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Adolescent psychopathy, heart rate, and skin conductance

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Abstract

Researchers have advocated for a greater focus on measuring neurobiological underpinnings of serious psychological conditions such as psychopathy. This has become particularly important to investigate early in the life span, when intervention efforts for psychopathy-related behavior like conduct disorder (CD) are more successful. Given that psychopathy is a complex syndrome, it is also important to investigate physiological processes at a dimensional level. Using a sample of 56 adolescent male offenders ($M_{age} = 15.92$; $SD = 1.31$), this study explored the relationship between the Psychopathy Checklist–Youth Version (Forth, Kosson, & Hare, 2003), heart rate (HR), and skin conductance (SC). A white noise countdown task was used to measure autonomic activity across a baseline, anticipatory (prenoise), and reactivity (postnoise) period. Findings revealed no significant associations between psychopathy and HR activity across the time intervals. However, results revealed a positive association between grandiose-manipulative traits and SC activity and a negative association between callous-unemotional traits and SC activity. The results indicate that autonomic processes may contribute to distinct psychopathic traits in different ways, implicating slightly differential brain functioning. The findings suggest that, in order to better understand and treat youth with CD, future research should continue to examine the biological correlates of psychopathy at the broader construct level but perhaps especially at the component level.

KEYWORDS

adolescents, heart rate, psychopathy, skin conductance

1 | INTRODUCTION

Child and adolescent psychopathy is a serious personality syndrome marked by an interpersonal facet, composed of grandiose-manipulative traits, an affective facet containing callous-unemotional traits, and a behavioral facet consisting of daring-impulsive traits. These traits map on to well-established conceptualizations of adult psychopathy (Cleckley, 1941, 1976; Hare, 1991, 2003), and factor analytic studies have continually shown the above-mentioned components to emerge across age groups (e.g., Frick, Bodin, & Barry, 2000; Hare, 2003). Due to the seriousness of the condition and the costs it can impose on society, researchers have attempted to better understand the etiology of psychopathy and have advocated for a greater focus on identifying the physiological underpinnings of psychopathy, albeit with a major focus on adult populations (Gao, Glenn, Schug, Yang, & Raine, 2009; Hare, 1978, 1982).

Key psychophysiological markers for psychopathy are thought to be heart rate (HR) and skin conductance (SC; Raine, Fung, Portnoy, Choy, & Spring, 2014). HR and SC reflect general emotional arousal, with SC being primarily associated with the sympathetic nervous system and HR being associated with both the sympathetic and parasympathetic nervous systems. Skin conductance level (SCL) is the most common measure of tonic (resting) level of electrical conductivity of skin, while skin conductance response (SCR) is the faster, phasic change in electrical conductivity. Baseline levels of HR have often been evaluated in conjunction with SCL, while cardiac reactivity (i.e., HR response to a stimulus) has often been assessed alongside SCR levels (Raine, 1997) to index emotional arousal. HR and SC have been evaluated primarily to examine the hypothesis that psychopaths show an absence of nervousness, low fear, and/or low levels of arousal, which could be detected through the peripheral nervous system (Hare, 1978; Patrick, Cuthbert, & Lang, 1994). However, elevated HR and SC can have distinct implications for brain functioning, a point to which we will return.

In his classic study, Hare (1970) used the "countdown" paradigm to assess anticipatory psychophysiological responses to aversive stimuli, finding that psychopathic individuals exhibited smaller increases in their SC to an impending aversive stimuli. Lykken (1957) correspondingly found that psychopathic individuals perspired to a lesser degree in anticipation of shock than nonpsychopathic individuals, suggesting lower levels of arousal and fear. Lykken (1967) also identified that HR acceleration prior to an expected shock was followed by lower levels of SCR. Interestingly, reduced physiological functioning, especially for electrodermal activity in psychopathic individuals, most consistently occurs when the anticipated aversive stimulus is predictable, or "signaled" (Hare, 1978, 1982; Ogloff & Wong, 1990). Some studies have found psychopathic individuals show abnormal emotional functioning, for instance, low fear (e.g., low SC and low HR), only under conditions in which the threat stimulus is unsignaled (Newman, Curtin, Bertsch, & Baskin-Sommers, 2010). These differences may pertain to the theoretical perspective (e.g., low fear or response modulation hypothesis, RMH; Hamilton & Newman, 2018) and the role that attention versus emotion plays in anomalous HR and/or SC functioning. Despite some differences in findings based on cuing, the results consistently show some irregularities in HR and SC for those with elevated psychopathic traits.

