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Psychopathy, Attention, and Oddball Target Detection: New Insights from PCL-R Facet Scores

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Abstract

Psychopathy is a disorder accompanied by cognitive deficits including abnormalities in attention. Prior studies examining cognitive features of psychopaths using ERPs have produced some inconsistent results. We examined psychopathy-related differences in ERPs during an auditory oddball task in a sample of incarcerated adult males. We extend previous work by deriving ERPs with principal components analysis (PCA) and relate these to the four facets of Hare's Psychopathy Checklist Revised (PCL-R). Features of psychopathy were associated with increased target N1 amplitude (facets 1, 4), decreased target P3 amplitude (facet 1), and reduced slow wave amplitude for frequent standard stimuli (facets 1, 3, 4). We conclude that employing PCA and examining PCL-R facets improve sensitivity and help clarify previously reported associations. Furthermore, attenuated slow-wave during standards may be a novel marker for psychopaths' abnormalities in attention.

Keywords

Psychopathy; ERP; Target Detection; Oddball; PCL-R; Factors; Facets

Psychopathy is a disorder of personality and behavior, characterized by traits that can be parsed into multiple dimensions (Hare & Neumann, 2005). The current clinical standard for measuring psychopathy, Hare's Psychopathy Checklist-Revised (PCL-R; Hare, 2003), distinguishes four facets of psychopathic traits nested within two factors. Factor 1 consists of *interpersonal* traits (facet 1), such as conning manipulation and grandiosity, and *affective* traits (facet 2), such as callousness and shallow affect. Factor 2 consists of *lifestyle* traits (facet 3), such as irresponsibility and impulsivity, and *antisocial* traits from childhood through adulthood (facet 4). Etiological models of psychopathy have emphasized the roles of emotional dysfunction (Blair, Peschardt, Budhani, Mitchell, & Pine, 2006; Kiehl, 2006) and

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abnormalities in attention (Newman, 1998) in the development of psychopathic traits. While the notion of emotional deficits in psychopathy is well established, evidence for attention-related abnormalities has also been steadily accumulating.

Individuals with psychopathy show limitations in adaptively distributing attentional resources at early stages of information processing (Newman, Schmitt, & Voss, 1997; Baskin-Sommers, Curtin, & Newman, 2011; 2013). Recent evidence suggests this abnormality in information processing is the result of an early attentional bottleneck that limits redistribution of cognitive resources once a primary selection for attention is established (Baskin-Sommers et al. 2011; Baskin-Sommers, Curtin, Li, & Newman, 2012). In certain contexts, this can present as a relative over-focusing of attention or resistance to peripheral distraction (e.g. Baskin-Sommers et al. 2012; Jutai & Hare, 1983). In other circumstances, it limits the availability of potentially useful information, such as threat-related cues (Newman, Curtin, Bertsh, & Baskin-Sommers, 2010). The *Response Modulation* model of psychopathy suggests these attention-related abnormalities are a fundamental feature of the disorder (Newman, 1998). Accumulating evidence for attention-based models of psychopathy is compelling. Still, this theory stands to gain additional specificity through expanded application of neurocognitive measures capable of identifying more discrete, primary features of attention.

Features of attention can be examined by measuring event-related potentials (ERPs) during oddball target-detection tasks (Herrmann & Knight, 2001). These tasks involve discrimination of target stimuli among more frequent non-targets, and occasionally include novel distracters as a third stimulus category. The target condition is valuable for assessing brain activity involved in identifying the task relevance of a stimulus and actively engaging it for further action. Novel distractors involve evaluation of qualitatively unique stimuli, promoting an orienting response, but also require response inhibition (see Polich, 2007 for review). Frequent standard stimuli comprise the contextual background against which novels and targets are comparatively evaluated and can provide information regarding basic mobilization of attention (García-Larrea, Lukaszewicz, & Mauguière, 1992).

Several ERP components elicited with oddball tasks are relevant to attention and models of psychopathy. The N1, N2, P3, and late positive slow wave have regularly been used as indicators of attention, cognitive performance, and elaborative processing in healthy individuals and in clinical samples, including studies of psychopathy. The N1 coincides with early perceptual processes, and its amplitude is influenced by a number of factors including selective attention and cognitive effort (Enge, Fleischhauer, Lesch, & Strobel, 2011). The N2 comprises a family of overlapping components highly dependent on task demands. In the context of auditory oddball tasks, the N2 may index qualitative differences in sequential stimuli (*N2a* or mismatch negativity) but also indexes attention to rare events (*N2b* and *N2c*; see Folstein & Van Petten, 2008). Similarly, the P3 component is sub-divided into a fronto-central *P3a*, in response to rare (usually non-target) events, as well as a centro-parietal *P3b*, which indexes task-related significance of low-probability events (Polich, 2007). P3 amplitude fluctuates with overall cognitive demands, where amplitudes increase with rarity and salience, but decrease with task complexity and perceptual load (Ferrari, Bradley, Codispoti, & Lang, 2010). Finally, the positive slow-wave following the P3 has been

described as indexing elaborative processing demands and its amplitude increases with perceptual and/or conceptual difficulty of the task (García-Larrea & Cézanne-Bert, 1998; Ruchkin, Johnson, Mahaffey, & Sutton, 1988). Each of these components holds potential relevance to neurocognitive models of psychopathy.

ERPs elicited during oddball tasks have often been examined in relation to psychopathy, but the nature of these findings, has differed substantially. Raine and Venables (1988) reported larger P3 amplitude for targets in adult inmates with high psychopathy scores. An earlier report by Jutai, Hare, and Connolly (1987) found no significant differences in the P3 for target identification but found sustained late positive slow waves in individuals with psychopathy. Kiehl and colleagues reported that, compared to other inmates, psychopaths consistently exhibit increased N2 amplitudes for both targets and novel stimuli along with enhanced late negative waves approximately 500 ms post-stimulus (Kiehl, Hare, Liddle, & McDonald, 1999; Kiehl, Bates, Laurens, Hare, & Liddle, 2006). Kiehl and colleagues (2006) also reported reduced target and novel P3 amplitude in one of two samples of psychopaths compared to non-psychopathic inmates. However, a second similar sample in this same report showed no P3 amplitude differences between psychopaths and non-psychopathic inmates. Brazil and colleagues (2012) have reported that smaller P3 amplitude for target and novel stimuli was characteristic of incarcerated participants in general compared to non-incarcerated controls, but found no P3 amplitude effects related to psychopathy among inmates. Gao, Raine, and Schug (2011) have reported that reduced P3 amplitude for target stimuli is specific to “unsuccessful psychopaths” who have been convicted of crimes, compared to “successful psychopaths” who have ostensibly avoided conviction. Successful psychopaths in this study also had larger P3 amplitudes for frequent standard stimuli than controls.

