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Psychopathy and semantic processing: An examination of the N400

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Abstract

Accumulating evidence suggests that psychopathy is associated with behavioral and event-related potential (ERP) abnormalities during semantic language tasks. Psychopaths' ERP abnormalities are most prominent in the 300–500 ms post-stimulus time window. It is unclear whether these ERP differences are related to neurocognitive processes associated with the P300 (i.e., poor attention/orienting/working memory) or N400 (i.e., aberrant semantic processes). To address this issue, the present study employed a canonical semantic sentence processing paradigm known to selectively elicit the N400. Fifty incarcerated participants were divided into psychopathic ($n = 25$) or nonpsychopathic ($n = 25$) groups based on scores from the Hare Psychopathy Checklist-Revised. The N400 and P600 components elicited by terminal words of sentences either congruent or incongruent with the previous sentence context were examined. No differences were observed between groups in the behavioral or ERP data. These data do not support the hypothesis that the semantic processes, and underlying neural systems, associated with the generation of the N400 during sentence processing tasks are abnormal in psychopathy.

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1. Introduction

Clinicians have noted that the behavior of psychopathic individuals is often strikingly inconsistent with their verbalized reports (Cleckley, 1976; Flor-Henry, 1972; McCord & McCord, 1964). This observation led some clinicians and researchers to speculate that psychopathy may be associated with abnormalities in language processing (Flor-Henry, 1972). Subsequent studies have found that abnormalities in language processes are most prevalent when psychopathic individuals perform tasks that engage semantic processing (Hare, 1979; Hare & Forth, 1985; Hare & McPherson, 1984). For example, Kiehl, Hare, McDonald, and Brink (1999a) tested the hypothesis that psychopathy is associated with language abnormalities during semantic processing of abstract word stimuli. Consistent with predictions, psychopaths made more errors than did nonpsychopaths when having to classify word stimuli as abstract during a concrete/abstract discrimination task. Event-related potential (ERP) data were also recorded and it was observed that psychopathic individuals failed to show the normal electrocortical differentiation between concrete and abstract words (Tasks 1 and 2 in their study). In noncriminals and in criminal nonpsychopathic individuals, concrete words elicit greater ERP negativity in the 300–800 ms window than do abstract words (Kiehl et al., 1999a; Kounios & Holcomb, 1994; Paller, Kutas, Shimamura, & Squire, 1987). Given that the ERP differentiation between concrete and abstract words appears to be most robust 300–500 ms post-stimulus, it has been argued that this effect is due to modulation of the semantic generators believed to contribute to the N400 potential typically observed in semantic word and sentence processing tasks (Kutas & Hillyard, 1980c, 1983, 1984). One hypothesis about the functional significance of the N400 suggests that it may reflect processes related to the integration of a word into ongoing cognitive context (Holcomb, 1993). Using this interpretation, Kiehl et al. (1999a) suggested that psychopaths may differ from others in the process responsible for N400 generation.

Several additional studies have reported that long-latency ERPs (later than 300 ms) are different in psychopaths than in nonpsychopaths, especially during tasks that present language stimuli in the visual modality. Psychopaths consistently show a large frontally distributed negative wave with a latency of approximately 500 ms to word stimuli. Williamson, Harpur, and Hare (1991) reported that psychopaths exhibited a larger fronto-central N500 to word stimuli during a lexical decision task than did nonpsychopaths. Kiehl et al. (1999a) reported that psychopaths exhibited a large centro-frontal negative wave with latency of about 350 ms during three different language tasks. While both Williamson et al. (1991) and Kiehl et al. (1999a) employed tasks that demanded linguistic processing of different word types, the late negative wave in both studies was elicited for all word types (i.e., positive, negative, and neutral words in Williamson et al., 1991); concrete and abstract words (Tasks 1 and 2) and positive and negative words (Task 3) in Kiehl et al. (1999a), raising the possibility that the negative wave is independent of stimulus content.

