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Relation of frontal N100 to psychopathy-related differences in selective attention☆

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ABSTRACT

Research indicates that psychopathy may be characterized by early attentional abnormalities that undermine the processing of peripheral information during goal-directed activity (Baskin-Sommers & Newman, 2012). Past work has found that psychopathic individuals show reduced interference on the Box Stroop task, in which color names are spatially separated from (i.e., peripheral to) colored stimuli (Hiatt, Schmitt, & Newman, 2004). The present study sought to replicate and extend these findings. A priori predictions were that psychopathy scores would be inversely related to interference and that psychopathy-related differences in Box Stroop conflict processing would emerge at an early stage as measured by event-related potentials (ERP). Results supported both hypotheses. Moreover, the association between the early attention-related component (N100) and interference was moderated by level of psychopathy. These findings suggest that psychopathic individuals have less coordinated responses to conflict than healthy individuals, a conjecture that has implications for information integration and self-regulation.

1. Introduction

Psychopathy is a personality disorder characterized by a collection of emotional, interpersonal, and behavioral features that include shallow affect, egocentricity, exploitation, lack of remorse, and impulsivity, as well as antisocial conduct (American Psychiatric Association, 2000; Hare, 1996). Although they represent only 15–20% of criminal offenders (Glenn & Raine, 2008), psychopathic offenders commit a disproportionate percentage of crimes (Harris, Skilling, & Rice, 2001) and have high rates of violent recidivism (Viding, 2004). Given the social and financial costs of their crime (Hare, 2006; Hare & Neumann, 2009; Reid, 1998), it is imperative to clarify the psychobiological processes responsible for psychopathic offenders' failures to manage their behavior.

One perspective suggests that psychobiological abnormalities in information processing underlie psychopathy's association with chronic antisociality and self-regulatory deficits. More specifically, research indicates that psychopathy is characterized by abnormalities in selective attention, such that psychopaths fail to allocate attention to potentially important peripheral stimuli while engaged in goal-directed activity. Baskin-Sommers, Curtin, and Newman (2011) propose that these abnormalities reflect an early attention bottleneck that limits the processing of information unrelated to their mental set (see Baskin-Sommers & Newman, 2012; Leber & Egeth, 2006).

The early stages of information processing involve the simultaneous processing of sensory elements; these sensory representations are only available for retrieval for a short length of time. When an organism is engaged in goal-directed behavior, the first stage of processing is influenced by the behavioral relevance of stimuli. Zylberberg, Dehaene, Mindlin, and Sigman (2009) postulate, "the 'memory' of a stimulus resides in the decaying trace of a stimulus transient response" (p. 13). Memory representations that are not selected for higher-level processing in working memory quickly fade. For psychopathic individuals, the establishment of an information-processing bottleneck may guide attention to stimuli consistent with the mental set and consequently preclude the elaborated processing of information that is inconsistent with or peripheral to goal-related focus (Baskin-Sommers, Curtin, Li, & Newman, 2012; Baskin-Sommers et al., 2011). Consequently, this peripheral information may remain "preconscious", or perceived but not consciously processed due to inattention (Dehaene & Changeux, 2011). As a result, representations of peripheral information may not be strong enough to modulate ongoing goal-directed behavior.

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In fact, across experimental contexts psychopathic offenders display a pattern of selective attention, such that they fail to process peripheral information when their attention is already engaged in a goal-directed task. For instance, when non-psychopathic control participants engage in tasks involving low perceptual load (i.e., there are few distracter stimuli), they are more likely to experience distracter interference (Lavie & Tsal, 1994). However, the same distractors elicit less interference in psychopathic individuals (Sadeh & Verona, 2008). Moreover, psychopathic individuals display significantly less behavioral interference than controls when engaged in tasks containing incongruent contextual cues (see Newman, Brinkley, Lorenz, Hiatt, & MacCoon, 2007; Newman, Schmitt, & Voss, 1997; Zeier, Maxwell, & Newman, 2009). A handful of electrophysiological studies support the proposal that psychopathic individuals show reduced responses to contextual cues when these cues are not directly related to their goal-directed focus of attention. Moreover, they provide evidence for the early nature of these attentional abnormalities. Event-related potentials (ERPs) provide a high-resolution, temporally precise look at the earliest changes in visual processing associated with visual-spatial selective attention (Herrmann & Knight, 2001; Hillyard & Anllo-Vento, 1998). Jutai and Hare (1983) found that psychopathy was associated with reduced N100 amplitudes to task irrelevant tone pips while engaged in a selective attention task. Baskin-Sommers et al. (2012) demonstrated that psychopathic individuals were able to effectively ignore threat-related distractors (as indexed by larger P140) when they were peripheral versus central to their goal-directed behavior. The temporal nature of these waveforms is consistent with the notion that psychopathy is characterized by abnormalities early in the processing stream. The fact that they were modulated by attentional focus further supports the proposition that psychopathy is associated with anomalous early selective attention.

One paradigm that is well suited to examine abnormal processing of contextual cues is the "Box Stroop" task (Hiatt, Schmitt, & Newman, 2004). During this task, color names (green, red, blue, or yellow) are displayed in black ink and are surrounded by a green, red, blue, or yellow box. Participants are told to say the color of the box. Like the standard Stroop effect, congruent word name and box color typically facilitate color naming, while incongruent stimuli generally cause interference. The Box Stroop, however, provides a clearer test of psychopaths' early selective attention compared to the standard paradigm because incongruent information (i.e., the word names) is spatially separated from, and thus peripheral to, the predominant focus of attention (i.e., the box color). Specifically, the spatial division enables the sensory amplification and early selection of attended to-be-processed features (Hillyard, Vogel, & Luck, 1998). Accordingly, individuals high in psychopathy display normal interference in the traditional Stroop task, yet they exhibit significantly less interference on the Box Stroop than controls (Hiatt et al., 2004). This finding is consistent with the proposition that psychopathy is associated with abnormal attention processes. Thus, the Box Stroop represents a validated paradigm that yields psychopathy-related effects with conflict-laden stimuli. However, to date, there is no direct substantiation linking performance on this task to early attentional processes.