While Hare and colleagues found rather consistent HR and SC results with adult psychopathic offenders, few studies examining heart functioning and skin conductance have been conducted with adolescent offenders. To our knowledge, only seven studies have investigated the relation between child psychopathy and HR and/or SC, and of those studies the findings have been somewhat mixed (Blair, 1999; Fung et al., 2005; Isen et al., 2010; Kavish et al., 2017; Raine et al., 2014; Wang, Baker, Gao, Raine, & Lozano, 2012; de Wied, van Boxtel, Matthys, & Meeus, 2012). The inconsistency between the aforementioned study findings indicates that it is not yet clear how HR and SC are linked to psychopathy and whether they are stable biological markers for the syndrome in childhood. For example, daring-impulsive traits are related to low resting HR (Raine et al., 2014), yet several other studies have found no association between reduced startle reactivity (and presumably HR and SC) and impulsive antisociality, a concept similar to disinhibition (Benning, Patrick, & Iacono, 2005; Dvorak-Bertsch, Curtin, Rubinstein, & Newman, 2009; Kyranides, Fanti, Sikki, & Patrick, 2017; López, Poy, Patrick, & Moltó, 2013; Vanman, Mejia, Dawson, Schell, & Raine, 2003). There have been similar disparities for studies that have examined grandiose-manipulative and callous-unemotional traits (e.g., Isen et al., 2010; Wang et al., 2012).

Varied findings may, in part, be due to the manner in which psychopathy has been indexed. To date, all child psychopathy studies have used self, parent, or teacher-report of psychopathic traits. Scales have included the Antisocial Process Screening Device (APSD; Frick & Hare, 2001), the Child Psychopathy Scale (CPS; Lynam, 1997), the Inventory of Callous-Unemotional Traits (ICU; Frick, 2003), and the Youth Psychopathic Traits Inventory (YPI; Andershed, Kerr, Stattin, & Levander, 2002). Aside from the important potential rater-based biases, several of the aforementioned measures appear to have other critical limitations. For instance, the APSD has poor internal consistency, especially in terms of its ability to tap callous-unemotional traits (e.g., de Wied, van der Baan, Raaijmakers, de Ruiter, & Meeus, 2014; Frick et al., 2000). Moreover, the APSD items do not map perfectly with the Psychopathy Checklist–Revised (PCL-R) items (see Dillard, Salekin, Barker, & Grimes, 2013). Similarly, the CPS subscales do not track well with Hare's original conceptualization of psychopathy, and researchers have suggested that the CPS is biased toward the antisocial behavior factor (e.g., Bezdjian, Raine, Baker, & Lynam, 2010). Furthermore, although the ICU alleviates reliability problems, it measures only one component of psychopathy (callous-unemotional) and does not measure the core interpersonal (grandiose-manipulative) or lifestyle/behavioral (daring-impulsive) traits. Finally, the ICU total scores only weakly relate to rater measures of affective, or callous-unemotional, psychopathy traits (Feilhauer, Cima, & Arntz, 2012; Johnson et al., 2014).

Despite some of these noted shortfalls and varied findings in past research, HR and SC appear quite important in relation to psychopathic traits, especially given the two-way communication between the brain and the heart via the autonomic nervous system. For example, increased SC may be related to varying levels of attention and implicate the ventromedial prefrontal cortex (vmPFC) regions, which is functionally and anatomically connected with the amygdala (Hare et al., 2008; Myers-Schulz & Koenigs, 2012). Considerable research has found a negative association between activity in the vmPFC and SCL (e.g., Zhang et al., 2014) and a positive association between vmPFC activity and SCR (e.g., Critchley, Elliott, Mathias, & Dolan, 2000). Activity in the vmPFC is related to many areas of emotional, behavioral, and cognitive functioning, including the inhibition of fear-related arousal and goal-directed attention (see Koenigs 2012; Nili, Goldberg, Weizman, & Dudai, 2010). These findings are consistent with the notion that the peripheral autonomic state is centrally integrated with systems important for monitoring behavior, further reflecting the importance of psychophysiological research to comprehensively assess and understand psychopathy. That is, while low HR and SC may indicate low arousal and low fear in psychopathic individuals, subsequently providing important theoretical and clinical information, higher levels of HR and SC could also have implications for cognitive functioning, thus helping us to better understand those with elevated levels of psychopathic traits.

