly low Agreeableness and low Conscientiousness, are strongly overlapping with psychopathic traits (e.g., Lynam & Miller, 2015; Hyatt et al., 2019) and that the five factor model provides an ideal framework for understanding the epidemiology and etiology of these traits (see Lynam & Miller, 2015). To date, however, there has not been much effort to test the relationship between heart rate and psychopathy using a Big Five personality-derived measure of psychopathic tendencies (with the exception of Kavish et al., 2018), and no studies have examined the association of heart rate with *both* the PCL-R and a personality-derived measure of psychopathic tendencies in the same sample.

It remains an open question whether resting heart rate is related to psychopathy, as captured by normative personality traits. If heart rate is not associated with a more personality-based assessment of psychopathy, this may suggest that previous research may have found a relationship due to the use of psychopathy measures which more explicitly included antisocial behavior. Supporting this possibility, Bergstrøm and Farrington (2018) reported significant

associations between resting heart rate (RHR) at 18 and Factor 2 on the PCL:SV (as well as the two components of Factor 2: facets 3 and 4) which explicitly assesses impulsive and antisocial behavior. They did not find a significant association with the affective Factor 1 or its subcomponents (facets 1 and 2; Bergstrøm & Farrington, 2018). The current study aims to investigate the relationship between RHR and psychopathy using a novel psychopathy measure focusing on psychopathic *personality* traits in a prospective longitudinal study. As such we are building on the study by Bergstrøm and Farrington (2018) by using a novel measure of psychopathy that is less behaviorally focused (for a discussion of the role of antisociality in the psychopathy construct, please see Skeem & Cooke, 2010). The focus and methodology allow for making novel conclusions about how autonomic arousal is related to psychopathy, as well as the temporal order of effects across the life course.

Methods

Design and participants

The current study analyzes data from the Cambridge Study in Delinquent Development (CSDD; see Farrington et al., 2006; Farrington, Piquero, & Jennings, 2013), a prospective longitudinal study located the United Kingdom (U.K.). The CSDD was started in the early 1960s by selecting participants (N=411) from a comparatively deprived area in South London. The aim was to identify and assess a "high-risk" community sample that were likely to engage in delinquency and offending over time. At the study commencement, the males were 8-9 years of age. The sample was representative of children from the area at that time. Most of the sample was of white British origin (87%) and of a mostly traditional working-class socioeconomic status (94%). Not all of the 411 participants had resting heart rate data, were administered the PCL:SV, and completed the BFI. After removing those who did not have data on all measures, the final

analytical sample size was 292. Because all participants were Caucasian males and were the same age, we could not compare those with data to those without data on those common demographic variables; however, those included in the analyses did not significantly differ from those excluded on childhood SES ($\chi^2(3) = 5.40$, $p = .145$) or whether or not they had been convicted of a crime ($\chi^2(1) = .881$, $p = .348$).

Procedure

The data collection was comprehensive. From the age of 8-9, the males were interviewed yearly until late adolescence. A total of 9 interviews were carried out across the life-course, and the final interview was carried out at age 48. In addition to interviews with the 411 males, a range of physiological measures were taken, as well as official criminal records were obtained. The current study uses data from the age 18 and age 48 interviews. Resting heart rate (RHR) was measured at the end of the age 18 interview and was measured using a pulsimeter. The men were sitting still ("resting") during the assessment, and it was noted whether someone was smoking during the interview (please see below for inclusion of covariates) (Farrington, 1997).

Measures

Psychopathy Checklist: Screening Version. The Hare Psychopathy Checklist: Screening Version (Hart, Cox, & Hare, 1995) is a shorter version of the full Hare Psychopathy Checklist-Revised (PCL-R; Hare, 1991/2003), and consists of 12 items instead of 20. Each item on the PCL:SV is rated on an ordinal scale (0, 1, and 2) as with the PCL-R, and each item describes a personality trait/symptom or a behavioral characteristic that loads onto the overarching psychopathic personality. Examples of items included are "superficial" (reflecting a glib individual), "deceitful" (reflects someone who engages in instrumentally motivated deceit and manipulation), and "doesn't accept responsibility" (relates to an individual who for example

blames others for their actions). A score of 0 means that the trait does not apply to the individual, and conversely, a score of 2 indicates that "yes", the trait does indeed apply to the individual in question. A score of 1 is given when the trait or behavior *might* apply. The PCL:SV for each subject was rated by a trained clinician based on an extensive interview with the participant. The PCL:SV has shown very good psychometric properties (e.g., Cooke, Michie, Hart, & Hare, 1999; Pedersen, Kunz, Rasmussen & Elsass, 2010).

Big Five Personality Inventory. The Big Five Inventory (BFI; John, Donahue, & Kentle, 1991) is a 44-item measure designed to assess the domains of the FFM of personality: Openness to Experience, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. Previous research (e.g., John & Srivastava, 1999) has used confirmatory factor analysis and demonstrated significant associations between the Big 5 traits on the BFI and the analogous five factors of the Revised NEO Personality Inventory (NEO-PI-R; Costa & McCrae, 1992). Internal consistency of the five domains in the current study ranged from .69 (Agreeableness) to .80 (Neuroticism).