The goal of the current study is threefold. On the behavioral level, the current research seeks to replicate and extend Hiatt et al.'s (2004) findings of attentional abnormalities in psychopathic individuals. Specifically, we hypothesize that there will be a significant effect for psychopathy such that individuals high in psychopathy will show less interference than individuals with lower psychopathy scores (i.e., the difference between the time it takes for individuals high in psychopathy to respond to an incongruent trial compared to a neutral trial will be significantly less than for nonpsychopathic individuals).

The second goal of the study is to clarify the temporal profile of the hypothesized information processing abnormality. Specifically, we were interested in locating an ERP window that might be interpreted as a feed-forward processes related to early selective attention (i.e., within 200 ms of stimulus onset; Lamme & Roelfsema, 2000). Although past research is consistent with our proposal that the spatial separation of box and word stimuli enables early selection in psychopathic individuals, the behavioral evidence revealing reduced interference alone cannot specify the early versus late onset of psychopathy-related differences in performance. In this study, we use ERPs to explore the temporal dynamics of psychopathy-related effects in the Box Stroop. We predict that the ERPs to incongruent versus neutral stimuli in psychopathic individuals will differ from those in non-psychopathic individuals, and that these differences will be evident early in the information-processing stream.

The final goal of the study is to explore psychopathy-related differences in the association between ERP and interference data to determine whether the relationship between ERP amplitude and interference varies as a function of psychopathy. In light of postulated abnormalities in early selective attention, we predict that the association between behavior and ERP data will differ for high versus low psychopathic participants. This finding would support the idea that psychopathy is typified by abnormalities in early attention responses to goal-incongruent information.

2. Methods

2.1. Participants

Participants consisted of 117 Caucasian male inmates ages 18–45 (M = 30.44, SD = 6.70) from a medium-security prison in central Wisconsin. To be included in the study, participants had to be between 18 and 45 years old, free of history of psychosis or bipolar disorder, not currently taking psychotropic medication, and have an IQ score of 70 or greater. Individuals meeting the inclusion criteria were invited to participate in an ongoing study. All participants provided written informed consent according to procedures approved by the University of Wisconsin – Madison Human Subjects Committee. On the first day of the study, inmates were called to a private office and completed a semi-structured life history interview with an experienced interviewer. This interview included questions on childhood, education, and occupational, interpersonal, and legal histories. Following the interview, the interviewer reviewed the institutional file in order to corroborate information provided during the interview. The combination of interview and file information was used to rate psychopathy according to Hare's (2003) Psychopathy Checklist-Revised (PCL-R). Four participants were excluded from analyses due to less than 90% accuracy on the experimental task.

2.2. Psychopathy Checklist-Revised (PCL-R)

We assessed psychopathy using Hare's (2003) Psychopathy Checklist-Revised (PCL-R). The PCL-R consists of 20 items that are rated according to the degree to which a characteristic is present (significantly = 2, moderately = 1, not at all = 0). In the present sample, scores on this measure ranged from 5 to 36, with a mean of 23.14 (SD = 6.86). Interrater reliability (intraclass correlation) for PCL-R total score, based on six dual ratings, was .98.

2.3. Materials

2.3.1. Stimuli

Stimuli were 120 color words (*red*, *blue*, *green*, or *yellow*, written in black font) or neutral stimuli (string of the letter *i*) presented on a white background surrounded by a colored rectangular frame (red, blue, green, or yellow). The frames measured 2.3 by 3.2 cm. Word and neutral stimuli were presented centrally in the frames.

2.4. Experimental task

The task consisted of 40 practice trials and 120 experimental trials. For the first 20 practice trials, color words (*red*, *blue*, *green*, or *yellow*) written in black font were presented centrally on the computer screen and participants were instructed to read the words. For the remaining 20 practice trials, colored rectangular frames were presented on the screen and participants were instructed to name the color of the frame (red, blue, green, or yellow). Each experimental trial consisted of a simultaneously presented color word or neutral stimulus enclosed by a colored rectangular frame. Participants were told to name the color of the frame while ignoring all other information. There were a total of 40 congruent trials (color word matched the frame

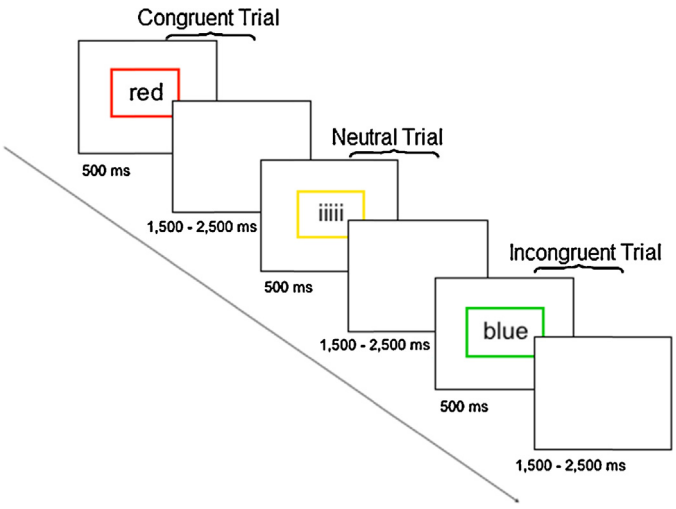

Fig. 1. Trial structure used in the experiment. At the onset of each trial, participants saw two stimuli: text (red, blue, yellow, green, or iiiii) and a colored rectangular frame (red, blue, yellow, or green). These stimuli were presented on the screen until the participant responded or 3 s had elapsed. During these trials, participants were told to name the color of the frame while ignoring all other information. Following the offset of the stimuli, a blank screen appeared.

color), 40 incongruent trials (color word differed from the frame color), and 40 neutral trials (iiiii surrounded by a frame color) (see Fig. 1). Trials were ordered such that no words or colors appeared twice in a row. Each stimulus appeared for a minimum of .5 s until the participant responded or 1.5 s had elapsed. The inter-trial interval ranged from 1.5 to 2.5 s. The 120 experimental trials were divided into two blocks (60 trials each) separated by a 30-s break.