1.1 | Current study

The present study aimed to investigate the relation between psychopathy, HR, and SC using both psychopathy total and component scores. To improve psychopathy measurement, this study used a structured interview and rating scale, the Psychopathy Checklist: Youth Version (PCL:YV), which has been shown to have substantial reliability and construct validity (Forth et al., 2003). A white noise countdown task was employed to measure levels of HR and SC during a baseline, anticipatory (prewhite noise), and reactivity (postwhite noise) period. Three a priori hypotheses were made. First, it was expected that psychopathy, at the broad construct level, would exhibit nonsignificant correlations with HR and SC, given that past research has shown this association (e.g., Fanti et al., 2017; Wang et al., 2012). Second, it was expected that the psychopathy dimensions (grandiose-manipulative, callous-unemotional, daring-impulsive) would show differential relations with HR and SC. Specifically, with respect to grandiose-manipulative traits (PCL:YV Facet 1 or interpersonal traits), it was hypothesized that there would be decreased baseline SCL and increased HR/SCR both in anticipation of the white noise stimuli during the signaled trials and in response to the stimuli, during both signaled and unsignaled trials. This hypothesis was based on theoretical models that refer to the psychopathic individual as alert, oriented, in control, and highly aware of their environment (Cleckley, 1941/1976; Hare, 1993) and corresponds to brain imaging findings (e.g., Nili et al., 2010). With respect to callous-unemotional traits (Facet 2 or affective traits), it was expected that there would be a positive association with baseline HR/SCL and a negative association with HR/SCR both in anticipation of the white noise stimuli during the signaled trials and in response to the stimuli during both signaled and unsignaled trials. These hypotheses were generated based on clinical research and theory that the psychopathic individuals, and perhaps those with callous traits, have an absence of nervousness, are cool in adverse situations, and can be shallow regarding the depth of their emotional experience (e.g., Cleckley, 1941/1976; Dindo & Fowles, 2011; Fung et al., 2005; Ogloff & Wong, 1990; Wang et al., 2012). Third, it was hypothesized that there would be no significant relation with daring-impulsive traits (Facet 3 or lifestyle traits). This hypothesis was based on clinical theory and the notion that psychopathic individuals frequently engage in risk taking, but that the risk-taking behavior tends to be described in terms of judicial risk taking that may well require signals from HR and SC to the brain (e.g., Cleckley, 1941/1976; Hare, 1993; see also Benning et al., 2005).

2 | METHOD

2.1 | Participants

During the study, 62 participants were successfully recruited from a Juvenile Court and Detention facility and completed the psychophysiological component of the study. However, data from six participants were excluded in the final analyses due to significant artifacts that rendered the data unusable. The remaining participants were 56 juvenile male offenders aged 13–18 years old (M_{age} = 15.92; *SD* = 1.31) with a mean education of 8.96 years (*SD* = 1.88). The sample was mixed in terms of racial composition (African American 82.1%, Caucasian American 16.1%, and biracial 1.8%). Charges for the participants included robbery, burglary, domestic violence, drug possession, disorderly conduct, truancy, and auto theft.

2.1.1 | Ethical considerations and procedure

Prior to data collection, the study was approved by the primary author's institutional review board. All participants were recruited during family visiting hours and probation appointments at the facility. Residents were eligible for participation if their parent/guardian was present and provided informed consent. Assent was also obtained from the adolescents themselves. Participants were informed that they could withdraw from the study at any time and that their withdrawal would not affect their placement at the detention center or their legal situation in any way. Participants completed the study measures in a quiet room in a single 2-hr session. The average room temperature across sessions was 71.9 ^{o}F; the average relative humidity was 57.0%. All participants received $15 in compensation for their involvement in the study.

