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FACETS OF PSYCHOPATHY, HEART RATE VARIABILITY AND COGNITIVE FUNCTION

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The aim of the present study was to investigate whether the four facets of Hare's Psychopathy Checklist-Revised (PCL-R; Hare, 1991; Bolt, Hare, Vitale, & Newman, 2004) were related to physiological and cognitive mechanisms. Fifty-three male prisoners participated in this study. Physiological responses were measured as heart rate variability (HRV) and heart rate (HR). Cognitive functions were measured using a continuous performance test (CPT; California Computerized Assessment Package, Abbreviated version) and a working memory test (WMT); based on Baddeley & Hitch (1974). The regression analysis of the HRV revealed that the interpersonal facet explained most of the variance during baseline (28%), CPT (16%), and WMT (12%). This was also true for the HR data during baseline (28%), CPT (20%), WMT (10%), and recovery (13%). The antisocial facet explained 10% of the variance only during baseline. Subjects scoring high compared to low on the interpersonal facet also showed better cognitive functioning. The study suggests that the different facets were differently associated with both physiological and cognitive functions.

Numerous studies have shown that crime and violence are closely linked to antisocial behavior and psychopathy. It has been argued that classifications of psychopathy are not synonymous with diagnoses of antisocial personality disorder but rather an extension. According to Hart and Hare (1996), psychopathy is defined by antisocial behavior in addition to emotional impairment such as lack of empathy. This definition is based on Cleckley (1976) who suggested that psychopathy can be described as a constellation of affective, interpersonal and behavioral characteristics.

The Psychopathy Checklist-Revised developed by Hare (1991) is regarded as the most valid and reliable way to measure psychopathy. The

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PCL-R consists of 20 items and each item is scored on a three point scale (0, 1, 2). These 20 items reflect both clinical (interpersonal/affective factor) and behavioral (antisocial factor) factors. A total score on this scale can vary from 0–40. A score of 30 and above has, in general, been regarded as an indication of psychopathy. Traditionally, researchers have compared psychopaths with nonpsychopaths in relation to different dependent variables. However, a few studies utilizing this two-factor model have suggested that the two factors might reflect different underlying correlates (Fowles, 2000; Patrick, Bradely, & Lang, 1993). The interpersonal/affective factor has been reported to correlate negatively with self-report anxiety scales and positively with narcissism (Harpur, Hare, & Hakstian, 1989) while the antisocial factor correlates positively with anxiety (Schmitt & Newman, 1999).

Recently, Bolt, Hare, Vitale, and Newman (2004) described 4 facets of psychopathy. Facet 1, the interpersonal facet, is characterized by superficial charm, grandiose sense of self-worth, pathological lying, and manipulating. Facet 2, the affective facet, consists of items such as lack of remorse or guilt, shallow affect, lack of empathy, and failure to accept responsibility. Facet 3, the impulsive lifestyle facet, involves items such as sensation-seeking, parasitic lifestyle, lack of realistic goals, and irresponsibility. Facet 4, the antisocial facet, consists of items such as poor behavior control, early behavior problems, juvenile delinquency, revocation of conditional release, and criminal versatility. The first two facets give a measure of the clinical aspect of psychopathy and they include features of narcissism, which is characterized by egocentricity, grandiosity, arrogance, envy, and lack of empathy (Kernberg, 1989). The two last facets are related to behavioral aspects such as impulsive and violent behavior. Differentiation between these variables might have implications with regard to development of preventive and treatment programs as well as risk assessment. Basic research on the underlying physiological and cognitive mechanisms related to these facets may help us to better understand the complexity of psychopathy and antisocial behavior.

Salekin, Neumann, Leistico, and Zalot (2004) reported that intelligence was positively related to the interpersonal facet and negatively related to the antisocial facet. Vitacco, Neumann, and Jackson (2005) reported a similar pattern. Apart from these studies, research on the different dimensions of psychopathy is scarce and few, if any, studies have examined the physiological and cognitive concomitants of the four facet model.

Explanations of abnormally aggressive or antisocial behavior have been both neurobiological and social. However, the relationships among psychopathy, antisocial behavior, and neurobiological variables in humans are not clearly understood. A similar conclusion can be drawn with respect to cognitive function given the diversity of findings on cognitive function and psychopathy or antisocial behavior. The definition of psychopathy may contribute to this confused state of affairs as some studies defined psychopathy in terms of personality traits whereas others defined it in terms of antisocial personality disorders. Thus the conflicting findings might be due to the variation in the diagnostic criteria for psychopathy (Dolan & Park, 2002).