Participants were instructed to state their responses as quickly and accurately as possible into a headset-mounted microphone. Reaction time (RT) for the onset of the verbal response was recorded automatically by a voice-activated relay device. The accuracy of the responses and the reaction times were assessed offline. Consistent with Hiatt et al. (2004), behavioral interference and facilitation scores were computed for each participant by subtracting RT on neutral trials from RT on incongruent trials and subtracting RT on congruent trials from RT on neutral trials, respectively.

2.5. Physiological recording and data reduction

Stimulus presentation and response collection were controlled by a PC-based MATLAB (The Mathworks) script and Neuroscan Synamps amplifiers and acquisition software (Compumedics, North Carolina). EEG was recorded at a 2500-Hz sampling rate from Ag–AgCl electrodes mounted in an elastic cap (Electro Cap International) along the midline (Fz, FCz, Cz, and Pz) and referenced to the left mastoid. EEG data were corrected for ocular artifacts from electrodes positioned to detect vertical electrooculogram (VEOG). The electrode impedance for all channels was kept below 10 kΩ. Data were further processed offline using the PhysBox plugin (Curtin, 2011) within the EEGLab toolbox (Delorme & Makeig, 2004) in MATLAB. Offline processing included low-pass filtering (4th-order, 20-Hz Butterworth low-pass filter), epoching (−500 to 1200 ms epochs), baseline correction, and artifact rejection (rejection of trials with voltages exceeding ±75 μV).

Given our prediction that the reduced interference response of psychopathic individuals is associated with abnormalities in early selective attention, a primary goal of this investigation was to find the earliest reliable component that tracked the condition manipulation (i.e., trial type) to assess whether there were psychopathy-related differences in the magnitude of this component. Visual inspection of the grand-averaged ERP data revealed that the earliest component on this task was a negative potential that peak around 100 ms post-stimulus onset (Fig. 2). The magnitude of N100 was measured as the peak amplitude value in 90 ms to 185 ms post-stimulus-presentation window.

Waveforms were averaged separately for correct trials within each trial type (congruent, incongruent, neutral). Participants were excluded from analyses if they had fewer than 25 out of 40 valid trials in each condition. After data processing (e.g., controlling for electrical noise and excluding trials with significant artifact [±75 μV]), we eliminated 26 participants with fewer than 80% valid trials remaining from the ERP analyses. The final sample for the ERP analyses was 91.

2.6. Data analysis

The goal of the analyses was threefold. To address the first hypothesis, we used regression to examine behavioral interference as a function of psychopathy using mean-centered PCL-R total scores. To address our second hypothesis that psychopathy is associated with early ERP differences, we computed difference scores for the N100 components at each of the four electrode sites by subtracting ERP amplitudes on neutral trials from those on incongruent trials. This variable represents a physiological response to incongruent versus neutral stimulus presentations. Given that N100 is a waveform of negative polarity, the larger (i.e., more positive) the difference score the smaller the ERP magnitude to incongruent versus neutral trials. These difference scores were analyzed using a general linear model (GLM), with scalp site (Fz, FCz, Cz, Pz) as a repeated measure and mean-centered PCL-R scores as a continuously distributed between-subject factor. The final set of analyses explored the relationship among behavioral interference, psychopathy total score, and the psychophysiological indices. To protect against violations of the assumption of sphericity, Greenhouse–Geisser corrected *p*-values are reported. Additionally, partial eta squared values are included as measures of effect size.

3. Results

3.1. Behavioral analyses

Consistent with Hiatt et al.'s (2004) findings, the analysis revealed a significant main effect of psychopathy, such that higher PCL-R ratings were associated with less behavioral interference, $F(1, 115) = 6.97$, $p = .01$, $\eta_p^2 = .06$ ($r = -.24$). Also consistent with the findings of Hiatt and colleagues, there was no significant relationship between psychopathy level and behavioral facilitation, $F(1, 115) = .14$, $p = .71$, $\eta_p^2 < .01$. Mean reaction times and ERP amplitudes, as well as estimated mean values for individuals high and low in psychopathy, for incongruent and neutral trials are presented in Table 1, while Table 2 provides the inter-correlations among the study variables.[1,2]

3.2. Psychophysiological analyses

For the following sets of analyses involving the scalp site measure, Mauchly's test indicated that sphericity had been violated ($\chi^2 = 131.01$, $p < .001$ and $\chi^2 = 107.38$, $p < .001$). Accordingly, degrees of freedom are adjusted using the Greenhouse–Geisser correction in all analyses involving this repeated variable.

There was no main effect of scalp site on N100, $F(1.61, 137.03) = .05$, $p = .92$, $\eta_p^2 < .01$. There was also no significant main effect of psychopathy on N100 difference score when collapsing across scalp-site, $F(1, 85) = .95$, $p = .33$, $\eta_p^2 = .01$. There was, however, a significant two-way interaction between scalp site and PCL-R score, $F(1.61, 137.03) = 4.56$, $p < .01$, $\eta_p^2 = .05$. Due to the lack of a priori hypotheses regarding scalp site, we unpacked this omnibus interaction by examining the simple effects of psychopathy on the N100 difference score at each scalp site. These tests revealed that psychopathy was positively associated with the N100 difference score at Fz ($B = .07$, $p = .05$, $r = .22$), but not at the remaining scalp sites, FCz: $B = .04$, $p = .22$; Cz: $B = .02$, $p = .61$; Pz: $B = -.01$, $p = .62$. More specifically, as scores on psychopathy increased the magnitude of frontal N100 amplitude to incongruent versus neutral stimuli decreased (see Fig. 3 for the grand-averaged

[1] One of the primary research questions in the study conducted by Hiatt et al. (2004) involved the interactive effect of psychopathy and anxiety on Box Stroop task performance. They found both a main effect of psychopathy on interference levels as well as a psychopathy by anxiety interaction on interference such that low-anxious psychopathic participants demonstrated significantly less interference than their high-anxious counterparts. Given the specificity of Hiatt et al.'s (2004) anxiety-related finding, we tested the interactive effect of psychopathy score and Welsh anxiety score on behavioral interference. Results were non-significant, supporting the a priori prediction of a simple main effect of psychopathy score on interference.