Based on the similar topography of the psychopathic individuals' N350 and N500, Kiehl et al. (1999a) suggested two possibilities for the functional significance of these components. The tasks employed by Williamson et al. (1991) and Kiehl et al. (1999a) both involved lexico-semantic

processing and required an online or concurrent behavioral response. In the 300–600 ms after a word stimulus is presented both decision-making and semantic processes are engaged and will elicit overlapping ERP components of opposite polarity (i.e., P300 and N400). In general, presentation of a word stimulus in the absence of any online task demands will elicit a large ERP negativity in the 300–500 ms time window (N4 or N400). Thus, one interpretation of the psychopaths' fronto-central ERP negativities offered by Kiehl et al. (1999a) and Williamson et al. (1991) was that they may be related to an abnormally large N400. The alternative interpretation of the late ERP negativities in psychopaths was that it may be related to an abnormally small positive potential (e.g., P300; Kiehl, Bates, Laurens, Hare, & Liddle, in press; Kiehl, Hare, McDonald, & Liddle, 1999b).

However, it is still not clear whether the fronto-central ERP negativities observed in psychopaths can be elicited by visual stimuli that involve semantic processing but do not involve any online behavioral response. One aim of this experiment was to examine the integrity of the neural systems underlying semantic processes in the absence of concurrent task demands to attempt to isolate and characterize the conditions in which large fronto-central negativities are elicited. A second aim was to determine whether the abnormalities observed in psychopaths during semantic language tasks are related to the processes known to elicit the N400 during sentence processing tasks. The literature reviewed above suggests two competing hypotheses. First, given that psychopathy is known to be associated with abnormalities in semantic processes and the interpretation that the N400 indexes semantic processes, psychopaths may show abnormal N400s to the terminal words of sentences that were either congruent or incongruent with the previous sentence context. The alternative hypothesis is that the neurocognitive systems underlying the processes related to the generation of the N400 are not abnormal in psychopathy and that the aberrant late ERP negativities observed in psychopaths are not related to the N400. This hypothesis is supported by aberrant late ERP negativities observed in psychopaths during tasks that place no explicit demands on linguistic processing.

2. Methods

2.1. Participants

The participants were 50 male inmates from a federal maximum-security prison facility near Vancouver, British Columbia. Inmates were participating in treatment programs for criminal behavior. The treatment programs mandated drug and alcohol abstinence and the prison authorities randomly drug tested inmates as often as every month. Volunteers were selected for the study if they were between 18 and 55 years of age, were free from any reported serious head injury or neurological impairment, and had no DSM-IV Axis I diagnosis (APA, 1994). No participants were receiving antipsychotic or antidepressant medication. Forty-eight inmates were right hand dominant and two were left hand dominant (Annett, 1970). Volunteers participated in two sessions: a videotaped semi-structured interview and the experimental recording session.

Information from the interview and review of institutional files were used to complete the Hare Psychopathy Checklist—Revised (PCL-R; (Hare, 1991, 2003) on each inmate). Each of the 20 items on the PCL-R is scored on a 3-point scale (0–2) according to the extent to which it applies to the inmate. Inmates with a PCL-R score of 30 or above ($n = 25$) were defined as Psychopaths

(mean = 33.5, SD = 2.0), and those with a score below 30 ($n = 25$) were defined as Nonpsychopaths (mean = 20.1, SD = 6.6).

The mean age and years of formal education for Psychopaths and Nonpsychopaths were 32.5 and 32.1, and 10.1 and 10.9 years, respectively. The NART and Quick IQ measures for Psychopaths and Nonpsychopaths were 107.8 (SD 10.0) and 102.7 (SD 12.6), and 106.8 (11.4) and 103.3 (11.76), respectively. There were no significant group differences on any of these measures (p 's > .50). Each inmate was paid \$5.00 for the PCL-R interview and \$10.00 for the ERP session. The total of \$15.00 was equivalent to two days prison wage. The study was approved by Institutional and University ethics review committees and participants provided written informed consent.

2.2. Stimuli

One hundred sentences (eight to ten words in length) were presented one word at a time (500 ms stimulus duration and ISI) on a computer monitor.¹ Sentences ended with a word that was either semantically congruent (50% of trials) or semantically incongruent (50% of trials) with the previous sentence context. The order of sentence presentation was random. Letters subtended an angle of approximately 2×1 visual degrees. All stimuli were presented in white on a black background, within a continuously displayed outline of a white rectangular box. A prompt (white asterisk) was presented 1000 ms after the offset of the last word to indicate that the participant should make the sense/no sense discrimination. The hand used to make the response was counterbalanced across participants. ERPs were analyzed only for correctly classified terminal words. Accuracy was stressed and response speed was de-emphasized. Four sentences were given as practice.