Big Five Inventory Psychopathy Scale. A psychopathy scale was created from the BFI using meta-analytic associations between the Big Five domains and psychopathy (Lynam & Derefinko, 2006) to create a global psychopathy score (see Marion & Sellbom, 2011). Briefly, participants' scores on each domain were multiplied by that domain's meta-analytic mean association (Openness = –.09, Conscientiousness = –.39, Extraversion = –.03, Agreeableness = –.51, Neuroticism = .16) and then summed. Prior research (Marion & Sellbom, 2011) has not reported exact associations between the BFI psychopathy scale and traditional psychopathy measures; however, Marion and Sellbom (2011) reported the scale was significantly associated with scores on the Levenson Self-Report Psychopathy (LSRP; Levenson, Kiehl, & Fitzpatrick, 1995) measure. Scores calculated using this method are all negative, with scores closer to zero

indicating higher levels of psychopathy; however, we have transformed the scores (subtracting the absolute value of the score from 100) so that the scores are positive with the highest score indicating the most psychopathic profile for ease of interpretation.

Covariates. Participants' Body Mass Index (BMI) at age 18, which is calculated by dividing weight in kilograms by the square of the individuals' height in meters, whether or not they smoked during the age 18 interview (coded 1 = smoked during the interview, 2 = did not smoke; n = 139 smokers), and a composite socioeconomic disadvantage (SES) variable from age 8-10 were included as covariates in regression analyses. The composite disadvantage variable is a categorical variable (coded from 1 to 4, with 4 indicating the greatest disadvantage) based on the occupation of the family breadwinner when the participant was age 8 and at age 10. Coding of occupations was derived from the General Register's Office's *Classification of Occupations* (1960).

Results

Descriptive statistics for study variables are shown in Table 1. Although recruitment for the CSDD specifically targeted boys in a depressed area, scores on the PCL:SV are relatively low and in line with other community samples (e.g., Neumann & Hare, 2008).

Insert Table 1 about here

Results of correlation analyses may be found in Table 2. The primary goal of the current study was to assess the associations between resting heart rate at age 18 and Big Five personality-based psychopathic traits at age 48. We first examined the association between the BFI psychopathy scale and total scores on the PCL:SV. In the current study, BFI psychopathy scores were significantly associated with total scores on the PCL:SV, suggesting at least a modest degree of convergent validity. Second, we reproduced the correlations between heart

rate at age 18 and PCL:SV at 48 because our sample is drawn from the same sample (the CSDD) as Bergstrøm and Farrington (2018). Due to non-overlap in availability of PCL:SV and BFI data, our analytical sample is slightly different from Bergstrøm and Farrington's (2018), and we employed a different correction for smoking in the data. Specifically, Bergstrøm and Farrington (2018) subtracted six beats per minute from the heart rate of all participants who were smoking during their age 18 interview because smoking has been found to increase heart rate. It is unlikely, however, that smoking uniformly affects each individual's heart rate (e.g., body composition and smoking history seem likely to moderate the effect). Therefore, in the current study we included a dichotomous smoking variable in all regression analyses and *did not* correct the raw heart rate data. As a result of these differences between our analytical sample and Bergstrøm and Farrington's (2018), we found a smaller zero-order correlation between heart rate and psychopathy (r = -.12 vs r = -.21), but the association was still statistically significant. Having partially reproduced the heart rate and psychopathy association found in Bergstrøm and Farrington, we next looked at the correlation between heart rate at 18 and BFI psychopathy at 48, but the association was not significant.

Insert Table 2 about here

We also included the five BFI domains in our correlation analyses to further test the association between heart rate and personality and found modest, positive associations between heart rate and BFI Openness and Conscientiousness. Heart rate was not significantly associated with BFI Extraversion, Agreeableness, and Neuroticism. The robustness of the two statistically significant associations were further assessed in linear regression models with interview smoking status, BMI at 18, and a composite socioeconomic disadvantage (SES) variable at 18 included as covariates. The results of the regression analyses are presented in Table 3. In the first model,

with heart rate at 18 and the covariates predicting BFI Openness at 48, heart rate remained a significant predictor. Indeed, after partialling out smoking, BMI, and SES, a one standard deviation increase in heart rate was associated with a 0.15 standard deviation increase in Openness. Similarly, heart rate at 18 also remained a significant predictor of BFI Conscientiousness at 48, with a one standard deviation increase in heart rate predicting a 0.18 standard deviation increase in Conscientiousness. Not smoking during the age 18 interview was also significantly associated with Conscientiousness at age 48. In short, we found that higher resting heart rates at age 18 were associated with more openness and more conscientiousness some thirty years later in middle adulthood.