[2] Although a priori hypotheses focused on behavioral interference, we also examined accuracy. First, there were relatively few errors and relatively little variability in accuracy. Second, we observed no psychopathy-related differences in accuracy. Third, controlling for accuracy did not alter the relationship between psychopathy (the independent variable) and behavioral interference (the dependent variable). Thus, we focused the remainder of our analysis on reaction time.

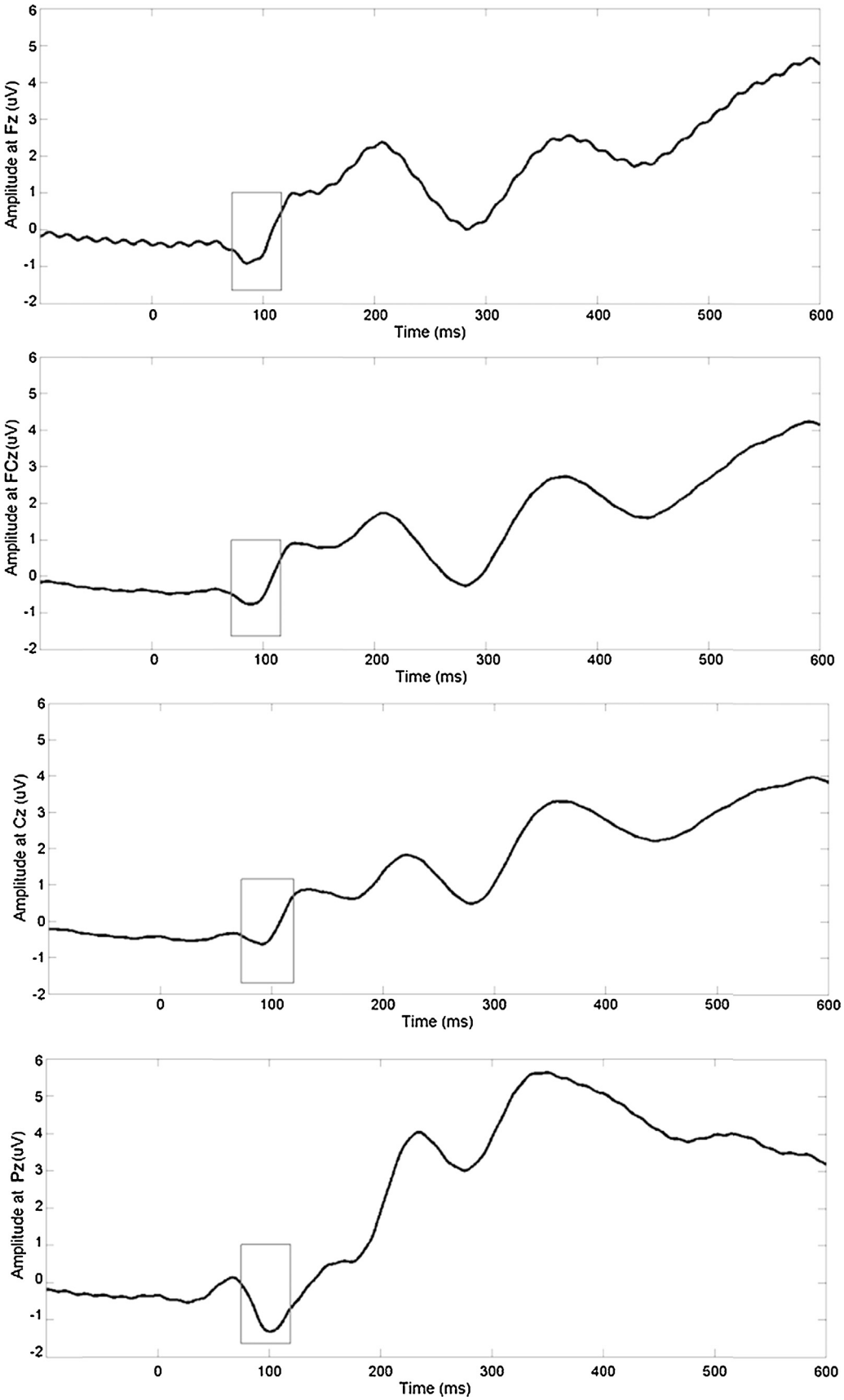

Fig. 2. Grand average waveforms across scalp sites (Fz, FCz, Cz, and Pz). Stimulus-locked average ERP waveforms for all participants at midline electrode sites. A digital low-pass filter was applied offline before plotting the waveforms shown here. The boxes represent the peak identified as N100.

Table 1
Mean RT and ERP amplitude values to incongruent and neutral trials by scalp site.

	Condition mean		High psychopathy		Low psychopathy	
	Incongruent	Neutral	Incongruent	Neutral	Incongruent	Neutral
RT	668 (9.76)	585 (6.72)	639 (14)	573 (10)	681 (14)	587 (10)
N100 Fz	−1.27 (.20)	−1.62 (.22)	−.84 (.28)	−1.64 (.31)	−1.70 (.28)	−1.60 (.31)
N100 FCz	−1.14 (.20)	−1.50 (.22)	−.80 (.29)	−1.43 (.32)	−1.49 (.29)	−1.57 (.32)
N100 Cz	−1.05 (.20)	−1.41 (.21)	−.78 (.28)	−1.24 (.30)	−1.33 (.29)	−1.58 (.30)
N100 Pz	−1.85 (.28)	−2.16 (.29)	−2.08 (.39)	−2.29 (.42)	−1.62 (.40)	−2.02 (.42)

Note: Psychopathy scores were obtained using the Psychopathy Checklist-Revised (PCL-R; Hare, 2003). Since we analyzed psychopathy continuously rather than using an extreme-group design, the values presented are point estimates (i.e., estimated using regression analyses) for low and high psychopathy points (1 *SD* below and above the sample mean PCL-R total score, respectively) on the distribution. Numbers in parentheses are standard errors. N100 Fz: N100 amplitude at Fz; N100 FCz: N100 amplitude at FCz; N100 Cz: N100 amplitude at Cz; N100 Pz: N100 amplitude at Pz.