2.3. Event-related potential recording

Scalp potentials were recorded from tin electrodes (ElectroCap International) placed over 29 electrode sites. Vertical and horizontal electrooculogram (EOG) were monitored from a bipolar electrode pair located on the lateral and supra orbital ridges of the right eye. All EEG electrodes were referenced to the nose. Electrical impedances were maintained below 5 k Ω throughout the experiment. The EEG channels (SA instruments) were amplified (20 k) within a bandpass of .01 to 100 Hz, digitized (256 Hz), and recorded on hard disk. The epoch length was 1200 ms with a 100 ms pre-stimulus baseline. Single-trials with peak-to-peak voltages greater than (+ or -) 75 μ V at any channel were excluded. Four participants (three nonpsychopaths and one psychopath) were excluded because of excessive artifacts (greater than 40% of trials). After exclusion of these participants, there were no significant group differences in the number of trials averaged in any condition. The ERPs were digitally filtered with a 30 Hz low-pass filter.

The behavioral analysis employed a repeated-measures [Group (Psychopath, Nonpsychopath) \times Condition (congruent, incongruent)] ANOVA. Two components were analyzed, the N400 and P600. The N400 is typically measured as the peak negative amplitude in the 300–500 ms post-stimulus time window in the difference wave of incongruent minus congruent conditions. However, several studies of the N400 in psychopathological populations have shown that

¹ The list of sentences is available upon request from the corresponding author.

relying solely on the difference wave can lead to misleading results (Adams et al., 1993; Grillon, Ameli, & Glazer, 1991; Nestor et al., 1997; Niznikiewicz et al., 1997). Thus, separate analyses were performed on the peak amplitude of the N400 and P600 measured in the difference wave and the original peaks from the incongruent and congruent conditions. The N400 and P600 were quantified as the peak negative and positive amplitudes (relative to the 100 ms pre-stimulus baseline) in the 300–500 ms and 500–800 ms time windows, respectively. These windows were centered upon the peak latency of each of the components in the grand average waveforms in this and previous studies. Separate ANOVAs were performed on midline (Fpz, Fz, Fcz, Cz, Pz, and Oz), medial (Fp1, Fp2, F3, F4, Fc3, Fc4, C3, C4, P3, P4, O1 and O2) and lateral sites (F7, F8, Fc7, Fc8, T3, T4, Tp7, Tp8, T5 and T6). The first set of ANOVAs for the difference wave included factors of Group [Psychopath and Nonpsychopath], and Site [frontal (i.e., F7, F3, Fz, F4, F8), fronto-central (Fc7, Fc3, Fcz, Fc4, Fc8), central (T3, C3, Cz, C4, T4), temporo-parietal (Tp7, P3, Pz, P4, Tp8), and temporo-occipital (T5, O1, Oz, O2, T6)]. For medial and lateral site ANOVAs there was an additional factor of Hemisphere (right: even numbered channels and left: odd numbered channels). Midline (Fpz) and medial (Fp1, Fp2) ANOVAs also included an additional level of Site [pre-frontal]. For the second set of ANOVAs for the peak amplitude analyses there was an additional factor of Condition [Incongruent and Congruent]. The Geisser–Greenhouse correction was employed where appropriate (Geisser & Greenhouse, 1958).

3. Results

3.1. Behavioral data

Across all participants accuracy was slightly higher for congruent than incongruent terminal words [main effect of Condition, $F(1, 44) = 5.41, p < .025$]. There were no significant group differences in the number of errors committed [Psychopaths, congruent stimuli, 2.45 (SD 2.79); incongruent stimuli, 3.86 (SD = 4.25); Nonpsychopaths, congruent stimuli, 1.58 (SD 1.24); incongruent stimuli, 2.91 (SD 2.73)].

3.2. Event-related potentials

Grand-mean ERPs for congruent terminal words, incongruent terminal words and for the incongruent-congruent difference waves are presented for psychopaths and nonpsychopaths in Figs. 1–3, respectively.