Insert Table 3 about here

Finally, we also ran regression analyses for the remaining BFI domains and the BFI psychopathy scale. These additional, exploratory analyses were run because we did not correct the raw RHR data for smoking, and thus included no correction for smoking in our correlation analyses, which may have biased the bivariate results. Similarly, we examined associations between RHR and PCL:SV total, factor, and facet scores while controlling for the same covariates. The results for these analyses are included in Tables 4 and 5[1]. After inclusion of covariates, heart rate was still unassociated with the remaining three BFI domains (Extraversion, Agreeableness, and Neuroticism). Interestingly, heart rate emerged as a significant, albeit weak, predictor of BFI psychopathy in regression analysis. Furthermore, our method of including smoking as a categorical covariate in regression (rather than the 6 BPM correction employed by Bergstrøm and Farrington (2018)) actually produced a seemingly larger regression coefficient (e.g., $\beta = -.20$ vs. $\beta = -.13$ for PCL:SV total), although we cannot test for a significant difference.

Insert Table 4 about here

[1] We include the results of regression analyses for PCL:SV factor and facet scores in the supplemental material.

Insert Table 5 about here

Discussion

Among all biologically-based correlates of crime, one of the most studied – and replicable ones – is resting heart rate. Empirical research linking resting heart rate to antisocial behavior has consistently demonstrated a negative relationship, whether the studies were conducted in the United States, Canada, Europe, and South America, and whether studies used official or self-report records of offending (see e.g., Ellis et al., 2009; Murray et al., 2016). Much less investigated is the extent to which low resting heart rate is related to other criminological and psychological constructs that are also related to antisocial and criminal behavior and the research undertaken in this area has revealed inconsistent findings. In particular, there has been less, and less consistent, research to consider whether low resting heart rate is related to psychopathy—a long established correlate of antisocial behavior.

The current study replicates Bergstrøm and Farrington's (2018) finding that RHR at age 18 was inversely related to psychopathy as measured by the PCL:SV at age 48. This association was robust, even when partialling out shared variance with potential covariates. There has however been several noted criticisms of the PCL:SV's focus on antisocial behavior as part of the construct (e.g. Skeem & Cooke, 2010), and more recent measures of psychopathy have placed less explicit focus on antisocial behavior and a greater emphasis on personality traits (e.g., Triarchic Psychopathy Measure, Patrick, 2010; Elemental Psychopathy Assessment, Lynam et al., 2011). Additionally, in their study, Bergstrøm and Farrington (2018) found that RHR predicted the Lifestyle and Antisocial facets, but not the Interpersonal or Affective facets, further supporting the possibility that the association they found between RHR and PCL:SV total score was driven primarily by the assessment of antisocial behavior. As a result, we here focused on

investigating the potential association between RHR and a personality-oriented measure of psychopathy created using the BFI.

With regards to our primary goal of assessing the longitudinal association between RHR and personality-based psychopathy, we did not find a significant correlation between RHR and the BFI psychopathy measure in our main analyses. There could be multiple reasons for this. First, the BFI psychopathy measure correlated modestly with the PCL:SV, and while this shows a degree of convergent validity, it also shows that they are not completely overlapping. This is not necessarily a problem with the BFI psychopathy measure, as it is designed to measure the normative personality-oriented features of psychopathy over the antisocial ones (although interestingly, the BFI psychopathy scale demonstrated the largest associations with the antisocial facet of the PCL:SV). It is also possible; however, that the BFI psychopathy scale is not an ideal measure of five factor model psychopathy. Although we used meta-analytic associations between the Big 5 and psychopathy to create our BFI psychopathy scale, it has previously been documented that BFI Agreeableness does not capture agreeableness-related traits of psychopathy as well as other FFM measures (e.g., the NEO-PI-R; Miller et al., 2011). Given that agreeableness typically demonstrates the strongest association with psychopathy (Lynam & Derefinko, 2006), the ability of the BFI psychopathy scales to fully capture FFM psychopathy may be somewhat reduced. A third possibility might be that the correlational results are confounded by our lack of correction for those who smoked during the interview, particularly given that in addition to smoking increasing heart rate, smoking during the interview (coded 1 = smoking, 2 = not smoking) was associated with higher levels of psychopathy at age 48 in our sample (r = -.27).

We also examined the association between RHR at 18 and normative personality traits (the Big 5) at 48 to further test the potential for an association between heart rate and personality (versus the association between RHR and traditional psychopathy measures, which we suspect is primarily driven by the inclusion of antisocial behavior in the operationalization of psychopathy). In our sample, we found that a higher heart rate was positively related to the Big Five Inventory subscales for openness and conscientiousness. When we examined whether these effects were robust to relevant confounds (BMI, smoking, and SES), we found that heart rate continued to be related to both parts of the Big Five Inventory, with higher resting heart rates being positively related to each of these two subscales. The finding that higher RHR is associated with higher BFI Conscientiousness is perhaps unsurprising, as low RHR consistently predicts antisocial behavior, which is inversely correlated with conscientiousness (Miller et al., 2008). The interpretation of the positive association between RHR and Openness is less clear, as it might have been assumed any association would be negative due to Openness including aspects of adventurousness which seems conceptually similar to sensation-seeking. More work is needed to replicate these findings, especially with instruments that allow for facet level examination (e.g., the NEO-PI-R) before more interpretation can be done.