Table 2
Bivariate correlations (*r* values) between PCL-R score, behavioral interference, and ERP amplitudes at Fz and Pz.

	PCL-R	Int	Acc	N100i Fz	N100n Fz	N100i Pz	N100n Pz
PCL-R	–						
Int	−.24*	–					
Acc	.16	−.05	–				
N100i Fz	.23*	−.07	.14	–			
N100n Fz	−.01	−.14	.13	.42**	–		
N100i Pz	−.09	.09	−.03	.42**	.19	–	
N100n Pz	−.05	−.04	−.10	.21	.31**	.78**	–

Note. PCL-R = PCL-R total score; Int = behavioral interference (incongruent RT minus neutral RT); Acc = accuracy; N100i Fz = N100 to incongruent trials at Fz; N100n Fz = N100 to neutral trials at Fz; N100i Pz = N100 to incongruent trials at Pz; N100n Pz = N100 to neutral trials at Pz.
* $p < .05$.
** $p < .01$.

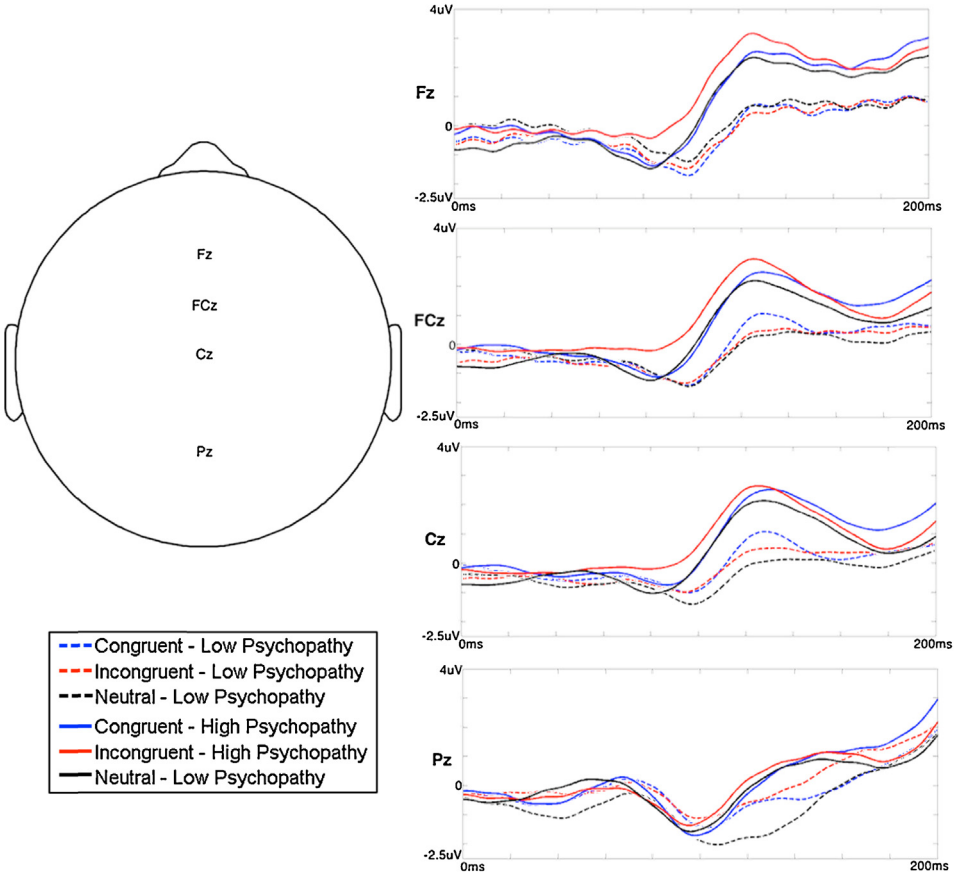

Fig. 3. N100 waveforms by trial type for individuals with low and high psychopathy scores. The grand averages represent waveforms averaged across participants with PCL-R scores 1 standard deviation or more below the mean (low psychopathy group) and 1 standard deviation or more above the mean (high psychopathy group).

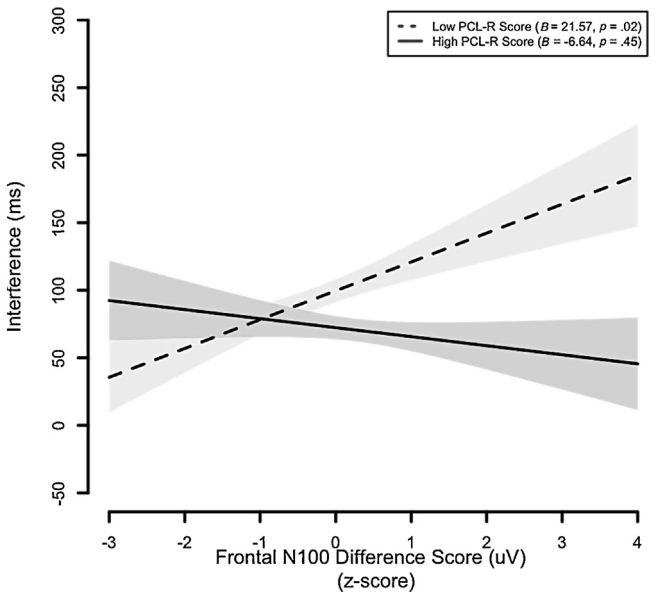

Fig. 4. Interference as a function of frontal N100 difference score (Incongruent Fz N100 amplitude – Neutral Fz N100 amplitude) and psychopathy (±1 *SD* from the mean). Point estimates representing the average PCL-R score plus or minus 1 standard deviation were used to compute the effect of N100 difference score on interference by psychopathy level. This figure was generated using the R statistics and graphics program.