The frontal lobes are clearly involved in executive function and some investigators have suggested that psychopaths suffer from a broader executive function deficit. Executive function involves abilities such as impulse control, reasoning, problem-solving, and planning goal-oriented behaviors (Fowles, 2000). Gorenstein (1982) found that psychopaths showed poorer results than nonpsychopaths on executive function tasks. A limitation of this study was the measurement of psychopathy: subjects were classified as psychopaths or nonpsychopaths based on the California Personality Inventory. In contrast, Hare (1984) found no differences in executive functioning when psychopathy was assessed with the PCL-R. Hart, Forth, and Hare (1990) and Hoffman, Hall, and Bartsch (1987) also found no support for a significant relationship between frontal lobe impairment and psychopathy. A recent meta-analytic study (Morgan & Lilienfeld, 2000) examined measures of psychopathy that correlated moderately with antisocial behavior, but not adequately with the core clinical traits associated with psychopathy as suggested by Cleckey (1976). Their results showed a strong relationship between antisocial behavior and executive deficits. The association between antisocial behavior and executive or cognitive deficits has further been supported by Dolan and Park (2002). These inconsistent results suggest that further investigation of the relationships between cognitive functioning and the four facets of psychopathy may help to clarify these inconsistent findings.

Another important concomitant of both psychopathy and antisocial personality is cardiovascular activity. Studies have shown that adults with antisocial personality disorder have autonomic disturbances characterized by lower resting heart rate (HR) compared to controls (Raine, 1997). It has also been argued (Raine, 2002) that low resting HR is the best replicated biological correlate of antisocial and aggressive behavior in both children and adolescents. Increased HR can be due to increased activation of the sympathetic nervous system (ANS), decreased activation of the parasympathetic nervous system, or some combination of the two. Heart rate variability (HRV) is a measure that has been used to characterize the autonomic influences (particularly parasympathetic) on the heart and that has been widely used in studies of psychiatric disorders including anxiety, depression, and schizophrenia. Although few studies of HRV in psychopathy and antisocial behavior have been reported, one study showed increased HRV in relation to aggression in young adults who had not been victims of violence but not in those who were victims of violence (Scarpa, Romero, Fikretoglu, Bowser, & Wilson, 1999). This suggests that the low HR found in such subjects might be caused by increased parasympathetic activation, because of the negative correlation between HR and HRV (Aasman, Mulder, & Mulder, 1987). To our knowledge, the relationship of HRV to the four facets of psychopathy has not been investigated.

A recent approach has linked the prefrontal cortex to autonomic activity such as HR and HRV. Thayer and Lane (2000) have proposed a model which links psychological processes with peripheral physiological responses via a set of common neural structures. This model emphasizes the link between HRV and central nervous system (CNS) specifically the central autonomic network (CAN). Functionally, the CAN can be regarded as an integrated component of an internal regulation system which allows the brain to control responses that are critical for goal-directed behavior and adaptability. The model emphasizes the importance of inhibitory processes in the regulation of behavior. They argue that inhibitory processes can be viewed as negative feedback circuits that allow for the interruption of ongoing behavior. Structurally, the CAN includes several components including the anterior cingulate, the insular, orbitofrontal and ventromedial prefrontal cortices, and brainstem motor outputs such as the nucleus ambiguous. These structures are reciprocally interconnected making it possible for both bottom-up and top-down modulation of environmental inputs (Thayer & Siegel, 2002). The primary output of the CAN is mediated through the preganglionic sympathetic and parasympathetic neurons that innervate the heart via the stellate ganglia and the vagus nerve, respectively. The interplay of these inputs at the sino-atrial node of the heart generates the complex variability that characterizes the healthy HR time series (Saul, 1990). Sensory information from the periphery such as the heart and the immune system is fed back to the CAN. Thus, there is a link between HRV and the CAN (Thayer & Lane, 2000), and HRV could be seen as an index of neural feedback mechanisms of the CNS. Similarly, Porges (1992) has emphasized the role of HRV in relation to attentional and emotional regulation, and suggests that higher HRV is associated with more flexible adaptation to environmental challenges.