2.2 | Measures

2.2.1 | Psychopathy

The PCL:YV (Forth et al., 2003) was used to index psychopathy. The PCL:YV is a 20-item interview-based assessment of psychopathic traits in youth 12–18 years of age. Each item is scored on a 3-point Likert scale from 0 (*no*) to 2 (*yes*) based on the degree to which behavior matches item descriptions. The PCL:YV was coded from interview questions and file information. The four-factor model includes interpersonal (grandiose-manipulative traits), affective (callous-unemotional traits), lifestyle (daring-impulsive traits), and antisocial domains. Studies have indicated that PCL-R (Hare, 1991, 2003) and PCL:YV scores demonstrate high internal consistency and high inter-rater reliability of 0.90 or greater (e.g., Forth et al., 2003; Salekin, Leistico, Neumann, DiCicco, & Duros, 2004). The interrater reliability analysis for the PCL:YV facet/factor ratings in the current study was calculated using intraclass correlation coefficients (ICC) with a two-way random effects model with consistency agreement. ICCs were within good to excellent range (i.e., between 0.71 and 0.81; Cicchetti & Sparrow, 1981; Fleiss, 1981).

2.2.2 | HR and SC

A BioLog recorder was administered to index HR and SC. Two skin conductance electrodes (silver/silver chloride) were filled with Biogel (UFI, Morro Bay, CA), an electrolyte contact medium, and attached to the index and middle finger of the participants' nondominant hand using adhesive tape. Three heart electrodes were also placed on the inside of the participants' left inner knee, just above the right collarbone, and on the right side of the neck. A white noise countdown paradigm was presented, modeled after a similar task used in other studies (e.g., Fung et al., 2005; Iacono, 1998). The paradigm consists of four trials; each trial recorded HR and SC patterns during the 3-min baseline period, a 12-s anticipatory period, and a 20-s reactivity period.

In order to collect baseline HR and SC information, participants were instructed to remain still for 3 min while fixating on a black dot against a white background displayed on a computer monitor positioned 1 m in front of them. Physiological recording was then paused while participants were administered several personality questionnaires. Following the completing of these measures, participants were again instructed to observe the computer monitor while wearing headphones. They were also given the following instructions:

> In this situation, you will see numbers counting down on the computer screen from 12 to 0. One number will appear every second. When you see the number 0, you will hear a loud noise for 1 s. Sometimes this loud noise will come on without any warning, however. There is nothing you need to do in this task apart from keeping your head and body as still as you can. Do you have any questions?

HR and SC recording then resumed with a 12-s resting period where participants were instructed to observe the monitor while wearing headphones. In Trials 1 and 3 (signaled trials), the anticipatory period included a numeric countdown running from 12 to 0 on a computer screen. When 0 appeared, participants heard a 1-s burst of 90 dB white noise with a 50-ms rise and fall time through a pair of headphones. The reactivity period encompassed the 20 s immediately following the noise burst. On Trials 2 and 4 (unsignaled trials), the numeric countdown was not visible to the participants. Following the 12-s resting period, an extra 12 s passed before the white noise appeared; no countdown was displayed on the computer screen.

For the purpose of this study, HR mean and SCL mean were calculated in the baseline condition. HR was derived from empirically supported techniques (Grossman, Van Beek, & Wientjes, 1990; Porges, 2007a, 2007b). Each participant's HR data were hand edited using the CardioEdit program (Porges, 2007b) in order to remove any unwanted artifacts, and then quantified in interbeat intervals. Each SCL pattern within a baseline period was averaged across the 3-min period and is quantified in microsiemens (μS; e.g., Dindo & Fowles, 2011).

Consistent with previous research (Wang et al., 2012), HR mean and SCR mean frequency were calculated by averaging anticipatory/reactivity periods in Trials 1 and 3 (signaled trials) and anticipatory/reactivity periods in Trials 2 and 4 (unsignaled trials) to create four conditions: (a) signaled anticipatory, (b) unsignaled anticipatory, (c) signaled reactivity, and (d) unsignaled reactivity. SCR was extracted using Ledalab, a MATLAB-based software that uses discrete deconvolution analysis and continuous deconvolution analysis (see Benedek & Kaernbach, 2010a, 2010b, for technical details). SC data were sampled at a frequency of 10 hertz (Hz). A SCR was defined as an increase in conductivity exceeding 0.05 microsiemens ($\mu S = 10^{-6}$ siemens) in amplitude, and SCR data were provided by the Ledalab output. SCRs within the anticipatory period were sampled within 1–4 s following the start of the 12-s countdown stimulus (signaled or unsignaled), and SCRs within the reactivity period were sampled within 1–4 s following the white noise stimulus. This is a typical latency window during which sampled event-related SCRs are considered to be elicited by that stimulus (Dawson, Schell, & Filion, 2001). Based on recommendations by Dawson et al. (2001), SCR mean frequency data (i.e., number of SCR peaks averaged across the two signaled trials and then across the two unsignaled trials) in each condition were examined.