N100 waveforms by trial type for individuals with low and high PCL-R scores).[3]

3.3. Relationship between psychophysiology and behavior

An underlying premise of this study is that individuals high in psychopathy process peripheral information differently than those low in psychopathy. Accordingly, psychophysiological processes may operate differently for individuals high and low in psychopathy and the association between frontal N100 difference score and behavioral interference may vary by level of psychopathy. To clarify the relationship among these variables, we used GLM to analyze the effects of frontal N100 difference score (standardized), PCL-R score (mean-centered), and their interaction, on the dependent variable of interest, interference. The effect of frontal N100 difference score on interference was non-significant ($F(1, 85) = .43$, $p = .49$, $\eta_p^2 = .01$), suggesting that across the entire sample frontal N100 difference score was not predictive of behavioral interference. As noted above, there was a main effect of psychopathy ($F(1, 83) = 5.08$, $p = .03$, $\eta_p^2 = .06$, $B = -.03$), such that higher psychopathy scores were associated with less interference. However, this effect was qualified by a significant frontal N100 difference score by psychopathy interaction, $F(1, 83) = 4.84$, $p = .03$, $\eta_p^2 = .06$. Results revealed that the relationship between frontal N100 difference score and interference was moderated by level of psychopathy (see Fig. 4). Whereas the magnitude of frontal N100 difference was significantly and positively related to interference among participants with low psychopathy scores ($B = 21.57$, $p = .02$), this frontal N100 difference was unrelated to interference in high scorers ($B = -6.64$, $p = .45$).

[3] To ensure that the effects of interest were not confounded by intelligence (computed based on scores on the vocabulary and matrix reasoning subtests of the Wechsler Adult Intelligence Scale (WAIS)), age, or education, we re-ran analyses with these variables as covariates. None of these variables had a significant effect on the behavioral or psychophysiological results.

3.4. Supplemental analyses

3.4.1. Total Stroop effect

The primary aim of the investigation was to replicate the findings of Hiatt et al. (2004), who focused their analyses on the interference difference score (incongruent minus neutral reaction times). However, we also computed the Total Stroop Effect (TSE; see Brown, Gore, & Pearson, 1998). This variable is defined as the difference in color-naming performance between incongruent and congruent stimuli. Better performance with congruent than with incongruent stimuli indicates that participants were less able to focus on naming the color than reading the word in the context of a task-incongruent word relative to a congruent word (see Donohue, Appelbaum, Park, Roberts, & Woldoroff, 2013).

3.4.2. Behavior

Using regression, we examined TSE as a function of psychopathy (i.e., mean-centered PCL-R total scores). The analysis revealed a significant main effect of psychopathy on TSE such that higher PCL-R ratings were negatively associated with the magnitude of the TSE, $F(1, 115) = 5.45$, $p = .02$, $\eta_p^2 = .05$ ($r = -.21$).

3.4.3. Psychophysiology

To assess the effect of psychopathy on psychophysiological correlates of the TSE, we computed N100 difference scores analogous to the TSE variable (abbreviated N100 TSE). Specifically, we subtracted the N100 amplitude on congruent trials from the N100 amplitude on incongruent trials for each of the four scalp sites. We entered these variables in a GLM as repeated measures with scalp site as a within subjects categorical factor and PCL-R total score (mean-centered) as a between-subjects continuous factor. There was no main effect of scalp site on N100 TSE ($F(1.70, 146.05) = .40$, $p = .64$, $\eta_p^2 < .01$) nor main effect of psychopathy on N100 TSE, $F(1, 85) = .65$, $p = .42$, $\eta_p^2 = .01$. There was also no significant interaction between scalp site and psychopathy score on N100 TSE, $F(1.70, 144.19) = .14$, $p = .84$, $\eta_p^2 < .01$.

3.4.4. Two-factor model of psychopathy

The primary goals of this study were to replicate and extend Hiatt et al.'s (2004) findings regarding PCL-R total scores. However, some researchers advocate decomposing psychopathy into two factors (Factor 1: Interpersonal/Affective; Factor 2: Impulsive/Antisocial) in order to examine the unique effects of these dimensions (Patrick, 2007). Accordingly, supplemental analyses were conducted to examine the effects of PCL-R Factors 1 and 2, rather than PCL-R total score, on behavioral interference and N100 difference score at Fz. These factors were mean-centered and entered simultaneously into regression models to quantify the unique effects of these constituents.

3.4.5. Interference

Analyzing behavioral interference within the two-factor framework demonstrated that the unique variance associated with Factor 1 was predictive of interference ($F(1, 114) = 4.81$, $p = .03$, $\eta_p^2 = .04$), while the unique effect of Factor 2 was non-significant, $F(1, 114) = .14$, $p = .71$, $\eta_p^2 < .01$. Individuals with high scores on Factor 1 displayed significantly less interference than individuals with low Factor 1 scores.

3.4.6. Psychophysiology

Paralleling the effect for PCL-R total scores, analysis of the frontal (Fz) N100 difference scores revealed a trend-level association of Factor 1, $F(1,84) = 3.36$, $p = .07$, $\eta_p^2 = .04$, $B = .07$. The relationship between Factor 2 and N100 difference score was non-significant, $F(1,84) = .00$, $p = .99$, $\eta_p^2 < .01$.

4. Discussion

Psychopathic individuals fail to process all relevant information during goal-directed behavior, purportedly due to irregularities in early selective attention (Newman & Baskin-Sommers, 2011). The current study provides three key lines of evidence for the hypothesis that psychopathy is characterized by attention-related abnormalities that emerge early in the information processing stream. First, it demonstrates that higher levels of psychopathy are associated with reduced behavioral interference in the Box Stroop paradigm, a result that replicates Hiatt et al.'s (2004) finding. This finding supports the notion that psychopathy is characterized by abnormal information processing of goal-incongruent information.

Second, the results provide psychophysiological evidence that psychopathy-related differences on the Box Stroop task are apparent during the early stages of information processing. Specifically, our results for N100 recorded from the Fz electrode site demonstrated that individuals with higher PCL-R scores displayed smaller N100 responses to incongruent versus neutral stimuli. The fact that individuals high and low in psychopathy displayed differential cascades of information processing within approximately 100 ms of stimulus presentation is consistent with previous findings of early, psychopathy-related differences in information processing differences reported by Sadeh and Verona (2012), Baskin-Sommers et al. (2012), and Veit et al. (2013). While these earlier studies found psychopathy-related differences in early ERPs in the context of affective stimulus processing, the present study complements these findings by demonstrating similar results in the context of a non-affective task containing incongruent information. The similarities between the results suggest that a comparable underlying process, such as reflexive orienting to salient stimuli, may account for these psychophysiological abnormalities (see Moul, Killcross, & Dadds, 2012; Yantis & Jonides, 1990).