The variability in these reported findings makes generalization elusive, yet each of these studies has examined psychopathy categorically (e.g. PCL-R total scores above a discrete cutoff). Considering the four facets comprising scores on the PCL-R, results from Brazil et al. (2012) and Gao et al. (2011) suggest that P3 reductions might be specific to antisocial features of psychopathy (facet 4). This interpretation is consistent with a body of literature linking P3 reductions to antisociality and externalizing vulnerability (Bauer, O'Connor, & Hesselbrock, 1994; Hicks et al., 2007; Gao & Raine, 2009). Evidence for unique ERP correlates of separable features of psychopathy has, for the most part, come from non-incarcerated, predominantly female samples (Anderson, Stanford, Wan, & Young, 2011; Carlson & Tháí, 2010; Carlson, Tháí, & McLarnon, 2009). Only very recently has this theoretical approach been extended to psychopathic features among incarcerated samples. Venables and Patrick (2014) reported that psychopathy-related reductions in P3 amplitude were limited to impulsive and antisocial facets of the PCL-R among male inmates. These outcomes highlight the utility of examining PCL-R facet-level associations with ERPs in forensic samples.

Among additional issues that may contribute to divergent ERP results in extant literature is the reliance on peak or mean amplitude within pre-defined time-windows. This method may not adequately separate variation in overlapping ERP components. Principal components analysis (PCA) provides a robust decomposition of overlapping variance (Chapman &

McCrary, 1995; Dien, Khoe, & Mangun, 2007), improving inferences that link psychiatric features to variation in specific cognitive processes. Finally, many studies examining psychopathy and attention-related ERPs have limited the scope of their investigation to ERPs for target stimuli, while others have specifically examined P3 amplitude on its own. Additional knowledge can be gained by examining a full set of principal components for target, novel, and frequent standard stimuli.

The current study examines psychopathy-related differences in ERPs elicited by a basic three-stimulus auditory oddball target detection task in an incarcerated adult male sample. Prior work is extended by examining a full set of PCA-derived ERP components and relating these to separable dimensional features of psychopathy. Based on evidence that reduced P3 amplitude is a feature common to externalizing and antisocial behavior (Bauer et al. 1994; Hicks et al., 2007), we hypothesized that reductions in P3 amplitude would be related to impulsive and antisocial features (factor 2; facets 3 and 4) of the PCL-R. We also expected that ERP increases in N2 and P3 for target stimuli would accompany the affective/interpersonal dimensions (facets 1 and 2) of psychopathy due to suggestions that these features of psychopathy are associated with heightened early selective attention for task-related stimuli (Baskin-Sommers et al., 2012; Gao & Raine, 2009), and related ERP findings in non-incarcerated samples (e.g. Carlson & Thái, 2010; Gao et al., 2011).

Method

Participants

Adult male volunteers were recruited from a medium security prison in New Mexico. All participants provided informed consent, and the protocol was approved by the University of New Mexico Health Science Center Human Research Review Committee and the Office of the Human Research Protections. Following informed consent procedures, participants were assessed for basic demographic variables, psychiatric diagnoses, IQ, and psychopathy via instruments described below. Participants were excluded when meeting DSM-IV-TR diagnostic criteria for schizophrenia ($n = 1$), bipolar ($n = 1$), and current major depression ($n = 2$). It was also confirmed that no participants were diagnosed with attention deficit disorder. Others were excluded for having a history of serious head injury resulting in prolonged loss of consciousness ($n = 8$). The final sample ($n = 59$) had a mean age of 34.9 ($SD = 10$); mean years of education was 11.85 ($SD = 1.69$); and mean IQ was 97.76 ($SD = 14.89$). The ethnic and racial composition of the sample was 27 Hispanic/Latino, 32 not Hispanic/Latino; 39 Caucasian, 5 black/African American, 5 American Indian/Alaskan native, 10 participants did not identify race.

Assessments

Clinical assessments—Psychopathy was assessed using the Psychopathy Checklist-Revised (PCL-R; Hare, 2003). The PCL-R is an expert-administered rating scale based on details collected during a semi-structured interview and an extensive collateral file review. Twenty PCL-R items are rated on a three-point scale: zero indicating no evidence, one indicating some evidence, and two indicating pervasive evidence in many domains of an individual's life. Out of a maximum of 40 points, a score of 30 or higher is the

recommended cutoff for an operational definition of psychopathy. The PCL-R also provides a dimensional assessment of psychopathic traits (Hare & Neumann, 2005). These traits have traditionally been divided into two major factors (Harpur, Hare, & Hakstian, 1989) and more recently into four facets: 1) *interpersonal* 2) *affective* 3) *lifestyle* 4) *antisocial behavior* (Hare, 2003; Hare & Neumann, 2005). Diagnoses for other psychiatric disorders were based on criteria from the Structured Clinical Interview for DSM-IV-TR, Axis I disorders (SCID I/P; First, Spitzer, Gibbon, & Williams, 2002). Participants were not excluded for substance abuse or dependence, as substance use is a common feature of psychopathy (Smith & Newman, 1990). IQ estimates were calculated using the vocabulary and matrix reasoning subtests of the Wechsler Adult Intelligence Scale III (WAIS-III).