Our original analytical plan was to only run regression analyses as robustness checks for personality variables which were significantly associated with RHR at the bivariate level; however, due to our concern regarding the potential confounding effect of smoking, we ultimately tested the remaining BFI domains and the BFI psychopathy scale. RHR at age 18 remained unassociated with BFI Extraversion, Agreeableness, and Neuroticism at age 48; however, RHR emerged as a significant predictor of scores on the BFI psychopathy scale. This may indicate that RHR, at least for this South London sample of males, predicts later

psychopathic traits, even assessed from a normative personality perspective, but we do not want to draw firm conclusions without further replication in more diverse samples and without the presence of smoking during RHR assessment.

Our results contribute to the nascent research bases that explore not only the long-term consequences of resting heart rate (above and beyond criminal behavior) but also on the correlates of psychopathy—where the majority of research has considered how psychopathy predicts other life outcomes as well as considering whether the overall relationship was sensitive to how we measured personality characteristics in adulthood. Some limitations that need to be acknowledged also pose a healthy agenda for future research. First, whether heart rate and psychopathy characteristics measured at different ages alter the pattern of findings cannot fully be answered within the Cambridge data. Although, Bergstrøm and Farrington (2018) reported that RHR at 48 was not associated with psychopathic traits at the same age, seemingly indicating that RHR in middle adulthood is less related to psychopathy relative to RHR assessed at age 18, research that includes multiple assessments of RHR *and* of psychopathic traits across adolescence and adulthood will be needed to better answer this question. Related to this point, because the Psychopathy Checklist suite of assessments (e.g., PCL-R, PCL:SV) use a lifetime time-frame (i.e., psychopathy scores at age 48 for the participants in our study included ratings of their antisocial behavior in adolescence) which limits the degree to which scores can change over time (Lee et al., 2009). Normative personality traits vary over time (e.g., Damian et al., 2018; Hampton & Goldberg, 2006), which may suggest that psychopathy measures which are personality trait-based and less lifetime-focused (e.g., many self-report psychopathy measures) may better capture variation in psychopathic traits across the life-course.

Second, because the CSDD included only males from South London, replicating our work among females and in other contexts would be important. Third, a recent meta-analysis reported that African Americans have greater heart rate variability than European Americans suggesting that a study considering the issues within this study across race (and potentially ethnicity) would be worth pursuing (see Hill et al., 2015). Fourth, our BFI psychopathy scale could only produce a single global psychopathy score. Evidence is quickly accumulating which indicates that psychopathic traits are multi-dimensional (see Lilienfeld, 2018 and the accompanying special issue) and that different dimensions or facets may be differentially related to other variables. For example, a meta-analysis of the associations between intelligence and psychopathy found that IQ scores are positively associated with the interpersonal and boldness/fearless dominance components of psychopathy, but inversely related to the affective component (blinded authors, under review). Finally, it is theoretically plausible that the relationship between HR and psychopathic traits is non-linear. We checked for potential non-linear effects through the use of a quadratic term in a regression model and did not find evidence indicating a non-linear effect, but we are unable to completely rule this possibility out.

Moving forward, research should seek to address the limitations mentioned above, ideally through the use of large, preregistered studies using multiple assessments of RHR over time and multi-method assessment of psychopathy (both self-report and clinician or informant ratings, as well as more and less behaviorally saturated measures). The current study adds to the growing body of research that suggests RHR may be particularly associated with antisocial behavior and less so with the personality components of psychopathy.

References

Bergstrøm, H., & Farrington, D. P. (2018). "The beat of my heart": the relationship between resting heart rate and psychopathy in a prospective longitudinal study. *Journal of Criminal Psychology, 8*(4), 333-344.

Button, K. S., Ioannidis, J. P., Mokrysz, C., Nosek, B. A., Flint, J., Robinson, E. S., & Munafò, M. R. (2013). Power failure: why small sample size undermines the reliability of neuroscience. *Nature Reviews Neuroscience*, *14*(5), 365-376.

Cleckley, H. (1941) The mask of sanity: an attempt to reinterpret the so-called psychopathic personality. Oxford, England: Mosby.

Cooke, D. J., & Michie, C. (2001). Refining the construct of psychopathy: Towards a hierarchical model. *Psychological Assessment*, 13, 171-188.

Cooke, D. J., Michie, C., Hart, S. D., & Hare, R. D. (1999). Evaluating the Screening Version of the Hare Psychopathy Checklist—Revised (PCL: SV): An item response theory analysis. *Psychological Assessment*, *11*(1), 3-13.

Costa, P. T., & McCrae, R. R. (1992). *Revised NEO personality inventory (NEO PI-R tm) and NEO five-factor inventory (NEO-FFI): professional manual*. Psychological Assessment Resources.