Research by our group based on Thayer and Lane's model revealed that there is an association between cognitive function and HRV (Hansen, Johnsen, & Thayer, 2003; Hansen, Johnsen, Sollers, Steinvik, & Thayer, 2004). Accordingly, an interesting question is whether there is an association between HRV, cognitive function and lower order traits of personality (Livesley, Jang, & Vernon, 1998), in this case facets of psychopathy. Investigation of this issue will contribute to understanding the different behavior patterns among criminals and the development of appropriate intervention and treatment programs.

The aim of this study was to investigate the relationships among the four facets of Hare's PCL-R, physiological measures and cognitive function. First, we explored the predictive power of the four dimensions of the PCL-R in relation to HRV and HR. Second, we investigate whether there was any relationship between the facets and cognitive function. We expected that facets that were associated with high HRV during the different conditions would also be associated with good performance on the cognitive tasks based on the reported association between HRV and cognitive function (Hansen et al., 2003, 2004).

METHODS

SUBJECTS

Fifty-three male subjects, from the Bergen prison, all Norwegian citizens, with a mean age of 32, 07 (range: 20–48) years participated in this study. Mean years of education were 10, 81 (range: 7–16) and the subjects that participated in the study were serving sentences of at least 1 year and up to 12 years. Types of crime that were committed included simple impulsive theft, violent behavior, drug dealing, and impulsive or planned homicides. Fourteen percent of the participants had a PCL-R score of 26 or above. Nineteen percents had a cut-off score between 26 and 20, and 17% had a cut-off score of 20 or lesss. Five subjects withdrew from the study because they were released during the period the experiment took place. Variations in degrees of freedom were due to technical problems related to the computers and the registration of the cardiovascular activity. All subjects reported to previous alcohol or drug abuse.

MEASURE

Two cognitive tests were presented. The tests were computerized versions of a continuous performance test (CPT), and a working memory test (WMT).

The California Computerized Assessment Package abbreviated version, (CalCAP) was chosen as a CPT. CalCAP is recognized as a test of sustained attention and consisted of four sub-tests, two with nonworking memory components (simple reaction time task which was an easy task and a choice reaction time task) and two with working memory components (detection of identical stimuli and a simple addition task; Hansen et al., 2003, 2004). The test was self-explanatory and needed only minimal supervision by the investigator.

A modified version of a working memory test developed by Hugdahl et al. (2000) based on Baddeley and Hitch‘s (1974) research was chosen as a WMT. The task was a 2-back task and consisted of a continuous flow of digits. Subjects were to detect identical digits to the one presented two trials previously. The stimuli were numbers from 1 to 9. The WMT was presented using the Micro Experimental Laboratory (version 2; Schneider, 1988) software installed on a Fujitsu Life Book with 10×7.5 inch screen.

Cardiovascular responses were measured by using an Ambulatory Monitoring System (AMS; Klaver, de Geus, & de Vries, 1994). The cardiac responses were measured with 8mm Ag/AgC1 ECG electrodes (Cleartrode, Disposable Pregelled Electrodes, 150, Standard Silver). One electrode was placed over the jugular notch of the sternum, between the collarbones, another was placed 4 cm under the left breast between the ribs, and the third electrode was placed at the right lateral side between the two lower ribs.

PROCEDURE

All subjects were tested individually. Before the start of the experiment the subjects signed an informed consent statement and informed about their rights to withdraw from the study at any time.

Before presenting the CalCAP, subjects were instructed to focus on the computer and respond to the target stimuli by depressing the spacebar of the computer using their dominant hand. During the Simple Reaction Time (SRT) sub-task, subjects were asked to press a key as fast as possible to target stimuli. This procedure provides a basal measure of reaction time. For the Choice Reaction Time (CRT) for single digits, subjects were asked to press a key as fast as possible when a specific number (7) was presented. For the Serial Pattern Matching (SPM 1), the subjects were asked to press a key only when they saw two identical numbers in succession. This procedure adds a more complex element of memory since the subject must keep in mind the last number that was seen. For the Serial Pattern Matching 2 (SPM 2), the subjects were asked to press a key only when they saw numbers in increasing order (Miller, 1999). The CalCAP program presented training trials before the start of every task, and the subjects were presented with a total of 315 trials. Target probability for the CalCAP was 22%.