Oddball task—Participants completed a three-stimulus auditory oddball task while undergoing EEG data collection. Data for each participant was gathered during two consecutive runs of the task. Auditory stimuli were delivered via headphones (*Philips SHP2500*) and consisted of frequent standard low-pitched (1000 Hz) tones (80% of trials), infrequent target high-pitched (1500 Hz) tones (10% of trials), and infrequent non-target, novel stimuli (10% of trials), which were computer-generated sounds (static, bells, beeps, varied in tone). Each stimulus was presented for 250 ms in pseudorandom order with variable interstimulus interval averaging 2000 ms. Participants were instructed to respond as quickly as possible to high-pitched target tones by pressing a single button with their right index finger on a response box. They were further instructed to inhibit responses to any of the other stimuli. A short practice session familiarized participants with the high and low tones, and assured task instructions were understood. The task is designed such that general performance is high, even in severe clinical cases. Behavioral performance was carefully monitored and recorded during the task. Summary information for behavioral data is described below. Following ERP data processing, the number of useable trials resulted in an average of 312 (SD: 55) standards, 38 (SD: 8) targets, and 39 (SD: 7) novel stimuli across runs.

ERP Data Collection and Processing

Participants were seated in a quiet, dimly-lit room, reserved for EEG data collection, separate from the general population housing. Stimuli were delivered via *Presentation* software (Neurobehavioral Systems Inc.) on a task-dedicated computer that also recorded participant responses and sent event triggers to a second computer that digitized EEG data. EEG data were amplified on a 64-channel *BioSemi ActiveTwo* system, with sintered Ag-AgCl active electrodes placed according to the 10–20 International System (Jasper, 1958). The participant's nose was used as the reference. Six electrodes were placed on the participants face to measure electrooculogram. These electrodes were placed above, below, and medial to the canthus of each eye. Offsets were kept below 10 k Ω . EEG signals were low-pass filtered using a fifth order sinc filter with a half-power cutoff of 204.8 Hz then digitized at 1024 Hz during data collection. Additional pre-processing included bad channel detection and replacement, epoching, and eye-blink removal. Bad channels were identified as having activity four standard deviations away from the mean of all other non-ocular channels. These channels were replaced using the mean of surrounding electrodes. ERP epochs were defined from 1000 ms pre-stimulus to 2000 ms post-stimulus. The epoched data

were eye-blink corrected using an independent component analysis (ICA) technique. The ICA utility in the EEGLab software (Delorme & Makeig, 2004) was used to derive eye components. A custom template matching algorithm (Jung et al., 2000) was used to identify and remove blink components from the data. Individual subject ICA decompositions were visually inspected to identify and remove residual eye-blink components.

EEG Data were processed in Matlab using a tool designed to perform PCA (Bernat, Williams, & Gehring, 2005). Temporal PCA with varimax rotation was carried out on the covariance matrix derived from all electrodes to define stimulus-locked components for target, novel, and frequent standard stimuli (Chapman & McCarry, 1995). A six-component PCA solution accounted for 90.21% of the variance in the stimulus-locked EEG signal at all electrodes. The mean amplitude over the time course of each component, for each stimulus-category, was used to quantify the ERPs. The mean amplitude values for each of six principal components at a subset of 9 electrodes (F3, Fz, F4, C3, Cz, C4, P3, Pz, P4) were submitted to a split-plot ANOVA, treating electrodes as the repeated measure and using PCL-R scores as a continuous variable for examining between-subjects effects. Separate models were calculated when accounting for PCL-R total score, factor scores, and facet scores (i.e. total score was not included in the same model as individual factors; factor scores were not included with facets). Furthermore, to investigate potential suppression effects among correlated scores (e.g. Carlson et al. 2009), parallel analyses were conducted to examine partial effects of psychopathy scores controlling for the remaining factor/facets (e.g. factor 1 and 2 together; facet 1, 2, 3, & 4 together). Significant between-subjects effects indicate amplitude differences over the nine electrodes that are systematically related to PCL-R scores included in each respective analysis.

To examine (unanticipated) topographical effects related to psychopathy, electrodes were grouped into three lateral divisions (left, midline, right) and three coronal divisions (frontal, central, parietal), entered as two additional levels in the repeated measures ANOVA. Effects involving the within-subjects levels alone, relating to standard topographical differences in amplitude across the scalp (e.g. quadratic effects indicating larger amplitude at midline electrodes) were not of theoretical interest and are not reported here; however, these were typical. Significant interactions involving within-subjects variables and between-subjects factors (PCL-R scores) would indicate topographical effects uniquely related to PCL-R scores. All repeated measures effects were examined with Greenhouse-Geisser corrections where Mauchly's test indicated sphericity was violated (Picton et al., 2000).

To allow comparisons with the preferred PCA approach, time-window components were also quantified by fitting epochs to visible ERP features. For target and novel stimuli, windows were fitted to capture an early negativity: 70–250 ms, the P3: 200–450 ms, and a late positive slow wave: 450–1000 ms (see figure 1). The peaks of the frequent standard stimuli occurred earlier than target and novel stimuli and the fitted windows were adjusted for the early negativity: 70–190 ms, and the P3: 170–275 ms. Time domain components were baseline-corrected using a 110 ms pre-stimulus onset window. Mean amplitude within each component window were analyzed using the same ANOVA procedure described for the PCA approach.

Results

Behavioral Data and Subject Variables

PCL-R total scores ranged from 7 to 38 ($M = 21.9$, $SD = 7.4$; see Table 1). Correlations between the Interpersonal/Affective (Factor 1) scores (range: 1–15) and Impulsive/Antisocial (Factor 2) scores (range 3–22) scores were typical, $r = .49$. Correlations between facets were also typical. Interpersonal (facet 1; range: 0–8) and Affective (facet 2; range: 0–8) were strongly correlated, $r = .44$. Lifestyle (facet 3; range: 1–10) and Antisocial features (facet 4; range: 0–12), were also strongly correlated, $r = .44$. Behavioral performance and several subject variables were evaluated for systematic relationships with PCL-R scores. Descriptive statistics and t -tests comparing these upper and lower quartiles of the sample are summarized in Table 1. There were no significant relationships between PCL-R scores and behavioral measures ($p > .60$). Across both runs of the task, participants on average performed with greater than 97% accuracy in target identification with a mean reaction time of 497.7 ($SD = 83.1$) ms. Participants averaged 4 false alarms with mean reaction time of 359.2 ($SD = 146.8$) ms. There were no significant relationships between PCL-R scores and age, education, IQ, or substance dependence ($p > .40$).