3.3. N400 difference wave

There were no significant group differences in the amplitude of the N400 at midline, medial or lateral sites. Across all participants, the N400 was largest at centro-parietal and temporal sites [main effect of Site, midline, $F(5, 220) = 11.31, p < .001$, medial, $F(5, 220) = 11.02, p < .001$]. Consistent with previous research (Kutas & Hillyard, 1982), this effect was slightly larger over the right than the left hemisphere at these sites [Site \times Hemisphere interaction, lateral, $F(5, 220) = 3.13, p < .017$; main effect of Hemisphere, lateral, $F(1, 44) = 4.80, p < .034$].

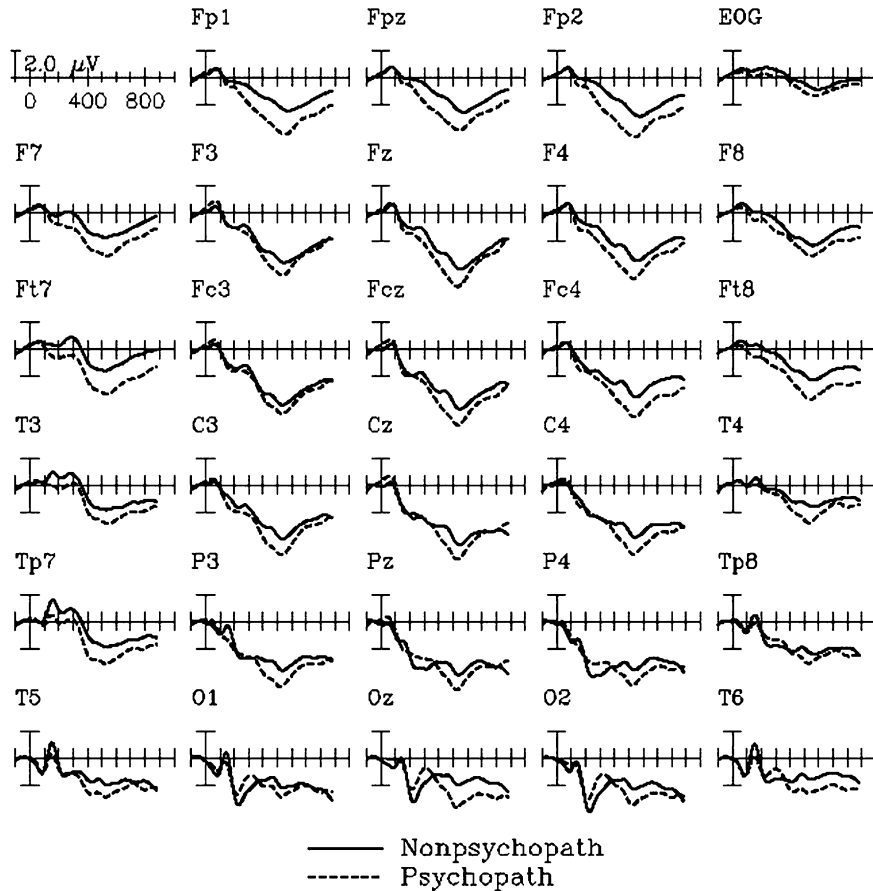


Fig. 1. Grand mean ERPs for congruent terminal words of sentences for psychopaths (dashed) and nonpsychopaths (solid). Negative amplitude is plotted up. Tick marks are in units of 100 ms.

3.4. N400 peak analyses

As in the difference wave analyses, there were no significant group differences in the N400 to congruent or incongruent terminal words. Across all participants, N400 was larger for incongruent than for congruent sentence endings [main effect of Condition, midline, $F(1, 44) = 18.62$, $p < .001$, medial, $F(1, 44) = 18.68$, $p < .001$, lateral, $F(1, 44) = 10.82$, $p < .002$]. This effect was largest at central, temporal and parietal sites [Condition \times Site interaction, midline, $F(5, 220) = 7.56$, $p < .001$, medial, $F(5, 220) = 7.14$, $p < .001$]. The N400 for incongruent stimuli was slightly larger over left hemisphere temporo-parietal and occipital sites than the analogous right hemisphere sites [Condition \times Site \times Hemisphere, medial, $F(5, 220) = 3.08$, $p < .018$, Condition \times Site \times Hemisphere interaction, lateral, $F(4, 176) = 2.73$, $p < .049$; Condition \times Hemisphere interaction, medial, $F(1, 44) = 7.53$, $p < .009$, lateral, $F(1, 44) = 8.99$, $p < .004$; Site \times Hemisphere interaction, medial, $F(5, 220) = 4.68$, $p < .029$, lateral, $F(4, 176) = 4.31$, $p < .010$; Main effect of Site, midline, $F(5, 220) = 6.04$, $p < .001$, medial, $F(5, 220) = 5.49$, $p < .011$]. There were no hemispheric asymmetries for the N400 elicited by congruent terminal words.