3 | RESULTS

3.1 | Data preparation and analyses

Evaluation of the normality assumption using Kolmogorov-Smirnov testing revealed nonsignificant results for HR and SCL data. Pearson product-moment correlation coefficients were used to analyze the relationships between the HR and SCL variables. However, the Kolmogoroz-Smirnov statistic for SCR frequency values was significant, and SCR frequency distribution values were positively skewed and leptokurtic. This is likely due to the prevalence of SCR nonresponders

TABLE 1 Descriptive statistics for study variables

Variable	Mean	*SD*	Range	Skewness	Kurtosis
PCL:YV					
Total	20.86	5.05	10–31	−0.14	−0.64
Grandiose-manipulative	3.40	1.45	0–6	−0.14	−0.53
Callous-unemotional	4.04	1.43	0–7	−0.30	0.46
Daring-impulsive	5.64	1.57	1–9	−0.38	0.15
Antisocial	5.02	2.09	1–9	−0.16	−0.87
Heart rate					
Baseline	69.58	10.53	47.05–98.42	0.49	0.27
Signaled anticipatory	68.49	10.30	45.88–100.43	0.43	0.92
Unsignaled anticipatory	68.56	9.77	46.96–96.94	0.50	1.10
Signaled reactivity	68.52	9.86	46.98–98.69	0.48	1.12
Unsignaled reactivity	68.54	9.77	46.97–97.82	0.50	1.14
Skin conductance level					
Baseline	4.99	3.60	0.12–12.84	0.44	−1.04
Skin conductance response					
Signaled anticipatory	0.17	0.31	0–1	1.64	1.63
Unsignaled anticipatory	0.14	0.28	0–1	1.90	2.65
Signaled reactivity	0.18	0.30	0–1	1.54	1.32
Unsignaled reactivity	0.13	0.28	0–1	2.01	3.17

Note. $N = 56$. *SD* = standard deviation; PCL:YV = Psychopathy Check-List: Youth Version.

(i.e., total SCRs = 0 across any trials; $n = 24$). Both log and square root transformations were used to correct the SCR frequency distributions (Boucsein, 2012; Dawson et al., 2001). Results revealed that neither of these transformations was sufficient to normalize the distribution of SCR values. Thus, in line with previous recommendations, nonparametric tests (i.e., Spearman's rank-order correlation) were used to analyze SCR data (Dawson et al., 2001; Fung et al., 2005).

Given the relationship between SC and race (Kredlow, Orr, & Otto, 2018), an independent samples *t* test was conducted to evaluate whether SCR scores differed between Black and White participants. Results indicated no significant difference in SCR scores between the two groups (Black youth, $M = 0.52$, $SD = 0.51$; White youth, $M = 0.78$, $SD = 0.44$), $t(53) = -1.42$, $p = 0.160$. A statistical power analysis was conducted to detect the minimal detectable effect (MDE). An alpha level of $p < 0.05$ and power = 0.80 were chosen. The analyses revealed that the MDE needed for this study's sample size of 56 was 0.30, which is considered a medium (Cohen, 1988) to large effect (see Hemphill, 2003).

3.2 | Descriptive statistics

Table 1 presents descriptive statistics for the current study. The mean psychopathy score was similar to past research examining psychopathy in youth ($M = 20.86$, $SD = 5.05$). Pearson product-moment correlations among PCL:YV scores are provided in Table 2. The range value for each PCL:YV item was grandiose-manipulative = 6, callous-unemotional = 7, daring-impulsive = 8, antisocial = 8, and total = 21. Baseline mean HR and SCL were 69.58 ($SD = 10.53$) and 4.99 ($SD = 3.68$), respectively. The observed range for SCR frequency values across all four trials (signaled trials = Trials 1 and 3; unsignaled trials = Trials 2 and 4) was 0–2. Once averaged across all four trials, the observed range for SCR mean frequency values was 0–1 (SCR mean frequency values = 0, 0.5, 1). Subdimension trait level descriptive statistics are also exhibited in Table 1.