Damian, R. I., Spengler, M., Sutu, A., & Roberts, B. W. (2018). Sixteen going on sixty-six: A longitudinal study of personality stability and change across 50 years. *Journal of Personality and Social Psychology.* Advance online publication. http://dx.doi.org/10.1037/pspp0000210

Ellis, Lee, Kevin M. Beaver, and John Paul Wright. (2009). Handbook of Crime Correlates. London, U.K.: Academic Press.

Eysenck, H. J. (1977). Crime and personality (3rd ed.). St. Albans, UK: Paladin.

Farrington, D. P., Coid, J. W., Harnett, L., Jolliffe, D., Soteriou, N., Turner, R., & West, D. J. (2006). *Criminal careers up to age 50 and life success up to age 48: New findings from the Cambridge Study in Delinquent Development* (Vol. 94). London, UK: Home Office Research, Development and Statistics Directorate.

Farrington, D.P., Piquero, A.R., & Jennings, W.G. (2013). *Offending from childhood to late middle age: Recent results from the Cambridge study in delinquent development*. New York: Springer.

First, M. B., Spitzer, R., Gibbon, M., Williams, J., & Benjamin, L. (1996). *Structured Clinical Interview for DSM-IV Axis II Personality Disorders (SCID-II).* New York: Biometrics Research Department, New York State Psychiatric Institute.

Frick, P. J. (2003). The Inventory of Callous-Unemotional Traits. Unpublished rating scale, University of New Orleans.

General Registrar's Office. (1960). *Classification of Occupations*. London: Her Majesty's Stationery Office.

Glenn, A. L., Raine, A., Venables, P. H., & Mednick, S. A. (2007). Early temperamental and psychophysiological precursors of adult psychopathic personality. *Journal of Abnormal Psychology*, *116*(3), 508-518.

Guay, J. P., Ruscio, J., Knight, R. A., & Hare, R. D. (2007). A taxometric analysis of the latent structure of psychopathy: Evidence for dimensionality. *Journal of Abnormal Psychology*, *116*(4), 701.

Hampson, S. E., & Goldberg, L. R. (2006). A first large cohort study of personality trait stability over the 40 years between elementary school and midlife. *Journal of Personality and Social Psychology*, *91*(4), 763.

Hare, R.D. (1991/2003). The Hare Psychopathy Checklist-Revised. Toronto, Ontario: Multi-Health Systems.

Hare, R. D., Frazelle, J., & Cox, D. N. (1978). Psychopathy and physiological responses to threat of an aversive stimulus. *Psychophysiology*, *15*(2), 165-172.

Hart, S. D., Cox, D. N., & Hare, R. D. (1995). *Hare psychopathy checklist: Screening version (PCL: SV)*. Toronto, Ontario: Multi-Heath Systems.

Henry, J., Dionne, G., Viding, E., Petitclerc, A., Feng, B., Vitaro, F., ... & Boivin, M. (2018). A longitudinal twin study of callous-unemotional traits during childhood. *Journal of Abnormal Psychology*, *127*(4), 374.

Hill, L. K., Hu, D. D., Koenig, J., Sollers III, J. J., Kapuku, G., Wang, X., ... & Thayer, J. F. (2015). Ethnic differences in resting heart rate variability: a systematic review and meta-analysis. *Psychosomatic Medicine*, *77*(1), 16-25.

Hyatt, C. S., Crowe, M. L., Lynam, D. R., & Miller, J. D. (2019). Components of the Triarchic Model of Psychopathy and the Five-Factor Model domains share largely overlapping nomological networks. *Assessment*, 1073191119860903.

Jennings, W. G., Piquero, A. R., & Farrington, D. P. (2013). Does resting heart rate at age 18 distinguish general and violent offending up to age 50? Findings from the Cambridge Study in Delinquent Development. *Journal of Criminal Justice*, *41*(4), 213-219.

John, O. P., Donahue, E., & Kentle, R. L. (1992). The Big Five Inventory: Versions 4a and 54., Berkley, CA: University of California, Institute of Personality Assessment and Research.

John, O. P. and Srivastava, S. (1999). "The Big Five Trait taxonomy: History, measurement, and theoretical perspectives". In O. P. John (Ed.) *Handbook of personality: Theory and research* (pp. 102–138). New York, NY: Guilford.

Kavish, N., Boisvert, D., Wells, J., Lewis, R., Cooke, E., Woeckener, M., & Armstrong, T. (2019). On the associations between indicators of resting arousal levels, physiological reactivity, sensation seeking, and psychopathic traits. *Personality and Individual Differences*, *141*, 218-225.

Kavish, N., Fu, Q. J., Vaughn, M. G., Qian, Z., & Boutwell, B. B. (2018). Resting Heart Rate and Psychopathy Revisited: Findings From the Add Health Survey. *International Journal of Offender Therapy and Comparative Criminology, 63*(4), 543-557.

Kavish, N., Sellbom, M., Anderson, J. L. (2018). Implications for the measurement of psychopathy in the DSM-5 using the Computerized Adaptive Test of Personality Disorder (CAT-PD). *Journal of Personality Assessment*. doi: 10.1080/00223891.2018.1475393.