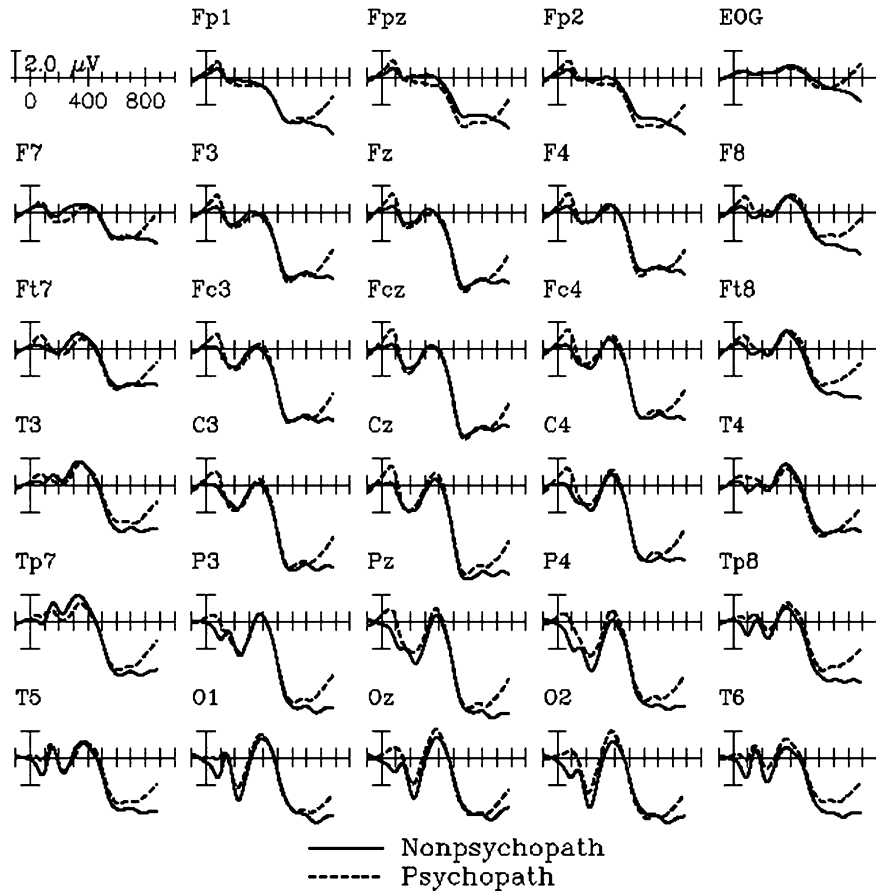


Fig. 2. Grand mean ERPs for incongruent terminal words of sentences for psychopaths (dashed) and nonpsychopaths (solid). Negative amplitude is plotted up. Tick marks are in units of 100 ms.

3.5. P600 difference wave analyses

There were no significant group differences in the amplitude of the P600. The P600 difference wave was largest at central and parietal sites [main effect of Site, midline, $F(5, 220) = 11.45$, $p < .001$, medial, $F(5, 220) = 10.18$, $p < .001$, lateral, $F(4, 176) = 15.61$, $p < .001$], an effect slightly larger in the right than the left hemisphere [Site \times Hemisphere interaction, medial, $F(5, 220) = 3.02$, $p < .019$; Site \times Hemisphere, lateral, $F(4, 176) = 2.97$, $p < .033$].