3.3 | Baseline period

Pearson product-moment partial correlations were produced to examine the relations between psychopathy and baseline HR and SCL.[1] Results showed that grandiose-manipulative, cal-

[1]Research has suggested that, because the heart is also subject to influence from the parasympathetic nervous system via vagal tone (Beauchaine, 2001), respiratory sinus arrhythmia (RSA) should be examined along with HR and SC. Thus, RSA activity at baseline was also measured and analyzed in this study, but the results were nonsignificant (*r*s = 0.11, 0.17, 0.02. and −0.16, with PCL:YV grandiose-manipulative, callous-unemotional, daring-impulsive, and antisocial traits, respectively). RSA was derived from the HR data using Porges's vagal tone method (Porges, 2007a, 2007b).

lous-unemotional, daring-impulsive, and antisocial traits showed small and nonsignificant correlation coefficients with HR (rs = −0.08, −0.09, 0.07, and 0.01, respectively). There was a significant, moderate association between grandiose-manipulative traits and SCL ($r = 0.29$, $p = 0.030$) while showing small, nonsignificant associations with callous-unemotional, daring-impulsive, and antisocial traits (rs = 0.12, 0.17, and 0.02, respectively; see Table 2).

3.4 | Anticipatory period

Pearson product-moment partial correlation analyses revealed no significant associations between PCL:YV and HR during the anticipatory period. Results from Spearman's rank-order correlation analyses indicated that SCR mean in the unsignaled condition is positively associated with grandiose-manipulative traits ($r = 0.28$, $p = 0.034$) and negatively associated with the callous-unemotional traits ($r = -0.26$, $p = 0.050$). No significant relationships were found in the signaled condition. All correlation analyses for the anticipatory period are provided in Table 2.

3.5 | Reactivity period

Pearson product-moment partial correlation analyses were run to examine the relation between psychopathy, HR, and SC during the reactivity period. The findings revealed no significant associations between PCL:YV scores and HR or SCR during the signaled or unsignaled conditions in the reactivity period. Similarly, Spearman's rank-order correlation analyses indicated no significant associations between PCL:YV scores and SCR mean frequency during either condition (see Table 2).

4 | DISCUSSION

Scientists have advocated for a focus on measuring the neurobiological underpinnings of serious mental health conditions like psychopathy. Neurobiological findings may help better understand the processes that underlie the disorder. This study is one of the first to assess HR and SC and psychopathic dimensions in adolescent offenders using the PCL:YV. It was hypothesized that the total score would be unrelated to HR and SC, but that the dimensions would show differential relations with HR and SC, with grandiose-manipulative traits and callous-unemotional showing some opposing relations. The findings revealed important differences in autonomic nervous system functioning that may pertain to potential differences in brain functioning.

TABLE 2 Intercorrelations between the PCL:YV, heart rate, and skin conductance data

	1.	2.	3.	4.	5.
PCL: YV					
1. Total					
2. Grandiose-Manipulative	0.70**				
3. Callous-Unemotional	0.31*	0.15			
4. Daring-Impulsive	0.67**	0.39**	−0.03		
5. Antisocial	0.65**	0.27*	−0.21	0.37**	
Heart rate					
Baseline	−0.02	−0.08	−0.09	0.07	0.01
Signaled anticipatory	0.02	−0.03	−0.12	0.12	0.08
Unsignaled anticipatory	−0.05	−0.09	−0.21	0.12	0.06
Signaled reactivity	−0.02	−0.06	−0.17	0.12	0.07
Unsignaled reactivity	−0.03	−0.08	−0.19	0.12	0.07
Skin conductance level					
Baseline	0.23	0.29*	0.12	0.17	0.02
Skin conductance response[a]					
Signaled anticipatory	−0.02	0.09	−0.10	0.18	−0.00
Unsignaled anticipatory	0.05	0.28*	−0.26*	0.21	0.10
Signaled reactivity	0.12	0.09	−0.05	0.24	0.05
Unsignaled reactivity	0.22	0.19	−0.14	0.16	0.23

Note. PCL:YV Total Score = Psychopathy Checklist: Youth Version Total Score.

[a]Skin conductance response values represent bivariate Spearman's rank order correlations. All other values represent Pearson product-moment correlations.

*Significant at the 0.05 level. **Significant at the 0.01 level.