Kavish, N., Vaughn, M. G., Cho, E., Barth, A., Boutwell, B., Vaughn, S., ... & Martinez, L. (2017). Physiological arousal and juvenile psychopathy: is low resting heart rate associated with affective dimensions? *Psychiatric quarterly*, *88*(1), 103-114.

Lee, K., & Ashton, M. C. (2005). Psychopathy, Machiavellianism, and narcissism in the Five-Factor Model and the HEXACO model of personality structure. *Personality and Individual Differences, 38*(7), 1571-1582.

Lee, Z., Klaver, J. R., Hart, S. D., Moretti, M. M., & Douglas, K. S. (2009). Short-term stability of psychopathic traits in adolescent offenders. *Journal of Clinical Child & Adolescent Psychology*, *38*(5), 595-605.

Levenson, M. R., Kiehl, K. A., & Fitzpatrick, C. M. (1995). Assessing psychopathic attributes in a noninstitutional population. *Journal of Personality and Social Psychology, 58*, 151-158.

Lilienfeld, S. O. (2018). The multidimensional nature of psychopathy: Five recommendations for research. *Journal of Psychopathology and Behavioral Assessment*, *40*(1), 79-85.

Lilienfeld, S. O., Patrick, C. J., Benning, S. D., Berg, J., Sellbom, M., & Edens, J. F. (2012). The role of fearless dominance in psychopathy: Confusions, controversies, and clarifications. *Personality Disorders: Theory, Research, and Treatment, 3*(3), 327-340.

Lynam, D. R., & Derefinko, K. J. (2006). Psychopathy and personality. In C. J. Patrick (Ed.), Handbook of psychopathy (pp. 133–155). New York: Guilford Press.

Lynam, D. R., Gaughan, E. T., Miller, J. D., Miller, D. J., Mullins-Sweatt, S., & Widiger, T. A. (2011). Assessing the basic traits associated with psychopathy: Development and validation of the Elemental Psychopathy Assessment. *Psychological Assessment*, *23*(1), 108-124.

Lynam, D. R., Miller, J. D. (2015). Psychopathy from a basic trait perspective: The utility of a five-factor model approach. Journal of Personality, 83, 611-626.

Marion, B. E., & Sellbom, M. (2011). An examination of gender-moderated test bias on the Levenson Self-Report Psychopathy Scale. *Journal of Personality Assessment*, *93*(3), 235-243.

Mawson, A. R., & Mawson, C. D. (1977). Psychopathy and arousal: a new interpretation of the psychophysiological literature. *Biological Psychiatry*, *12*(1), 49-74.

Miller, J. D., Gaughan, E. T., Maples, J., & Price, J. (2011). A comparison of agreeableness scores from the Big Five Inventory and the NEO PI-R: Consequences for the study of narcissism and psychopathy. *Assessment*, *18*(3), 335-339.

Miller, J. D., & Lynam, D. R. (2003). Psychopathy and the five-factor model of personality: A replication and extension. *Journal of Personality Assessment*, *81*(2), 168-178.

Miller, J. D., & Lynam, D. R. (2012). An examination of the Psychopathic Personality Inventory's nomological network: A meta-analytic review. *Personality Disorders: Theory, Research, and Treatment*, *3*(3), 305.

Miller, J. D., Lynam, D. R., & Jones, S. (2008). Externalizing behavior through the lens of the five-factor model: A focus on agreeableness and conscientiousness. *Journal of Personality Assessment*, *90*(2), 158-164.

Miller, J. D., Lynam, D. R., Widiger, T. A., & Leukefeld, C. (2001). Personality disorders as extreme variants of common personality dimensions. Can the Five-factor model of personality adequately represent psychopathy? *Journal of Personality, 69*, 253–276.

Mitchell, K. J. (2018). Innate: How the wiring of our brains shapes who we are. Princeton and Oxford: Princeton University Press.

Murray, J., Hallal, P. C., Mielke, G. I., Raine, A., Wehrmeister, F. C., Anselmi, L., & Barros, F. C. (2016). Low resting heart rate is associated with violence in late adolescence: a prospective birth cohort study in Brazil. *International Journal of Epidemiology*, *45*(2), 491-500.

Murrie, D. C., Marcus, D. K., Douglas, K. S., Lee, Z., Salekin, R. T., & Vincent, G. (2007). Youth with psychopathy features are not a discrete class: A taxometric analysis. *Journal of Child Psychology and Psychiatry*, *48*(7), 714-723.

Neumann, C. S., & Hare, R. D. (2008). Psychopathic traits in a large community sample: links to violence, alcohol use, and intelligence. *Journal of Consulting and Clinical Psychology*, *76*(5), 893-899.

Ortiz, J., & Raine, A. (2004). Heart rate level and antisocial behavior in children and adolescents: A meta-analysis. *Journal of the American Academy of Child & Adolescent Psychiatry*, *43*(2), 154-162.