3.6. P600 peak analyses

As in the difference wave analyses, there were no significant group differences in the amplitude of the P600 for the two Condition analyses. Across all participants, the P600 was larger for incongruent stimuli than for congruent stimuli [main effect of condition, midline, $F(1, 44) = 9.42$, $p < .004$, medial, $F(1, 44) = 6.48$, $p < .01$]. This latter effect was strongest at central and parietal

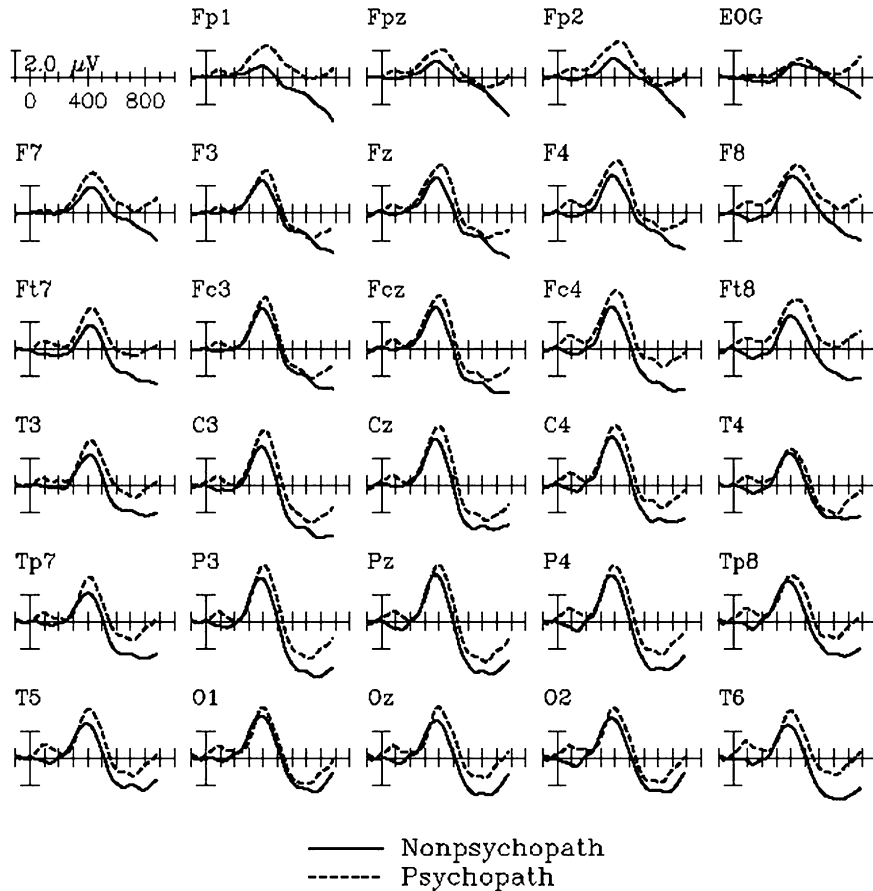


Fig. 3. Grand mean ERP difference wave for incongruent minus congruent terminal words of sentences for psychopaths (dashed) and nonpsychopaths (solid). Negative amplitude is plotted up. Tick marks are in units of 100 ms.

sites [Condition \times Site interaction, midline, $F(5, 220) = 8.83$, $p < .001$, medial, $F(5, 220) = 7.98$, $p < .001$], lateral, $F(4, 176) = 13.01$, $p < .001$; Main effect of Site, midline, $F(5, 220) = 20.64$, $p < .001$; medial, $F(5, 220) = 10.16$, $p < .001$, lateral, $F(4, 176) = 8.12$, $p < .001$. The P600 was larger over right frontal and central sites than left hemisphere frontal and central sites [Site \times Hemisphere interaction, medial, $F(5, 220) = 3.03$, $p < .019$].

4. Discussion

This study was designed to examine the relationship between psychopathy and semantic processes related to the generation of the scalp recorded N400 ERP. No group differences were observed between psychopaths and nonpsychopaths in the amplitude of the N400 for either congruent or incongruent terminal words of sentences. The present data do not support the hypothesis that psychopathy is associated with abnormalities in processes related to the genera-

tion of the N400 ERP elicited during sentence processing tasks. In general, sentence processing studies of the N400 elicited by terminal word stimuli suggest that the N400 component is related to processes involved with accessing and integrating word meanings within ongoing context. Thus, these data suggest that psychopaths are able to develop an ongoing representation of sentence context in a manner similar to that seen in nonpsychopaths and noncriminals (see Niznikiewicz et al., 1997).