Frequency of correct responses to target stimuli was recorded as true positive responses, and subject's responses to nontarget stimuli were classified as false positives. The responses were recorded in milliseconds from the stimulus onset to the manual reaction by the subjects. The reaction times indicate the average speed with which the individual was able to respond to target stimuli. Reaction time data were logarithmically transformed prior to analysis.

On the WMT, the subjects were instructed to depress the spacebar when the number that was presented two stimuli previously appeared on the screen. A total of 200 stimuli, separated into four blocks, were presented to the subjects. Target probability for this task was 33%. Also on this task, the frequencies of correct responses were recorded as true positives, and responses to nontargets were recorded as false positives. The mean reaction time (mRT) for trials was recorded in milliseconds by the internal clock of the computer, from stimulus onset, until the subjects had depressed the space-bar. The cognitive tests were administered in counterbalanced order.

After the AMS system was placed on the subjects, the sequence of 5 min baseline, tests (CalCAP and WMT) and 5 min recovery was performed on all subjects. HRV was measured as the root mean of the squared successive differences (rMSSD), and also averaged over task period. Each R- to Rwave inter-beat interval in the selected period was used to calculate the average HR and the rMSSD. rMSSD is an index of vagally mediated cardiac control that correlates highly (about .90) with spectrally derived measures of vagally-mediated HRV (Thayer, Friedman, Borcovec, Johnsen, & Molina, 2000). In addition, this measure acts as a high pass filter and thus removes the slower, blood pressure mediated variability from the signal. HR was measured as beats per minutes, based on the inter-beat intervals (IBI) averaged over 30 second periods. The rMSSD data and the cognitive data were logarithmically transformed prior to analysis.

Ratings of PCL-R were performed by a specialist in clinical psychology trained by Robert Hare (Assessing Psychopathy: Clinical and Forensic application of the PCL-R; May 28–30, 2003, Bergen, Norway; PCL-R Workshop). Six of the subjects were scored by different raters. The inter-rater reliabilities for the PCL-R total score was $r = .96$. For the interpersonal/affective factor the correlation was .70 and for the antisocial factor the correlation was .68. The PCL-R was scored based on the information from the semi-structured interview, and prison file data.

DESIGN AND STATISTICS

To investigate the relationships among the PCL-R, cardiac measures, and cognitive measures, Pearson's product moment correlations were used. Forward stepwise regression approach was performed with the four facets as predictor variables, and HRV and HR (baseline, test conditions, and recovery) as dependent variables. When the multiple regression analyses were performed, groups were made based on the median split of the facets. In order to investigate whether there was any differences in cognitive abilities between high and low scores on the facets, t-test for independent sample were used. High and low scores on the facets were used as grouping variables, whereas cognitive measures were used as dependent variables. Because of the predicted direction of the means for the cognitive data, one-tailed tests were used (Vogt, 1999). A repeated measure of ANOVA of the conditions was used to investigate whether the cognitive tasks had any impact on the HR and HRV.

RESULTS

Means and standard deviations for the independent and dependent variables are shown in Table 1.

The correlations between the four facets and physiological data (HRV and HR) are presented in Table 2.

For the tasks that involved working memory there was a significant positive relationship (one-tailed) between the interpersonal facet and correct responses on the WMT, ($r = 27$, $p < 04$). Additionally, there was a significant negative relationship between the interpersonal facet and error responses on CalCAP, the SPM2 subtask, ($r = 29$, $p < .04$). For the non-work-

TABLE 1. Means and Standard Deviations for PCL-R, Cognitive Tasks, Heart Rate Variability (HRV) and Heart Rate (HR)

Variables	Mean	Std.Dev.
PCL-R		
Total PCL-R	19.76	8.15
Facet 1	3.38	2.86
Facet 2	2.98	2.68
Facet 3	6.56	2.51
Facet 4	5.78	3.23
Cognitive tasks		
WMT	34.58	11.31
SPM2, CalCAP	3.65	2.65
Physiology		
HRV Baseline	34.62	21.75
HRV CalCAP	36.74	28.29
HRV WMT	34.61	27.01
HRV Recovery	37.39	26.24
HR Baseline	78.73	12.84
HR CalCAP	76.58	12.42
HR WMT	77.54	13.02
HR Recovery	76.13	11.98

ing memory tasks there was a positive relationship between the affective facet and reaction time on the SRT, (r = 28, p < .04). The correlation analysis showed a negative relationship between the impulsive facet and the SRT Calcap, (r = 30, p < .03).