The third line of evidence for psychopathy-related differences in the processing of peripheral information concerns the relationship between the early psychophysiological differences and behavioral interference. As hypothesized, analysis of the association between frontal N100 difference score and interference across psychopathy levels revealed that highly psychopathic individuals do not exhibit the same relationship between N100 difference score and interference as individuals low in psychopathy. Specifically, for individuals with low PCL-R scores, there was a positive relationship between frontal N100 difference score and interference, such that larger N100 amplitudes to incongruent relative to neutral trials were associated with more behavioral interference; this relationship was virtually absent in high psychopathy individuals.

Given the pattern of this finding and previous research, we presume the relationships between frontal N100 difference score and interference in individuals low in psychopathy reflects normal information processing. In past work, researchers have linked the N100 component to early attentional engagement and orienting (see Esposito, Mulert, & Goebel, 2009; Mangun & Hillyard, 1991; Vogel & Luck, 2000; Zani & Proverbio, 2006). Moreover, smaller N100 amplitude may represent a failure to "gate in" sensory information, whereas larger N100 responses reflect attentional allocation to this information (Brenner et al., 2009; Lijffijt et al., 2009). The positive relationship between interference and relatively larger incongruent N100 amplitude seen in low PCL-R scorers suggests that, among these individuals, larger N100 amplitudes reflect increased attentional allocation to incongruent information.

For individuals with high PCL-R scores, there was no relationship between the N100 difference score and interference. Although the absence of a direct relationship between the ERP data and interference among psychopathic individuals prohibits any definitive statement regarding the connection between brain and behavior, the significant interaction demonstrating that psychopathy moderates the association between frontal N100 and interference provides evidence that highly psychopathic individuals do not process conflict in the same manner as non-psychopathic individuals. Moreover, this difference is apparent within 100 ms of display onset. As such, it may be that the lack of a relationship between psychophysiological and behavioral measures is quite meaningful and indicates a unique pattern of processing among psychopathic individuals.

More specifically, the reduced frontal N100 response to incongruent versus neutral trials may reflect a failure to allocate attention to salient information (see Moul et al., 2012). According to the Differential Amygdala Activation Model (DAAM), psychopathy may be characterized by basolateral amygdala (BLA) under-activation and central amygdala (CeA) over-activation. The BLA integrally mediates endogenous gaze shifting, and a relative imbalance of amygdala-based processes may disrupt the ability to reflexively shift attention to process peripheral bottom-up stimuli. Within the context of the current study, a failure to shift attention to the salient peripheral information (i.e., the color word) would enable psychopathic individuals to experience less conflict, thus resulting in decreased behavioral interference. It would not, however, necessarily eliminate the facilitation effect, since semantic facilitation is a highly automatized process (see Balota, Yap, & Cortese, 2006).

One potential issue with the aforementioned interpretation is that it suggests a direct relationship between the N100 difference score and behavioral interference; however, no such relationship was found. An alternative, but not mutually exclusive, interpretation is that psychopathy may be characterized by a deficiency in integrative processes. There is increasing evidence of psychopathy-related variation in neural connectivity between regions such as the amygdala and prefrontal cortex (Craig et al., 2009; Glenn & Raine, 2008; Koenigs, Baskin-Sommers, Zeier, & Newman, 2011; Motzkin, Newman, Kiehl, & Koenigs, 2011) and the insula and anterior cingulate cortex (Ly et al., 2012). Recently, researchers have speculated that reduced neural connectivity may be associated with less integrative processing of multi-component information (Hamilton, Racer, Wolf, & Newman, 2014). In psychopathy, abnormal patterns of connectivity may create a context whereby early brain responses are dissociated from later behavioral reactions. With regard to the current study, lack of behavioral interference and smaller frontal N100 are both indicative of weaker conflict registration in psychopathic individuals, yet their lack of association may reflect a more general problem integrating the products of multi-component processing. Thus, abnormalities in neural connectivity may account for the psychopathy-related differences present in the presented results.

4.1. Supplemental analyses

Supplemental analyses revealed a negative association between psychopathy score and Total Stroop Effect (TSE). Within the context of the current task, a low TSE reflects similar reaction times to incongruent and congruent stimuli and is the sum of facilitation and interference effects. Typically, interference effects are greater than facilitation effects (MacLeod, 1991). Within the context of the current task, better (i.e., fast) performance in the incongruent condition manifests as a lower TSE. A low TSE suggests that a participant is able to pay attention to the box color despite the presence of conflicting information (see Donohue et al., 2013). The negative relationship between PCL-R total score and TSE, therefore, is consistent with the supposition that psychopathic individuals have anomalous selective attention.

While there was a significant relationship between psychopathy and the behavioral TSE score, there were no significant associations between PCL-R score and N100 TSE. Although on the surface this result may seem contradictory, it likely can be understood

as a consequence of stimulus content. Specifically, one key difference between the congruent and neutral conditions (i.e., the control conditions used in the two different interference measures) is the presence of semantic content; congruent trials merit linguistic processing, whereas neutral trials do not. Given that both congruent and incongruent trials have meaningful semantic content, these trial types likely activate brain processes that are uninvolved in the neutral trials. The N100 amplitude differences in the incongruent versus neutral trials may thus relate to differences in the demand for semantic processing, with higher demand in the incongruent trials relative to the neutral trials. Accordingly, the psychopathy-related differences seen in the N100 difference scores (reflecting the discrepancy between incongruent and neutral trials) might relate to depth of semantic processing. Since the N100 TSE difference score relates to two trial types that involve semantic processing (i.e., incongruent and congruent), this variable would not show this difference in depth of processing. Consequently, at the brain level, psychopathy-related differences in semantic processing would manifest in the N100 difference score but not the N100 TSE score. The presence of the behavioral TSE effect may relate to the relative automaticity associated with semantic facilitation versus interference (see Balota et al., 2006).