First, consistent with our predictions, no significant associations were found between total psychopathy scores and HR or SC. These findings are partially in line with Fanti and colleagues (2017) who found that total psychopathy was not associated with SC and only associated with resting HR. Second, the results did show differences at the dimensional level indicating that the factors may in fact have distinct processes. Specifically, a positive relationship between grandiose-manipulative traits and mean SCL at baseline and mean SCR in the unsignaled anticipatory period were discovered, suggesting a lower level of cerebral activity at rest (↑ SCL), but also greater activity in relation to the unpredictable anticipation of an aversive stimulus (↑ SCR). The increase in SCL at baseline suggests that those with elevated grandiose manipulative traits may be somewhat relaxed at rest (Critchley et al., 2000); however, the increase in SCR in anticipation of the stimulus is consistent with preparation for an adaptive organic response to stimuli. Once the stimulus occurs, however, individuals with elevated levels of psychopathic traits, and especially those with elevated GM traits, return to normal and do not show an aberrant response in HR or SCR. Thus, the aftereffects of the stimuli are similar for those with low and high levels of grandiose-manipulative traits.

Although higher SCL at rest and SCR in anticipation of stimuli may be associated with varying levels of cerebral activity, both may be impacted by greater or lesser amygdala activity. Research has found that the amygdala, in addition to other midbrain and limbic structures, interacts with the vmPFC to regulate physiological arousal involved in processes such as affect and cognitive control (e.g., Brooks et al., 2012; Hare et al., 2008). Neuroimaging evidence posits that higher SCL is associated with decreased activity in the vmPFC (Zhang et al., 2014). However, higher SCR is associated with greater vmPFC activity (Critchley et al., 2000), reflecting greater goal-directed attention and orientation to the environment (e.g., Nagai, Critchley, Featherstone, Trimble, & Dolan, 2004). Thus, it is possible that the relation between goal-oriented, grandiose-manipulative traits (like planning, manipulation, charm) and SC is specifically related to cerebral activity, and that youth with this set of psychopathic traits are more cognitively activated and prepared for unpredictable aversive stimuli.

Alternately, callous-unemotional traits showed a strong negative association with SCR in the unsignaled anticipatory period, suggesting lower cerebral activity during unpredictable anticipation of the aversive stimuli. This might account for the fearless style of those with callous unemotional traits, although likely from a bottom-up perspective. That is, increased vmPFC activity can cause inhibition of fear-related arousal (Nili et al., 2010; Zhang et al., 2014), which is consistent with research showing that children high on callous-unemotional traits have lower levels of fearfulness, anxiety, and insensitivity to punishment (Frick, 2012). However, given the pattern of interactions between the vmPFC and the amygdala, it may also be that the negative association between callous-unemotional traits and SCR points to decreased amygdala activity. That the decreased SCR occurred without the ability to predict the aversive stimulus (during the unsignaled period) suggests that callous-unemotional youth may not be able to detect threat in their environment without predictable cues that could indicate a need for caution and a need to change strategies. Thus, this threat signal never makes it to the frontal cortex or only makes it to the prefrontal cortex as a weak signal. This is consistent with functional neuroimaging studies demonstrating that children and adolescents with higher conduct disorder and callous-unemotional traits have lower amygdala activity than normal controls in response to empathy-eliciting stimuli (Sebastian et al., 2012; Viding et al., 2014).

There were no significant results with regard to HR activity and psychopathy across any conditions, although a larger sample size may have produced significant results or at least produced a more precise estimate of the relationship between HR and psychopathy. These findings are discrepant with the literature on psychopathy and resting HR, which has been described as the best-replicated biological correlate of antisocial behavior (Moffitt et al., 2008; Raine et al., 2014). There were also no statistically significant relations between daring-impulsive traits or antisocial traits and HR or SC. This is consistent with some research that has not found associations between startle reactivity and impulsive antisociality (e.g., Kyranides et al., 2017).

It should be noted that our results diverge from Fanti et al. (2017) in some ways. First, although our findings were similar at the total score level for the relation between HR and SC, there were differences with respect to the grandiose-manipulative findings, where Fanti et al. (2017) found a negative association between grandiose-manipulative traits and baseline HR and SC and lower HR in response to stimuli. However, there were some key differences between the studies, including that Fanti et al. (2017) used a self-report measure of psychopathy (YPI-S) instead of an interview-based measure of psychopathy (i.e., PCL:YV). In addition, the lower HR was in response to violent stimuli, which may differ from a response to a signaled and unsignaled startle stimulus. The current findings, however, are interesting in that HR does not become elevated in response to a startle stimulus for those with grandiose-manipulative traits, but that SC does become significantly elevated. This finding of a stable HR but elevated SC speaks to a more regulated brain functioning (Nili et al., 2010). While these two studies do show some differences, one commonality is that they support a multiprocess model of psychopathy (Fowles & Dindo, 2009; Patrick, 2018; Patrick & Bernat, 2009) where the factors or components of psychopathy are showing differential relations to HR and SC.