With regard to the relationship between physiological data and cognitive data there was a significant negative correlation between HR and number of correct responses on the WMT (r = 30, p < 05; two-tailed).

The regression analysis showed that the interpersonal facet predicted a positive relationship with HRV during baseline accounting for 28% of the total variance, (see Table 3). For the test conditions, the interpersonal facet had the strongest influence during the CalCAP task, 16%. During the WMT the interpersonal facet explained 12% of the variance. Interestingly, the antisocial facet was responsible for 10% of the total variance only during baseline. No other facets showed had any significant relationships.

For the HR data, the results from the regression model showed that the

TABLE 2. Correlations Between Facets on PCL-R and Physiological Measures

	Log HRV Baseline	Log HRV Calcap	Log HRV 2Back	Log HRV Recovery
Facet 1	.51, p < .00	.46, p < .00	.46, p < .00	.25, p < .14
Facet 2	.37, p < .03	.34, p < .05	.35, p < .04	.20, p < .23
Facet 3	.29, p < .09	.21, p < .20	.23, p < .18	–.01, p < .93
Facet 4	.41, p < .01	.37, p < .03	.38, p < .03	.07, p < .67
	Log HR Baseline	**Log HR Calcap**	**Log HR 2Back**	**Log HR Recovery**
Facet 1	–.62, p < .00	–.52, p < .00	–.44, p < .00	–.41, p < .02
Facet 2	–.40, p < .02	–.29, p < .09	–.20, p < .25	–.22, p < .21
Facet 3	–.12, p < .48	–.14, p < .40	–.18, p < .31	–.09, p < .60
Facet 4	–.31, p < .07	–.36, p < .03	–.18, p < .09	–.30, p < .08

TABLE 3. Regression Model of Facets Related to Heart Rate Variability (HRV) and Heart Rate (HR; *p* < .05)

Variable	β	Multiple R-square	R-square	*p* < 0.05
Log HRV baseline				
Facet 1	0.47	0.28	0.28	*
Facet 4	0.33	0.38	0.10	*
Log HRV Calcap				
Facet 1	0.33	0.16	0.16	*
Facet 4	0.26	0.22	0.06	
Log HRV 2Back				
Facet 1	0.28	0.12	0.12	*
Facet 4	0.25	0.18	0.05	
Log HR baseline				
Facet 1	–0.51	0.30	0.30	*
Facet 4	–0.22	0.34	0.04	
Log HR calcap				
Facet 1	–0.40	0.20	0.20	*
Facet 4	–0.23	0.25	0.05	
Log HR 2back				
Facet 1	–0.27	0.10	0.10	*
Facet 2	–0.19	0.10	0.03	
Log HR recovery				
Facet 1	–0,31	0.13	0.13	*
Facet 4	–0.20	0.17	0.03	

interpersonal facet predicted 30% of the HR during baseline. The same pattern was evident for the reactivity during test conditions. The interpersonal facet explained 20% of the HR during exposure to the CalCAP test and 10% of the variance during the WMT. With regard to the recovery the interpersonal facet explained 13% of the total variance. All associations for HR were negative and no other facets than the interpersonal facet showed any association (see Table 3).

T-test for independent samples were used to investigate whether subjects scoring high on the interpersonal facet had better cognitive performance compared to subjects scoring low on the interpersonal facet. The results from the SPM 2 showed that a high score on the interpersonal facet (mean = 0.39; standard deviation; SD = 0.33) was associated with less false positive responses than subjects low on the interpersonal facet (mean = 0.57; SD = 0.28), $t(38) = 1.84$ $p < .04$).

With regard to the WMT, the results demonstrated again that subjects scoring high on the interpersonal facet showed better performance compared to those with low scores. High interpersonal subjects (mean = 1.59; SD = 0.09) had more true positive responses than low interpersonal subjects (mean = 1.41; SD = 0.30), $t(42) = 2.55$, $p < 0.005$. There were no differences between high and low score on any of the other facets.