ERP Components

Grand average ERPs are provided in figure 1. These results exhibit well-known electrocortical features and topographical distributions for target, novel, and frequent standard stimuli (García-Larrea et al., 1992; Polich, 2007). There were no significant interactions between psychopathy scores (total, factors, or facets) and coronal or lateral divisions of electrodes for any of the three task conditions (target, novel, standard), indicating an absence of topographical differences related to PCL-R. Between-subjects effects representing psychopathy-related differences across all selected electrodes are summarized for targets, novels, and standards, in turn below. Both PCA and time-domain effects are summarized in the text for comparison. A complete account of effects for PCA-derived components by PCL-R total, factor, and facet scores is provided in tables 2 and 3. To demonstrate the topographical distribution of significant effects, correlations between PCL-R (facet 1) scores and PCA components at each electrode site were plotted in EEGlab and are presented in figure 2. These head maps show effects treating PCL-R scores as continuous variables in all 59 subjects, paralleling results from the ANOVAs. Head maps are accompanied by waveforms separated into upper and lower quartiles on PCL-R facet 1 for visualization of ERP differences only.

Targets—Higher PCL-R scores were associated with an augmentation of an early target-related negativity between 100 and 200 ms post-stimulus. In the time domain, this was a marginal trend for PCL-R total score [$F(1, 57) = 2.95$, $p = .091$], which was partially accounted for by variation in PCL-R facet 1 [$F(1, 57) = 3.32$, $p = .074$] and facet 4 [$F(1, 57) = 2.86$, $p = .096$]. Effects for factor scores and facets 2 and 3 were not significant ($p > .10$). PCA, however, separated this negativity into early and late components, which more closely resemble typical N1 and N2 ERP components. The early (N1) component showed significant increase in amplitude (greater negativity) by PCL-R total score [$F(1, 57) = 5.20$, $p = .026$] and trends for factor 1 [$F(1, 57) = 3.00$, $p = .089$] and factor 2 [$F(1, 57) = 3.97$, p

= .051]. Just as in the time domain, the effect for this component was partially influenced by facet 1 [$F(1, 57) = 4.27, p = .043$] and facet 4 [$F(1, 57) = 4.24, p = .044$]. The later (N2) component showed no significant relationships with PCL-R total, factor, or facet scores. See figure 2.

Higher PCL-R scores were also associated with reduced amplitude of the P3 for target stimuli. In the time-domain, the reduced P3 effect was only marginal for facet 1 [$F(1, 57) = 3.76, p = .058$] and not significant for either PCL-R total, factor scores, or remaining facet scores (all $ps > .3$). However, PCA captured this effect by separating out two components within the P3 window, an early and late component. The earlier of the two P3 components exhibits a marked reduction in amplitude, which was specifically related to facet 1 [$F(1, 57) = 6.18, p = .016$] and not significant for PCL-R total score or factor scores (all $ps > .12$). The later P3 component showed no significant relationships with PCL-R total, factor, or facet scores. See figure 2.

Novels—As shown in figure 1, novel distractors elicited a P3 with an augmented fronto-central distribution compared to P3 for targets, which is typical (Friedman, Cycowicz, & Gaeta, 2001). None of the analytic strategies implemented with these data, using PCA or time-window analysis, revealed any psychopathy-related ERP differences in processing novel stimuli during the oddball task.

Frequent standards—Additional psychopathy-related differences were recognized in ERPs for the frequent standard condition. Both time-domain and PCA revealed a psychopathy-related negativity during the late slow-wave following frequent standard stimuli. Time domain slow-wave reductions were significant for PCL-R total score [$F(1, 57) = 5.13, p = .027$] and factor 2 [$F(1, 57) = 4.63, p = .036$], with a similar trend in factor 1 [$F(1, 57) = 3.98, p = .051$]. Examining facets, these effects were mostly driven by facet 1 [$F(1, 57) = 6.29, p = .015$], but also showed trends for facet 3 [$F(1, 57) = 3.65, p = .061$], and facet 4 [$F(1, 57) = 3.00, p = .089$]. PCA separated the slow-wave window into an early and a late component (see figure 2), and revealed that effects were stronger for the earlier slow wave, with significant effects on PCL-R total score [$F(1, 57) = 7.283, p = .009$], factor 1 [$F(1, 57) = 5.22, p = .026$], and factor 2 [$F(1, 57) = 6.62, p = .013$]. Examining facets, these effects are largely driven by facet 1 [$F(1, 57) = 7.39, p = .009$], but also facet 3 [$F(1, 57) = 5.13, p = .027$], and facet 4 [$F(1, 57) = 4.28, p = .043$]. The later slow-wave showed marginal trends for PCL-R total [$F(1, 57) = 3.92, p = .052$], factor 1 [$F(1, 57) = 3.01, p = .088$], and factor 2 [$F(1, 57) = 3.75, p = .058$], but these slow wave reductions were significant only for facet 1 (and no other facet scores) [$F(1, 57) = 5.15, p = .027$]. (Insert Tables 2 & 3 about here)

Supplementary Analyses

We carried out several supplementary analyses to explore these trends in the context of other theoretical issues. Potential suppression effects are a concern when two correlated factors have opposing relationships with the dependent variable. This can obscure the size and direction of statistical effects when not controlling for the correlated factor in the model (*cf.* Carlson et al. 2009). We examined this possibility by duplicating the analyses above while

including remaining factors and facets in the appropriate models (e.g. factor 1 and factor 2 together). No evidence of suppression effects was apparent—i.e. no new significant results emerged. Rather, this strategy uniformly reduced individual effects as one would expect under standard circumstances when including highly correlated factors together in a model (without suppression). As a separate supplementary analysis, we also examined individual contributions of substance dependence on ERP measures using the same analyses employed for PCL-R scores, including time windows and principal components. No relationships were significant (all p -values $> .20$). Finally, it has been suggested that psychopathy may be associated with abnormal hemispheric asymmetry (see Jutai et al. 1987; Kiehl et al. 1999). We duplicated all analyses using only right-handed participants ($N = 49$). Effects reported above were overwhelmingly stable, with slightly improved power in most cases. No new categorical effects emerged (e.g. for novel stimuli); however, six previously marginal trends emerged as significant. With right handed participants only, the late slow component showed significant negative associations with PCL total [$F(1, 47) = 7.06, p = .011, \eta^2 = .13$], Factor 1 [$F(1, 47) = 5.17, p = .028, \eta^2 = .10$], Factor 2 [$F(1, 47) = 5.26, p = .026, \eta^2 = .10$], and Facet 3 [$F(1, 47) = 4.49, p = .039, \eta^2 = .09$]. Furthermore, Factor 2 significantly influenced target N1 amplitude [$F(1, 47) = 5.44, p = .024, \eta^2 = .10$], as well as the early target P3 amplitude [$F(1, 47) = 4.09, p = .049, \eta^2 = .08$].