Previous ERP studies of psychopathy employing oddball target detection (Kiehl et al., 1999b), response inhibition (Kiehl, Smith, Hare, & Liddle, 2000), concrete/ abstract discrimination (Kiehl et al., 1999a), emotional polarity discrimination (Kiehl et al., 1999a), emotional lexical decision task (Williamson et al., 1991) and contingent negative variation (Forth & Hare, 1989) have all observed that psychopaths' ERPs are associated with aberrant late negativities in the 300–600 ms post-stimulus time window. One interpretation of the late ERP negativities in these latter studies was that they may be related to abnormal processes associated with the generation of the N400 (see Kiehl et al., *in press*). However, the present N400 results do not support this interpretation. It is important to note that in the studies which have reported excess late ERP negativity in psychopaths, the participants were required to make an immediate decision and a motor response, whereas in the current study the participants were not required to make a response until over one second later. This suggests that the excess late ERP negativity in psychopaths is only observed when an immediate decision and response is required. Future studies should consider exploring the issues related to decision making and response selection on the late ERP negativities in psychopaths.

The present study sought to examine the canonical N400 response associated with processing terminal words of sentences that were either congruent or incongruent with the current sentence context (Kutas & Hillyard, 1980a, 1980b, 1980c). It is important to recognize that other aspects of semantic analyses may be abnormal in psychopathy. For example, processing of single words during lexical decision or concrete/abstract discrimination tasks might be abnormal in psychopaths (Kiehl et al., 1999a; Kiehl, Smith, Mendrek, Hare, & Liddle, 2004). It is also relevant to note that the present study sought to mitigate the possible influence of online or concurrent decision making on the task by postponing the decision about whether the sentence made sense or not from the offset of the terminal word of the sentence by 1000 ms. Participants were also instructed to perform accurately and reaction time was de-emphasized. Nevertheless, it is possible that the task still required some online decision making processes. However, if online decision making processes were engaged, psychopaths' ERPs should have been characterized by a large late ERP negativity as has been observed in studies that required online decision making processes in psychopaths with and without semantic processes (Kiehl et al., *in press*; Kiehl et al., 1999b). No such late ERP negativities were observed. Thus, the present design appears to have successfully reduced the contribution of concurrent task demands. To more fully address this issue, future studies might consider employing designs that further reduce the demands on decision making processes.

In addition to the absence of any group differences in the amplitude of the N400, no group differences were observed for the P600 component. The P600 is believed to reflect late syntactic reanalysis (Friederici, 2004; Frisch, Kotz, von Cramon, & Friederici, 2003). There are currently no published reports suggesting that psychopathy is associated with abnormalities in syntactic processes.

It is important to consider whether the absence of any group differences may have been due to low power. The present study employed a relatively large sample size for psychophysiology studies ($n = 50$). Moreover, a power analysis estimated from the nonsignificant F -tests indicated that a sample size of 271 would be required to demonstrate significant group differences, if there was an effect of the magnitude observed in this study. This suggests that there are no substantial group differences in the amplitude of the N400 elicited during sentence processing.

Our data indicate that psychopathy as measured by high PCL-R score is not associated with abnormal N400 when compared to individuals with low PCL-R scores. However, it may be possible that comparisons of high and low PCL-R groups may show abnormal N400s compared to nonincarcerated healthy controls. We find this explanation unlikely however, as visual comparison of the N400 amplitude, latency, and morphology elicited in healthy controls in the source study of Niznikiewicz et al. (1997) are nearly identical to that elicited by high and low PCL-R groups in the present study. Nevertheless, future studies should consider including a healthy control group to unambiguously examine this issue.

To summarize, no group differences were observed between psychopaths and nonpsychopaths in the amplitude of the N400 or P600 for either congruent or incongruent terminal words of sentences. The present data do not support the hypothesis that psychopathy is associated with abnormalities in processes related to the generation of the N400 ERP elicited during sentence processing tasks. Rather, the data imply that the processes and neural systems underlying the generation of the N400 elicited during sentence processing are relatively normal in psychopaths. The results provide evidence that the late ERP negativities observed in psychopaths during semantic language tasks (Kiehl et al., 1999a; Williamson et al., 1991) are not related to abnormally large N400s.

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