EFFECTS OF TASK CONDITIONS ON PHYSIOLOGICAL MEASURES

There was no significant main effect of test-condition. However, LSD tests revealed that there was significant difference between WMT and recovery for HRV, ($p < .03$). HRV was higher during recovery compared to WMT. Moreover, for HR there was a significant effect of conditions, $F(3,126) = 6.69$, $p < 00$. HR during baseline was higher than HR during all other conditions (all p's < .01).

DISCUSSION

The results of the present study showed that it was the interpersonal facet that explained most of the variance with regard to the physiological data, both HRV and HR, during all the conditions. One exception was HRV during recovery. Additionally, there was a relationship between antisocial behavior and baseline HRV. There was an association between the interpersonal facet and performance on both cognitive tasks, the CalCAP and the WMT. Thus, the study suggested that the different facets were differentially associated with both physiological and cognitive functions.

For the physiological data, the regression approach showed that the interpersonal facet was a significant predictor of HRV and HR during almost all conditions. Since the interpersonal facet is characterized by features of narcissism, the results are consistent with Kesley, Ornduff, McCann, and Reiff's (2001) results which found that narcissism was associated with enhanced HR deceleration in anticipation of an aversive stimulus. Interestingly, they found that during different coping tasks, subjects with a high score on the Narcissistic Personality Inventory (NPI) showed a greater anticipatory lengthening of heart period, and thus greater parasympathetic modulation of the heart, as compared to subjects scoring low on NPI. It has also been suggested that "primary" psychopathy is associated with anxiety deficit (Gray, 1971). The positive relation between the interpersonal facet and HRV during both baseline and test conditions demonstrated in this study could indicate that the interpersonal facet is associated with low anxiety. This finding is consistent with prior research that found that high HRV is related to low anxiety (Thayer, Friedman, & Borkovec, 1996), but also high ability to self-regulate and high flexibility (Thayer & Lane, 2000). The results from the present study, taken together with the research concerning HRV, is also consistent with unpublished data from our research group that showed a negative relationship between the interpersonal facet and depression, psychasthenia and the anxiety scale of MMPI 2 (Stokkeland, Hansen, Johnsen, Pallesen, & Waage, 2007).

The cognitive data in the present study revealed that subjects scoring high on the interpersonal facet demonstrated fewer error responses on a working memory task of the CalCAP compared to those with low scores on the interpersonal facet. This pattern was supported by the results from the WMT. High scorers on the interpersonal facet exhibited significantly more true positive responses than low scorers on the interpersonal facet. The results correspond with Salekin et al. (2004), and also Vitacco et al. (2005) who found a significant relationship between the arrogant and deceitful interpersonal style and intelligence by using the Psychopathy

Checklist-Youth Version and Psychopathy Checklist Short version. According to the findings from Salekin et al. (2004) and Vitacco et al. (2005), the interpersonal facet is not associated with an intellectual deficit, which has been found to be true for antisocial subjects (Raine, 1997). In addition the results support the suggestion that there is a link between HRV and cognitive function (Hansen et al., 2003).

The results of the present study also indicated that there was a relationship between antisocial behavior and HRV during baseline. The results are in line with Scarpa et al. (1999) who found a relation between aggression and increased HRV. Since heart rate regulation is a complex process that involves both the sympathetic and parasympathetic systems, and there is a negative correlation between HR and HRV in healthy individuals (Aasman et al., 1987) these results are also consistent with Raine (1997) who found that antisocial adults had lower resting HR. The results also fit into the stimulation-seeking theory (Eysenck, 1997), which suggests that individuals with low arousal experience an unpleasant physiological state. One of the characteristics of antisocial individuals is that they seek stimulation in order to increase their arousal back to an optimal or normal level.

Thus, in spite of the positive relationship between the antisocial facet and baseline HRV, there was no relationship between high scores on this facet and good cognitive performance. Importantly, the regression analysis did not show any relationship between the antisocial facet and HRV during any of the cognitive tasks or recovery. One possible explanation of this issue might be that the subjects experienced the task condition as a stressful event. Other investigations have shown that during exposure to sustained attention tasks HRV normally decreases (Porges, 1992). Examination of the present results showed that HRV was significantly lower during the WMT compared to recovery. This observation confirms that the WMT, which is the most demanding task, might have been stressful.