Discussion

This study examines psychopathy-related differences in an auditory oddball task utilizing PCL-R total, factor, and facet scores as well as PCA-derived ERP components to maximize sensitivity. Comparisons of time-domain component windows and PCA derived-components revealed that PCA provided a more comprehensive and powerful representation of effects. Likewise, facet scores were a more sensitive means of accounting for individual differences compared to PCL-R total or factor scores. Several ERP differences during the auditory oddball task were uniquely specific to facet scores on the PCL-R; however, the facet-level associations were somewhat different than anticipated. PCL-R total scores were associated with increased amplitude in an early target-related negativity peaking around 100 ms post-stimulus. This effect was driven by interpersonal (facet 1) and antisocial features (facet 4), and was not limited to interpersonal and affective traits as expected. Features of psychopathy were also associated with reduced amplitude in target P3. The reduction in P3 was specific to the interpersonal facet (1) of the PCL-R rather than antisocial features (facet 4). Finally, PCL-R scores were associated with unanticipated reductions in the late negative slow wave during frequent standard stimulus presentations. This effect was broadly related to PCL-R total, both factors, and three facets (interpersonal, lifestyle, and antisocial features, respectively). These effects are each discussed in turn below.

Target Stimuli

N1—Data revealed psychopathy-related increases in N1 amplitude following target stimuli. Our choice to label this negativity a target N1 stems from the PCA decomposition which differentiated between an early and late negativity both preceding the P3. Kiehl and colleagues (2006) reported a similar augmentation of an early negativity (N2) in psychopaths compared to non-psychopathic inmates. Both the N1 and N2 have been

described as indexing aspects of early selective attention (Hillyard, Hink, Schwent, & Picton, 1973; Näätänen & Gaillard, 1983) and several others have reported an association between psychopathy and increased N1 amplitude (Flor, Birbaumer, Hermann, Ziegler, & Patrick, 2002; Forth & Hare, 1989; Sadeh & Verona, 2012). The *Response Modulation* model of psychopathy specifically suggests that early selective attention is relatively strong in psychopaths, and subsequently resistant to interference by secondary features of the environment, once established (Newman, 1998). An early demonstration of this using ERP data indicated that psychopaths showed smaller N1 amplitude for tones designed as distractors from a primary task, suggesting reduced attentional interference (Jutai & Hare, 1983). The current findings suggest that psychopaths show an enhanced early ERP component in a basic oddball target detection task, during the primary focus of the task (i.e. target detection). This finding aligns with recent reports that have demonstrated strong mechanisms of early selective attention related to psychopathy (e.g. Baskin-Sommers et al. 2011; 2012; Hiatt, Schmitt, & Newman, 2004). PCA revealed significant associations with PCL-R total score, marginal trends for both factor scores, and significant effects for interpersonal and antisocial features (facets 1 and 4). The distribution of these effects across multiple features suggests that this specific cognitive abnormality is related to a broad constellation of traits represented in both factors of the PCL-R, as well as the psychopathy construct as a whole.

P3—Data revealed psychopathy-related reductions in target-P3 amplitude. Reduced P3 has been associated with various forms of psychopathology including schizophrenia (e.g. Friedman & Squires-Wheeler, 1994), depression (e.g. Santosh, Malhotra, Raghunathan, & Mehra, 1994), substance dependence (Singh & Basu, 2009), and more recently has been suggested as an endophenotype for those vulnerable to externalizing disorders (Iacono & Malone, 2011). The general interpretation of these findings is that smaller P3 amplitude indexes abnormalities in executive function and/or attention; however, the exact functional relationship between the P3 amplitude and psychopathology has not been fully described.

Previous reports comparing psychopathic inmates and non-psychopathic inmates have suggested that psychopaths exhibit smaller P3s (Kiehl, Hare, Liddle, et al., 1999; Kiehl et al., 2006). However, this finding has not been universal (e.g. Raine & Venables, 1988; Brazil et al., 2012). Gao and Raine (2009) have suggested that reduced P3 amplitude is more specifically related to antisocial features than to psychopathy *per se*. It is reasonable to suspect that psychopathic inmates would have comparatively smaller P3 amplitudes due to heightened antisocial features, even compared among other inmates (Walters, 2003), and that antisocial elements (factor 2, facet 4) would account for most of this variance (see also Venables & Patrick, 2014). In the current sample, facet 1 (interpersonal traits) of the PCL-R captures this effect with the greatest specificity. However, note that when only right handed participants are included, factor 2 emerges with a significant influence on this effect as well. It may be true that, among inmates who more uniformly exhibit antisocial behavior, P3 reductions are not driven by the same variation in antisociality recognized when comparing antisocial groups to non-antisocial groups (e.g. Bauer et al. 1994; Gao & Raine, 2009). The current findings suggest that in incarcerated samples, personality-related features of

psychopathy also impact ERP measures above and beyond the reductions of P3 amplitude attributable to antisocial traits *per se*.