In addition to analyzing the effects of psychopathy on ERPs and Box Stroop performance, we also examined the effects of the major PCL-R factors in order to clarify the psychopathy effects. Like the PCL-R total score, high Factor 1 scores were associated low levels of interference. Moreover, there was a positive trend-level association between Factor 1 and small frontal N100 difference scores. No brain or behavior differences were found for Factor 2. This link between Factor 1 scores and reduced interference is consistent with recent findings linking Factor 1 to superior selective attention (e.g., Baskin-Sommers, Zeier, & Newman, 2009; Dvorak-Bertsch, Curtin, Rubinstein, & Newman, 2009; Ishikawa, Raine, Lencz, Bihrle, & Lacasse, 2001; Racer et al., 2011). Moreover, the fact that the interference and N100 difference score effects found in this study are more closely related to the unique variance of Factor 1 versus Factor 2 suggests that they may be relevant for understanding the interpersonal and affective components of psychopathy. It additionally suggests that although Factor 1 is traditionally conceptualized as an affective-interpersonal deficit, it might be associated with broader information processing abnormalities that affect fear conditioning and associative learning (see Moul et al., 2012). The fact that the affective-interpersonal dimension of psychopathy was related to a lack of association between behavioral interference and psychophysiological correlates of attention alternatively suggests that a deficit in integrative processing may contribute to the expression of the affective and interpersonal symptoms of psychopathy as well as to their impulsive and antisocial symptoms (see Baskin-Sommers et al., 2012, 2011).

4.2. Limitations

A notable strength of this investigation was the inclusion of psychophysiological measures to clarify the timing of attention effects associated with psychopathy-related differences on the processing of peripheral conflict information. However, the novelty of this application of psychophysiological techniques to the Box Stroop task creates problems of interpretation. In the absence of a substantial literature clarifying the meaning of the ERP components during performance on the Box Stroop task, interpretation of such results is necessarily ambiguous. Furthermore, it is not possible to ascertain whether participants were focusing on the color word or the rectangular frame. Nevertheless, one of the primary goals of this investigation was to examine the earliest observable waveform regardless of specific theoretical connotations. The fact that nonpsychopathic participants showed an association between their ERP responses and task performance suggests that the frontal N100 waveform is sensitive to peripheral conflict processing in these individuals. Future research is needed to address these concerns and allow for more confident interpretation of the abnormal selective attention displayed by psychopathic individuals on Box Stroop and other conflict-related tasks (see Wolf et al., 2012; Zeier et al., 2009; Zeier & Newman, 2013).

Potential concerns about the current investigation relate to minor analytical differences from Hiatt et al.'s (2004) study. Whereas Hiatt and colleagues evaluated this hypothesis using an extreme group approach, the current study employs dimensional analyses. Additionally, one of Hiatt et al.'s research questions centered on the interaction between psychopathy and anxiety, whereas the current study did not emphasize this variable. With regard to the analytic strategy, continuous analyses increase statistical power and preclude variability from being subsumed by categorization (Altman & Royston, 2006). The presented analyses do not focus on anxiety because Hiatt et al. observed less interference in psychopathic participants regardless of their level of anxiety (i.e., not just among primary psychopaths). Our different focus emphasizes our efforts to conceptually replicate Hiatt et al.'s finding. In other words, we aimed to show the generality of the replication to demonstrate the robustness of the effect. Lastly, other than employing psychophysiological procedures (e.g., having participants wear an EEG cap), the methods between the two studies remained identical.

A final limitation of the current study relates to the exclusion of non-Caucasian inmates. Although this exclusion limits the generalizability of the findings, previous research suggests that non-Caucasian participants generally do not demonstrate similar laboratory correlates of psychopathy as Caucasian psychopathic individuals. In other words, the information processing deficiencies found in Caucasian psychopathic individuals do not appear to generalize to all racial groups (Baskin-Sommers, Newman, Sathasivam, & Curtin, 2010; Kosson, Smith, & Newman, 1990; Lorenz & Newman, 2002; Sullivan & Kosson, 2006; Thornquist & Zuckerman, 1995). Future research should explore difference and similarities between psychophysiological correlates of selective attention in psychopathic individuals as a function of race.

4.3. Conclusion

On the whole, the present experiment contributes to the growing body of research demonstrating that psychopathy is characterized by abnormalities in the early stages of information processing as indexed by ERPs. The lack of relationship between early neural responses and behavioral responses seen in psychopaths suggests that individuals with and without psychopathy cannot be equated on a single metric for task performance or neurobiological responses. More specifically, it suggests that individuals with psychopathy process information differently and their cognitive processes cannot be understood under the same framework as healthy individuals (e.g., Glenn, Raine, Schug, Young, & Hauser, 2009; Kiehl, 2006).

Modern models of self-regulation emphasize the crucial role of attention in determining what information is passed on for further processing or gated out of awareness (see Baumeister & Vohs, 2011; Kaplan & Berman, 2010). With regard to psychopathology, many individuals have difficulty suppressing stimulus-driven attention to salient cues, a bias that interferes with goal-directed behavior and social adjustment more generally (see MacCoon, Wallace, & Newman, 2004). Psychopathy appears to be characterized by an attentional bottleneck that, once established, hinders the processing of information that is peripheral to the current attentional focus. In other words, once a goal-related cue captures the attention of individuals with psychopathy, these

individuals have difficulty reorienting to subsequent information that is inconsistent with or unrelated to their attentional set. Failure to rapidly integrate multiple streams of information, in turn, may undermine processing of motivationally salient cues that contraindicate goal-directed behavior and trigger the suspension of ongoing approach behavior (see Patterson & Newman, 1993; Vuilleumier & Driver, 2007); these processes are the cornerstones of adaptive self-regulation. Ultimately, a better understanding of psychopaths' information processing deficits can aid in the formation of interventions, enhance self-regulation, and reduce recidivism in psychopathic offenders.

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