However, there was neither any relationship between antisocial facet (nor the affective and the impulsive facet) and poor cognitive functioning as found in other studies. Ishikawa, Raine, Lencz, Bihrle, and Lacasse (2001) showed that unsuccessful psychopaths with a high score on the antisocial factor had lower resting HR and poorer performance on executive function tasks compared to successful psychopaths with a high score on the interpersonal/affective factor. It has been suggested that a deficit in dorsolateral prefrontal cortex, which is a region found to be associated with the working memory component of executive functions in some studies (Pantelis et al., 2004), is associated with physical aggression, poor impulse control or poor self-regulation of thought and action in antisocial personality (Séguin, 2004). One possible explanation of why there was no relationship between the antisocial facet, or the other two facets and poor cognitive performance might be because of the small sample size. Another explanation might be that the cognitive tasks that were used in this study were too easy. They did not involve aspects of more complex planning and reasoning such as Iowa Gambling task, Tower of Hanoi, or more complex n-back tasks.

The results from the present study suggest that subjects with high scores on the interpersonal facet have good inhibitory control because the task in the present study taxed both attention and working memory processes. This requires good inhibitory control and inhibition of irrelevant stimuli. It has been demonstrated in healthy subjects that during performance of a 2-back task significant activation of the frontopolar and dorsolateral cortex (DLPFC), anterior cingulate, anterior insula, and posterior parietal cortical regions (Adler, Holland, Schmithorst, Tuchfarber, & Strakowski, 2004) are observed. Based on the present results and those of Salekin et al. (2004) and Vitacco et al. (2005), there is no reason to suggest that subjects scoring high on the interpersonal facet have prefrontal dysfunction. The results however do support recent research that has emphasized the potential for better differential information from the four facet model of the PCL-R (Bolt et al., 2004), rather than the simple dichotomy between the presence or absence of psychopathy.

Consistent with Hansen et al. (2003, 2004), the present study supports the model developed by Thayer and Lane (2000), which integrates psychological processes with a set of underlying physiological structures. They emphasized the role of HRV as an index of self-regulation and its ability to reflect neural feedback mechanisms of the CNS and the ANS. The interplay of sympathetic and parasympathetic (vagal) outputs of the CAN at the sino-atrial node produces the complex beat to beat variability that is characteristic of a healthy, adaptive organism. Thus, the results suggest that HRV plays a major role with regard to the inhibitory influences that allow for efficient self-regulation including the shifting of attentional focus. The present study expands previous research in the field of HRV and cognition, by showing that these two underlying mechanism can be linked to personality dimensions, in this case specific clinical features of psychopathy. The study extends previous investigations concerning psychopathy and antisocial behavior by suggesting that the influence of the vagus nerve and parasympathetic activity are important in addition to the sympathetic nervous system. Still there is very little literature concerning HRV and psychopathy and thus the present results while suggestive are certainly not definitive. However, the present results are consistent with Eysenck's (1990) notion that individual variations in personality dimensions reflected differences in neurophysiological functioning. In order to develop appropriate preventive measures and treatment programs for these kinds of personality disorders, it is necessary to have knowledge about the relationship between different factors like brain functioning, behavior, and personality. Clearly, this needs further investigation.

A critical issue is whether psychopaths are a homogeneous group, as earlier emphasized. As suggested by Weiner (2002) there is no common MMPI-2 profile of serial killers, arsonist, pedophiles, or rapists, because of personality differences among persons who commit these offenses. Thus, psychopathy may be a combination of different psychopathic traits rather than a simple dichotomy between its presence or absence. In this respect it is necessary to investigate whether the different facets of psychopathy can be linked to different underlying mechanisms.

In summary, this study investigated different facets of psychopathy in relation to underlying physiological and cognitive mechanisms. This is the first time these three variables have been investigated together. Furthermore, the results from this study suggested that it is not enough to differentiate between psychopathic and nonpsychopathic criminals. Psychopathy is more complex and the present study suggests that the different facets of psychopathy might have different underlying characteristics. Additionally, the results supported the suggestion that there is an association between cognitive function and HRV. Knowledge concerning the underlying organization of the psychopathic personality will help us to get a better understanding of this important condition and help us to develop appropriate intervention programs in the future.

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