The current findings do not necessarily conflict with other reports that have identified increased P3 amplitude with respect to psychopathic traits in various other contexts (e.g. Anderson et al. 2011; Carlson & Thi, 2010). For instance, in studies measuring psychopathic traits in non-incarcerated samples, it should be clear that self-report psychopathy scales only modestly correlate with the PCL-R, with particularly low convergence with factor 1 elements of the PCL-R (Miller & Lynam, 2012). Additionally, much of the non-forensic work has reported data from predominantly female participants (university students). Neural correlates associated with typically low, normal-range levels of psychopathic traits may not be equivalent with those recognized in clinically-relevant cases (see Neumann & Hare, 2008). Furthermore, task conditions should also be carefully considered. The current findings cannot be directly compared to other studies that have used more complex tasks that introduce additional cognitive effects (e.g. Anderson & Stanford, 2012; Flor et al. 2002; Munro et al., 2007; Raine & Venables, 1988). It is important to remember that the P3 is not a unitary trait (see Pfefferbaum, Ford, & Kraemer, 1990). The P3 represents complex processes dependent upon multiple neural generators (Halgren, Marinkovic, & Chauvel, 1998; Soltani & Knight, 2000), likely representing several overlapping cognitive mechanisms (Polich, 1987; 2007). Properties of the P3 change within-subjects under varying circumstances such as task complexity, memory load, and even biological states (Polich, 1987; Polich & Kok, 1995). In a thorough meta-analysis, Gao and Raine (2009) suggest that P3 amplitude in psychopaths may increase with increasing task complexity, but in simpler tasks it may be reduced. Evidence from the current study suggests that under very simple demands, P3 amplitude is reduced as a function of facet 1 on the PCL-R. But it is certainly reasonable to suspect that this relationship could vary due to changes in task demands, stimulus properties, and population differences.

Novel Stimuli

No psychopathy-related ERP effects for processing novel stimuli were identified. Kiehl and colleagues (2006) have previously reported increased N2 for novel stimuli at midline electrode sites in two samples comparing psychopathic and non-psychopathic inmates. This report also noted topographical differences suggesting a reduced novelty P3 in one of two samples of psychopaths, which was limited to lateral electrode sites. Venables and Patrick (2014) reported reductions in novelty P3 amplitude; however, the novel stimuli in their task were emotional pictures, limiting the generalizability to a simple auditory oddball task. Brazil and colleagues (2012) reported small topographical differences in the novelty P3 between psychopathic and non-psychopathic inmates, but no overall amplitude differences related to psychopathy. Gao and colleagues (2011) also reported no amplitude differences between groups for novelty P3. Likewise, we found no psychopathy-related effects for novel stimuli. It may be sufficient to say that these effects for novel stimuli have not been universal, and thus additional focused investigation is merited.

Frequent Standard Stimuli

The current findings suggest that psychopathy scores are associated with reduced amplitude (less positive) in the late-slow wave components of the frequent standard condition, beginning around 400 ms post-stimulus, extending through 1000 ms. Previous research in psychopathy has not typically examined ERPs during the frequent standard condition of oddball tasks, yet the importance of this condition should not be overlooked. García-Larrea and colleagues (1992) demonstrated that despite the non-response imperative, frequent standards elicit task-dependent differences in the ERP waveforms conferring important information cognitive processes in an oddball task. Recent work demonstrates the importance of frequent standard stimuli for the process of context formation and expectancy in oddball paradigms (Stevens, Calhoun, & Kiehl, 2005). ERPs during these stimuli convey information about attentional resources being summoned in early evaluative processes for stimuli that do not require further action. As such, evaluation of frequent standards may be particularly important in psychopaths, whose attentional abnormalities are characterized by devoting fewer resources to stimuli that are not of immediate motivational significance (Jutai & Hare, 1983; Kosson & Newman, 1986; Newman, 1998). The late slow wave is associated with sustained evaluative processing following response selection (García-Larrea & Cézanne-Bert, 1998), which may be fundamentally limited among psychopaths.

Differences processing frequent standards have previously been studied in the context of other psychiatric disorders such as schizophrenia and in patients with brain lesions. Patients with temporo-parietal lesions have been found to exhibit reduced amplitude in late positive slow waves elicited by frequent standard stimuli in oddball tasks; this in addition to the familiar reduced target P3 amplitude (Verleger, Heide, Butt, & Kompf, 1994; Yamaguchi & Knight 1991), which we also report here. The relevance of temporal lobe dysfunction to psychopathy has a prominent standing in extant literature. In a thorough review, Kiehl (2006) argues that neuropsychological, ERP, and fMRI evidence converge to suggest that psychopathy-related brain dysfunction extends beyond primary limbic regions and includes cingulate and several temporal lobe structures. Notably, Kiehl suggests that many ERP abnormalities recognized in psychopaths are similar to those seen in patients with temporal lesions. Kiehl further notes a conspicuous trend in ERP studies of psychopathy noting that nearly every study of ERPs in a well-defined group of psychopaths has observed abnormal late ERP negativities in wide variety of tasks and contexts (see Forth and Hare, 1989; Kiehl, Hare, Liddle, et al., 1999; Kiehl, Hare, McDonald, & Brink, 1999; Kiehl et al., 2006; Williamson, Harpur, & Hare, 1999). The current findings are the first to suggest that abnormal late negativities in psychopathy are also apparent in the frequent standard condition of a simple oddball task.

Reduced amplitude in the frequent standard slow wave was apparent for PCL-R total score, both factor scores, and facets 1, 3, and 4 (*interpersonal, lifestyle, and antisocial behavior* respectively), suggesting broadly distributed associations with features of psychopathy. Previous research has indicated that psychopaths show abnormalities in processing the relevance of contextual stimuli and re-allocating attentional resources appropriately (e.g. Kosson & Newman, 1986; Newman et al. 2010; Zeier, Maxwell, & Newman, 2009). While the present finding is not specifically predicted by the Response Modulation theory, slow-

wave differences in ERPs during the frequent standard condition could prove an important neurophysiological representation of cognitive abnormalities recognized by the model. Together with other significant effects noted in this study, it is compelling to consider the heightened early attentional response (N1) and reduced longer latency responses (P3 and slow-wave) as representing strong early selection processes paired with diminished sustained elaborative processing in this simple attention-related task. This effect naturally deserves additional consideration in future investigations.