Patrick, C. J. (2010). *Operationalizing the triarchic conceptualization of psychopathy: Preliminary description of brief scales for assessment of boldness, meanness, and disinhibition*, Tallahassee, FL: Unpublished manual, Department of Psychology, Florida State University.

Patrick, C. J., Fowles, D. C., & Krueger, R. F. (2009). Triarchic conceptualization of psychopathy: Developmental origins of disinhibition, boldness, and meanness. *Development and Psychopathology*, *21*(3), 913-938.

Pedersen, L., Kunz, C., Rasmussen, K., & Elsass, P. (2010). Psychopathy as a risk factor for violent recidivism: Investigating the Psychopathy Checklist Screening Version (PCL: SV) and the Comprehensive Assessment of Psychopathic Personality (CAPP) in a forensic psychiatric setting. *International Journal of Forensic Mental Health*, *9*(4), 308-315.

Piquero, A. R., Farrington, D. P., Fontaine, N. M., Vincent, G., Coid, J., & Ullrich, S. (2012). Childhood risk, offending trajectories, and psychopathy at age 48 years in the Cambridge Study in Delinquent Development. *Psychology, Public Policy, and Law*, *18*(4), 577-598.

Polderman, T. J., Benyamin, B., De Leeuw, C. A., Sullivan, P. F., Van Bochoven, A., Visscher, P. M., & Posthuma, D. (2015). Meta-analysis of the heritability of human traits based on fifty years of twin studies. *Nature Genetics*, *47*(7), 702-709.

Portnoy, J., & Farrington, D. P. (2015). Resting heart rate and antisocial behavior: An updated systematic review and meta-analysis. *Aggression and Violent Behavior*, *22*, 33-45.

Raine, A. (1993). The psychopathology of crime: Criminal behavior as a clinical disorder. San Diego, CA: Academic Press.

Raine, A., Reynolds, C., Venables, P. H., Mednick, S. A., & Farrington, D. P. (1998). Fearlessness, stimulation-seeking, and large body size at age 3 years as early predispositions to childhood aggression at age 11 years. *Archives of General Psychiatry, 55*, 745-751.

Skeem, J. L., & Cooke, D. J. (2010). One measure does not a construct make: directions toward reinvigorating psychopathy research--reply to Hare and Neumann (2010). *Psychological Assessment*, *22*(2), 455-459.

Tsang, S., Piquero, A. R., & Cauffman, E. (2014). An examination of the Psychopathy Checklist: Youth Version (PCL: YV) among male adolescent offenders: An item response theory analysis. *Psychological Assessment*, *26*(4), 1333-1346.

Tuvblad, C., Wang, P., Patrick, C. J., Berntsen, L., Raine, A., & Baker, L. A. (2018). Genetic and environmental influences on disinhibition, boldness, and meanness as assessed by the triarchic psychopathy measure in 19–20-year-old twins. *Psychological Medicine*, 1-10.

Walters, G. D., Gray, N. S., Jackson, R. L., Sewell, K. W., Rogers, R., Taylor, J., & Snowden, R. J. (2007). A taxometric analysis of the Psychopathy Checklist: Screening Version (PCL: SV): Further evidence of dimensionality. *Psychological Assessment*, *19*(3), 330.

Williamson, S., Harpur, T. J., & Hare, R. D. (1991). Abnormal processing of affective words by psychopaths. *Psychophysiology*, *28*(3), 260-273.

Table 1. Descriptive statistics for study variables.

	Mean	SD	Min	Max
Resting Heart Rate	70.65	9.73	46.00	100
BFI Openness	35.16	6.25	16.00	50.00
BFI Conscientiousness	35.08	5.40	13.00	45.00
BFI Extraversion	27.48	5.95	10.00	40.00
BFI Agreeableness	34.60	5.24	18.00	45.00
BFI Neuroticism	19.98	6.28	8.00	38.00
BFI Psychopathy	67.90	4.51	56.32	86.58
PCL:SV Total	3.50	3.85	0.00	17.00
PCL:SV Factor 1	1.17	1.58	0.00	8.00
PCL:SV Factor 2	2.32	2.62	0.00	11.00
PCL Interpersonal	.52	.85	0.00	4.00
PCL Affective	.65	1.03	0.00	5.00
PCL Impulsivity	.62	1.06	0.00	5.00
PCL Antisocial	1.70	1.81	0.00	6.00
BMI	22.31	2.84	14.78	34.28

Note. BFI = Big Five Inventory; PCL:SV = Psychopathy Checklist Screening Version. BMI = Body Mass Index (kg/m^2) at age 18.