The influential theories in psychopathy (Lykken, 1957) have implied that psychopaths show less arousal and that this necessarily results in diminished classical conditioning and quasiconditioning to aversive stimuli, diminished fear-potentiated startle (see Lorber, 2004), and impaired recognition of fearful faces (Marsh & Blair, 2008). In addition, Lykken's (1957) seminal work demonstrated that psychopathic individuals fail to learn from punishments intended to induce fear and passive avoidance paradigms. However, the fearlessness hypothesis is controversial, with some researchers arguing that it is not well supported by evidence (Newman & Brinkley, 1997) and susceptible to alternative explanations, including an attention to fear-provoking cues (Baskin-Sommers, Curtin, & Newman, 2011). Since the significant results of our study are specific to situations in which no cues were provided, our results appear consistent with research suggesting that abnormal emotional functioning in psychopathic individuals occurs when these individuals are not actively attending to threat stimuli (Newman et al., 2010). These findings may indicate that, in the unsignaled conditions, those with elevated grandiose-manipulative traits pay greater attention to the potential of an aversive stimulus, whereas those with elevated callous-unemotional traits are less attentive. These findings may have implications for both the RMH and low fear models. For instance, the low fear model or low arousal model may be most specific to callous-unemotional traits, given the negative associations with HR and SC. However, these association might also support the RMH given that cognitive functioning would be decreased. On the other hand, those with elevated grandiose-manipulative traits are cognitively active in the unsignaled condition and attuned to their environment. This tends to offer little support for the RMH. These findings highlight the importance of psychopathy as a configural condition (Lilienfeld, 2018). Overall, results from this study indicate that different dimensions have different physiological and neurological correlates that likely then have implications for issues such as learning and other information processing (Dindo & Fowles, 2011) as well as how the disorder may manifest depending on what components are elevated.

4.1 | Strengths, limitations, and conclusions

A primary strength of this study is the use of a structured interview and rating scale, as opposed to self-report measures, to assess psychopathy, as well as the measurement of an important psychophysiological variable. However, the study also had limitations that require consideration in order to contextualize our findings. First, this study had a relatively small sample, which, combined with the multiple comparisons, increases the risks of Type I error. Nonetheless, this study's significant findings are considered moderate in magnitude (Cohen, 1988; Hemphill, 2003), which is consistent with the sensitivity analyses indicating that an MDE of 0.30 is the maximum effect given this study's sample size. Significant findings in other studies have also produced similar small to moderate effect sizes comparable to this study. Second, the sample consisted of adolescent males, and future research is needed to detect whether these findings can be replicated with adolescent females. The physiological nature of the study also limits the ability to infer and apply the study's results directly to potential neurobiological systems. Future work should combine HR and SC data with brain imaging data, perhaps by utilizing identical tasks. Lastly, the use of a countdown paradigm and 90 dB white noise stimuli may not have elicited a large enough startle response to produce a large enough SCR. Fung et al. (2005) also found a high rate of SCR nonresponding, suggesting that the countdown task and/or the white noise aversive stimuli may not be sufficiently aversive.

Research with children with conduct problems and psychopathic traits is beginning to indicate that use of psychopathy total scores independent of the three underpinning dimensions of psychopathy may obscure meaningful information about the important biological factors that undergird psychopathy (Salekin, 2016). In a similar vein, researchers have argued that investigating callous-unemotional traits alone hampers what we know about child psychopathy and conduct problems. The findings of the current study indicate that those with grandiose-manipulative traits have heightened SCL and SCR but show no difference in HR acceleration, and that callous-unemotional traits are associated with decreased SCR, raising the possibility that findings previously interpreted as supportive of the fearlessness- or attention-based theories of psychopathy may depend on the dimension of psychopathy that is elevated. These findings also suggest that the configuration of psychopathy may constitute a complex set of psychological and biological factors. In order to understand theoretical models, we will need to unpack these findings by examining the various components of psychopathy as was done in the current investigation.

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