Limitations

The present findings carry certain limitations. First, this study examines a small sample with somewhat limited variation on certain relevant personality features. This is a strategic comparison examining variation specific to facets of psychopathy among those exhibiting serious antisocial behavior. A consequential limitation is that these data will not reveal effects otherwise apparent between incarcerated and non-incarcerated individuals. The value of this comparison is in limiting variation in associated factors such as substance abuse and dependence and antisocial behavior *per se*. This provides some valuable control, but also limits the generalizability. Future studies may gain unique insight by including non-incarcerated individuals for comparison. Another limitation stems from the nature of factor and facet scores on the PCL-R. While demonstrating increased specificity for certain ERP effects, factor and facet scores may suffer from limited reliability compared to PCL-R total scores due to the smaller number of items that comprise them. All else being equal, measures with increased reliability will produce more stable relationships with criterion variables. Finally, an additional limitation stems from the nature of ERP recordings, which provide superb temporal resolution for cognitive events but rather restricted spatial resolution. Several ERP components relevant to target detection are influenced by multiple neural generators. Indeed Kiehl and colleagues (2005) have described at least 38 brain regions engaged in oddball target detection. Furthermore, psychopathy has been associated with abnormalities in a number of distributed brain regions throughout the paralimbic system (Anderson & Kiehl, 2012; Kiehl, 2006). Event-related functional neuroimaging studies could help to specify a functional-anatomical basis for psychopathy-related abnormalities during oddball tasks.

Summary and Conclusions

Attention-related abnormalities in psychopathy have been well supported by behavioral evidence for decades; however, consistent neurophysiological accounts of these differences have been more elusive. The current study demonstrates an important replication of previously reported effects showing enlarged N1 and reduced P3 amplitude for target stimuli during a simple auditory oddball task in a sample of male inmates assessed for psychopathy using the PCL-R. In addition to extending these findings to the present four-facet model of psychopathy, data reveal a previously unreported reduction in amplitude during the late, slow components elicited by frequent standard stimuli. Together, these effects align with suggestions that psychopaths demonstrate enhanced early selective attention that is relatively less susceptible to adaptive interference by potentially salient features of the environment. Furthermore, reduced amplitude long latency components suggest fewer cognitive resources devoted to sustained elaborative processes in evaluating stimulus significance. We suspect

that the ERP effects recognized in frequent standard stimuli represent fundamental differences in the contextual representation of sequential stimuli. These differences could play a role in selection of salient features of the environment and may help to account for psychopaths' enigmatic attentional abnormalities.

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Figure 1.

Main effects (A): Grand averaged ERPs in the time domain for all subjects with target, novel, and frequent standard stimuli superimposed at midline electrode sites (Fz, Cz, Pz). (B). PCA decomposition showing 6 components (C) explaining 90.21% of variance, and the respective topographical distributions (D) of each component (head maps). Note: by convention, ERPs are shown with positive plotted down, negative plotted up.

Figure 2.

Average waveforms for standard stimuli (A) and target stimuli (D): Waveform differences (red and blue lines) represent upper and lower quartiles (17 high, 17 low) for scores on the interpersonal facet of the PCL-R (facet 1) for waveform representation only. PCA-derived components for standard stimuli (B) and target stimuli (E) showing differences related to the interpersonal facet of the PCL-R (facet 1). Headmaps (C, F) as well as analyses described in the text utilize continuous scores for all participants ($N=59$). Headmaps demonstrate the topographical distribution of significant effects. PC1: N1; PC2: Late slow wave; PC3: N2; PC4: Early slow wave; PC5: Late P3; PC6: Early P3.

Table 1

Descriptive Statistics and Independent Samples t-tests for Variables

Variable	All Participants (N= 59) Mean (SD)	PCL-R Lower Quartile (N = 17) Mean (SD)	PCL-R Upper Quartile (N = 17) Mean (SD)	t (32)	p
PCL-R Total	21.94 (7.38)	14.29 (3.69)	32.18 (3.76)	-14.00	<.01
PCL-R Factor 1	7.12 (3.88)	3.53 (1.12)	11.65 (2.34)	-8.12	<.01
PCL-R Factor 2	13.33 (4.01)	9.00 (3.12)	16.76 (2.31)	-7.76	<.01
PCL-R Facet 1	3.12 (2.38)	1.12 (1.45)	5.76 (1.68)	-4.65	<.01
PCL-R Facet 2	3.97 (2.19)	2.41 (1.62)	5.88 (1.36)	-3.47	<.01
PCL-R Facet 3	6.00 (2.08)	4.06 (1.60)	7.76 (1.39)	-3.71	<.01
PCL-R Facet 4	6.36 (2.88)	4.94 (2.56)	9.00 (1.50)	-4.06	<.01
Age	34.88 (10.06)	33.94 (10.03)	35.24 (10.23)	-0.37	.71
Education (years)	11.85 (1.69)	11.88 (1.32)	12.29 (2.05)	-0.70	.49
Number Sub. Dep.	2.14 (1.58)	2.12 (1.58)	2.00 (1.54)	0.22	.83
IQ	97.76 (14.89)	97.06 (15.49)	101.41 (14.29)	-0.85	.40
Target Accuracy	0.974 (.047)	0.978 (.051)	0.984 (.051)	-0.46	.65
Reaction Time (ms)	497.7 (83.11)	490.7 (84.19)	486.70 (85.88)	0.14	.89

Note. Assessments: PCL-R Total and Facet 1, 2, 3, and 4 scores were derived from the Psychopathy Checklist – Revised (PCL-R) (Hare, 2003); Intelligence Quotient (IQ) was calculated from the Wechsler Adult Intelligence Scale III (WAIS-III) (Wechsler, 1997); Number of Lifetime Substance Dependencies (Number Sub. Dep.) were calculated from the Structured Clinical Interview for DSM-IV Axis I Disorders – Patient Version (SCID I/P) (First, Spitzer, Gibbon, & Williams, 1995). ERP analyses were completed using PCL-R scores as continuous variables; for comparative purposes here, t-tests are based on upper and lower quartiles on PCL-R total score.