Table 2. Correlation matrix for resting heart rate at 18 and personality and psychopathy measure scores at age 48.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. RHR	-																
2. BFI-P	-.09	-															
3. BFI-O	.13*	-.28**	-														
4. BFI-C	.12*	-.74**	.21**	-													
5. BFI-E	.04	-.31**	.21**	.21**	-												
6. BFI-A	.02	-.82**	.05	.31**	.10	-											
7. BFI-N	-.03	.55**	-.07	-.25**	-.38**	-.32**	-										
8. PCL	-.12*	.24**	.01	-.13*	.08	-.26**	.12*	-									
9. F1	-.04	.15*	.04	-.02	.05	-.23**	.06	.86**	-								
10. F2	-.15*	.26**	-.01	-.17**	.09	-.25**	.14*	.95**	.67**	-							
11. Int	.01	.03	.10	.00	.16**	-.09	-.04	.67**	.81**	.48**	-						
12. Aff	-.07	.21**	-.03	-.04	-.05	-.28**	.13*	.78**	.87**	.62**	.41**	-					
13. Life	-.15*	.17*	.03	-.13*	.04	-.15*	.13*	.80**	.56**	.84**	.38**	.54**	-				
14. Anti	-.13*	.27**	-.04	-.18**	.10	-.27**	.12*	.90**	.62**	.95**	.47**	.57**	.63**	-			
15. BMI	-.05	.01	-.01	-.03	-.06	.02	.02	.04	.04	.03	.04	.02	.04	.02	-		
16. SES	-.08	-.07	-.01	.09	.03	.08	.08	.13*	.09	.14*	.12*	.05	.13*	.12*	.10	-	
17. Smoke	-.27	-.10	.03	.12*	-.13	.09	.04	-.27**	-.23**	-.26**	-.23**	-.16**	-.16**	-.28**	.08	-.03	-

Note. RHR = Resting heart rate. BFI-P = Big Five Inventory global psychopathy scale. BFI-O = BFI Openness. BFI-C = BFI Conscientiousness. BFI-E = BFI Extraversion. BFI-A = BFI Agreeableness. BFI-N = BFI Neuroticism. PCL = Psychopathy Checklist: Screening Version Total Score. F1 = PCL:SV Affective factor. F2 = PCL:SV Antisocial factor. Int = PCL:SV Interpersonal facet. Aff = PCL:SV Affective facet. Life = PCL:SV Lifestyle facet. Anti = PCL:SV antisocial facet. BFI Psychopathy coded such that higher scores indicate higher levels of psychopathy. *p<.05 **p<.01.

Table 3. Regression analyses for heart rate at 18 predicting personality at 48.

	BFI Openness				BFI Conscientiousness			
	b	SE	β	*p*	b	SE	β	*p*
RHR	.10*	.04	.15	.02	.10**	.03	.18	.004
BMI	-.03	.13	-.01	.82	-.09	.11	-.05	.41
Smoking	.90	.76	.07	.24	1.87**	.65	.17	.004
SES	.07	.44	.01	.87	.71	.38	.11	.06

Note. RHR = Resting heart rate. BFI = Big Five Inventory. Heart Rate = Resting Heart Rate at age 18. BMI = Body Mass Index. Smoking = Dichotomized variable indicating whether or not participant smoked during the interview (coded 1 = smoked, 2 = did not smoke). SES = Socioeconomic disadvantage variable (with highest category indicating greatest disadvantage). *$p < .05$ **$p < .01$.

Table 4. Regression analyses for heart rate at 18 predicting BFI Psychopathy and PCL:SV Total score at 48.

	BFI Psychopathy				PCL:SV Total			
	b	SE	β	*p*	b	SE	β	*p*
Heart Rate	.-.06*	.03	-.13	.03	-.08**	.02	-.20	.001
BMI	.04	.09	.03	.67	.06	.08	.04	.43
Smoking	-1.23*	.55	-.14	.02	-2.50***	.44	-.32	<.001
SES	-.46	.32	-.09	.15	.48	.26	.10	.06

Note. BFI = Big Five Inventory. PCL:SV = Psychopathy Checklist: Screening Version. Heart Rate = Resting Heart Rate at age 18. BMI = Body Mass Index. Smoking = Dichotomized variable indicating whether or not participant smoked during the interview (coded 1 = smoked, 2 = did not smoke). SES = Socioeconomic disadvantage variable (with highest category indicating greatest disadvantage).
*$p < .05$.

Table 5. Regression analyses for heart rate at 18 predicting personality at 48.

	BFI Extraversion				BFI Agreeableness				BFI Neuroticism			
	b	SE	β	*p*	b	SE	β	*p*	b	SE	β	*p*
Heart Rate	.01	.04	.01	.85	.03	.03	.05	.42	-.01	.04	-.01	.87
BMI	-.10	.12	-.05	.43	.01	.11	.01	.92	.02	.13	.01	.87
Smoking	-1.42	.72	-.12	.05	1.09	.64	.10	.16	.43	.77	.03	.58
SES	.20	.42	.03	.63	.53	.37	.08	.06	.59	.45	.08	.19

Note. BFI = Big Five Inventory. Heart Rate = Resting Heart Rate at age 18. BMI = Body Mass Index. Smoking = Dichotomized variable indicating whether or not participant smoked during the interview (coded 1 = smoked, 2 = did not smoke). SES = Socioeconomic disadvantage variable (with highest category indicating greatest disadvantage). *$p < .05$.