Table 2

Target Stimulus ERP Variation by Psychopathy Scores During Auditory Oddball Task

PCL-R Total Score			
Component	<i>F</i> statistic (1, 57)	<i>p</i> value	eta²
PC1 (N1)	5.20	.026	.084
PC2 (Late SW)	1.88	.175	.032
PC3 (N2)	<.01	.950	.000
PC4 (Early SW)	0.25	.622	.004
PC5 (Late P3)	0.09	.763	.002
PC6 (Early P3)	2.42	.126	.041
PCL-R Factor 1			
Component	<i>F</i> statistic (1, 57)	<i>p</i> value	eta²
PC1 (N1)	3.00	.089	.050
PC2 (Late SW)	0.29	.595	.005
PC3 (N2)	0.01	.922	.000
PC4 (Early SW)	0.02	.896	.000
PC5 (Late P3)	0.01	.935	.000
PC6 (Early P3)	1.96	.167	.033
PCL-R Factor 2			
Component	<i>F</i> statistic (1, 57)	<i>p</i> value	eta²
PC1 (N1)	3.97	.051	.065
PC2 (Late SW)	2.16	.147	.037
PC3 (N2)	0.02	.898	.000
PC4 (Early SW)	0.55	.463	.009
PC5 (Late P3)	0.14	.709	.002
PC6 (Early P3)	2.15	.148	.036
PCL-R Facet 1			
Component	<i>F</i> statistic (1, 57)	<i>p</i> value	eta²
PC1 (N1)	4.27	.043	.070
PC2 (Late SW)	1.04	.312	.018
PC3 (N2)	0.29	.595	.005
PC4 (Early SW)	0.04	.836	.001
PC5 (Late P3)	0.79	.378	.014
PC6 (Early P3)	6.18	.016	.098
PCL-R Facet 2			
Component	<i>F</i> statistic (1, 57)	<i>p</i> value	eta²
PC1 (N1)	0.69	.410	.012
PC2 (Late SW)	0.02	.897	.000
PC3 (N2)	0.57	.453	.010

PCL-R Total Score			
Component	<i>F</i> statistic (1, 57)	<i>p</i> value	eta²
PC4 (Early SW)	0.21	.648	.004
PC5 (Late P3)	1.25	.269	.021
PC6 (Early P3)	0.02	.898	.000
PCL-R Facet 3			
Component	<i>F</i> statistic (1, 57)	<i>p</i> value	eta²
PC1 (N1)	1.50	.226	.026
PC2 (Late SW)	2.14	.149	.036
PC3 (N2)	0.03	.867	.000
PC4 (Early SW)	1.37	.246	.024
PC5 (Late P3)	0.73	.396	.013
PC6 (Early P3)	1.55	.219	.026
PCL-R Facet4			
Component	<i>F</i> statistic (1, 57)	<i>p</i> value	eta²
PC1 (N1)	4.24	.044	.069
PC2 (Late SW)	1.15	.288	.020
PC3 (N2)	0.11	.741	.002
PC4 (Early SW)	0.04	.842	.001
PC5 (Late P3)	0.01	.917	.000
PC6 (Early P3)	1.53	.220	.026

Note: PCL-R total scores are comprised of four facet scores. Facet 1: Interpersonal, Facet 2: Affective, Facet 3: Lifestyle, Facet 4: Antisocial Behavior. PCs = Six principal components from PCA decomposition, with corresponding time-course-matched ERP (SW = slow wave). Statistical values are for the between-subjects effects (psychopathy scores) in a mixed-model ANOVA using 9 electrodes as a repeated measure.

Table 3

Frequent Standard Stimulus ERP Variation by Psychopathy Scores During Auditory Oddball Task

PCL-R Total Score			
Component	<i>F</i> statistic (1, 57)	<i>p</i> value	eta²
PC1 (N1)	1.33	.254	.023
PC2 (Late SW)	3.93	.052	.064
PC3 (N2)	0.20	.653	.004
PC4 (Early SW)	7.28	.009	.113
PC5 (Late P3)	1.05	.309	.018
PC6 (Early P3)	0.10	.758	.002
PCL-R Factor 1			
Component	<i>F</i> statistic (1, 57)	<i>p</i> value	eta²
PC1 (N1)	1.16	.287	.020
PC2 (Late SW)	3.01	.088	.050
PC3 (N2)	0.36	.549	.006
PC4 (Early SW)	5.22	.026	.084
PC5 (Late P3)	0.59	.446	.010
PC6 (Early P3)	<.01	.956	.000
PCL-R Factor 2			
Component	<i>F</i> statistic (1, 57)	<i>p</i> value	eta²
PC1 (N1)	0.91	.343	.016
PC2 (Late SW)	3.75	.058	.062
PC3 (N2)	<.01	.988	.000
PC4 (Early SW)	6.62	.013	.104
PC5 (Late P3)	1.00	.320	.017
PC6 (Early P3)	0.72	.406	.012
PCL-R Facet 1			
Component	<i>F</i> statistic (1, 57)	<i>p</i> value	eta²
PC1 (N1)	0.54	.466	.009
PC2 (Late SW)	5.15	.027	.083
PC3 (N2)	<.01	.962	.000
PC4 (Early SW)	7.40	.009	.115
PC5 (Late P3)	1.87	.177	.032
PC6 (Early P3)	0.15	.697	.003
PCL-R Facet 2			
Component	<i>F</i> statistic (1, 57)	<i>p</i> value	eta²
PC1 (N1)	1.22	.275	.021
PC2 (Late SW)	0.41	.526	.007
PC3 (N2)	1.04	.312	.018

PCL-R Total Score			
Component	<i>F</i> statistic (1, 57)	<i>p</i> value	eta²
PC4 (Early SW)	1.22	.274	.021
PC5 (Late P3)	0.01	.914	.000
PC6 (Early P3)	0.27	.602	.005
PCL-R Facet 3			
Component	<i>F</i> statistic (1, 57)	<i>p</i> value	eta ²
PC1 (N1)	.002	.969	.000
PC2 (Late SW)	2.90	.094	.048
PC3 (N2)	1.45	.234	.025
PC4 (Early SW)	5.13	.027	.083
PC5 (Late P3)	0.85	.361	.015
PC6 (Early P3)	0.03	.874	.000
PCL-R Facet4			
Component	<i>F</i> statistic (1, 57)	<i>p</i> value	eta ²
PC1 (N1)	2.29	.136	.039
PC2 (Late SW)	2.49	.120	.042
PC3 (N2)	0.96	.331	.017
PC4 (Early SW)	4.28	.043	.070
PC5 (Late P3)	0.63	.429	.011
PC6 (Early P3)	1.35	.251	.023

Note: PCL-R total scores are comprised of four facet scores. Facet 1: Interpersonal, Facet 2: Affective, Facet 3: Lifestyle, Facet 4: Antisocial Behavior. PCs = Six principal components from PCA decomposition, with corresponding time-course-matched ERP (SW = slow wave). Statistical values are for the between-subjects effects (psychopathy scores) in a mixed-model ANOVA using 9 electrodes as a repeated measure.