
Reduced P300 Responses in Criminal Psychopaths during a Visual Oddball Task

Kent A. Kiehl, Robert D. Hare, Peter F. Liddle, and John J. McDonald

Background: *Clinicians have long recognized that psychopaths show deficits in cognitive function, but there have been few experimental studies exploring these deficits. We present here the first in a series of event-related potential (ERP) experiments designed to elucidate and characterize the neural correlates of cognitive processes of psychopaths.*

Methods: *We recorded ERPs from a topographic array from 11 psychopathic and 10 nonpsychopathic prison inmates, assessed with the Hare Psychopathy Checklist-Revised, during performance of a visual oddball task. ERPs to target (25% of trials) and nontarget (75% of trials) visual stimuli were analyzed.*

Results: *Consistent with previous research, there were no group differences in the latency or amplitude of the ERPs for the nontarget stimuli. For nonpsychopaths, the P300 amplitude was larger when elicited by the target stimuli than when elicited by the nontarget stimuli. In contrast, psychopaths failed to show reliable P300 amplitude differences between the target and nontarget conditions. Psychopaths had a smaller amplitude P300 to target stimuli than did nonpsychopaths. In addition, the amplitude of the P300 was less lateralized in psychopaths than in nonpsychopaths. Psychopaths also had a larger centro-frontal negative wave (N550) during the target condition than did nonpsychopaths.*

Conclusions: *The results of this study indicate that there are substantial differences between psychopaths and others in the processing of even simple cognitive tasks and provide support for information processing models of psychopathy. Biol Psychiatry 1999;45:1498-1507 © 1999 Society of Biological Psychiatry*

Key Words: Psychopathy, event-related potentials, P300, attention, visual stimuli, oddball

Introduction

Event-related potentials (ERPs) provide researchers with a powerful tool for elucidating the neural substrates of cognition in psychopathological disorders. Although there have been far fewer ERP studies of psychopathy than other disorders (e.g., schizophrenia), its limited use has proved fruitful. For example, Hare and colleagues have interpreted the results of a number of ERP studies as support for the hypothesis that psychopathy is associated with abnormal language processing (Hare 1998; Jutai and Hare 1983; Jutai et al 1987; Kiehl et al in press; Williamson et al 1991); however, the interpretation of results from these studies and subsequent theoretical advancements have been hampered by a paucity of studies employing well-characterized ERP paradigms and consistent diagnostic criteria for psychopathy (see review by Raine 1989, and criticisms by Jutai 1989 and Howard 1989).

A widely accepted diagnostic instrument for psychopathy is the Hare Psychopathy Checklist-Revised (PCL-R; Hare 1991), conceptually based on clinical traditions (e.g., Cleckley 1976). There is now a substantial literature attesting to the reliability and validity of the PCL-R as a measure of psychopathy in offenders and forensic patients (Hare 1980, 1991, 1993, 1996a, 1996b; Hare et al 1990; Harpur et al 1988, 1989; Hart and Hare, 1989; see Fulero 1996 for a review). Factor analyses of the PCL-R have revealed two correlated dimensions or factors (Harpur et al 1988, 1989). Factor 1 includes items related to emotional and interpersonal relationships (e.g., superficial charm, egocentricity, grandiosity, deceitfulness and manipulativeness, and absence of remorse, guilt, or empathy). Factor 2 items reflect impulsive and antisocial behaviors (e.g., impulsivity, poor behavioral controls, proneness to boredom, poor life planning, and irresponsibility). This latter factor is most closely related to DSM-IV classification of antisocial personality disorder (APD; American Psychiatric Association 1994). It is important to note that although APD was intended to capture the essential components of psychopathy, it has been criticized for overly relying on antisocial behaviors, while excluding the affective and interpersonal characteristics considered to be central to the

From the Department of Psychology (KAK, RDH, JJM) and Department of Psychiatry (PFL), University of British Columbia, Vancouver, British Columbia, Canada.

Address reprint requests to Robert D. Hare, 2136 West Mall, Department of Psychology, University of British Columbia, Vancouver, B.C., V6T 1Z4, Canada.

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construct of psychopathy (Hare 1996a, 1996b; Widiger et al 1996).

The present study is the first in a series of experiments that seek to explore and clarify the relationships between psychopathy (as assessed by the PCL-R) and several well-studied ERP components. The focus of this study is the visual P300 component.

The P300, as used here, refers to a family of positive potentials occurring at a latency of 300 msec or more. The amplitude, latency, and scalp morphology of these potentials are sensitive to a wide variety of experimental manipulations (e.g., stimulus modality, attention manipulations, target probability, stimulus complexity) and have been reported to be abnormal in a wide variety of clinical conditions (e.g., such as schizophrenia and depression; Blackwood et al 1987; Gooden et al 1986; Hansch et al 1982; Pfefferbaum et al 1984; Squires et al 1975). The diversity of P300 findings and convergent data from depth electrode recordings and neuroimaging have led to the conclusion that there are multiple generators of the P300. The present study sought to investigate the posterior P300, also commonly referred to as the P3b. The amplitude of the posterior P300 is maximal when participants are asked to respond to low-probability events (known as "oddball" paradigms) and is thought to be sensitive to changes in the allocation of attentional resources and processes involved in contextual updating and decision making (Prichard 1981; Alexander et al 1995). Since defective allocation of attentional resources and abnormal decision-making processes are postulated features of psychopathy (Kosson 1996; Kosson and Newman 1986; Harpur and Hare 1990; Newman 1998), the oddball paradigm is potentially an informative tool for investigating these processes.

There have been six ERP studies on psychopathy defined according to PCL (an early version of the PCL-R, Hare 1980) or PCL-R scores (Jutai and Hare 1983; Jutai et al 1987; Forth and Hare 1989; Williamson et al 1991; Kiehl et al in press; Raine and Venables 1988). Five have reported information concerning P300, though only two studies employed paradigms in which the salience of stimuli was manipulated in a manner expected to elicit a P300 response. These were the study by Jutai et al (1987), which employed an auditory phoneme discrimination task, and the study by Raine and Venables (1988), which employed a visual continuous performance task.

Jutai et al (1987) found no significant difference between psychopaths and nonpsychopaths in the amplitude or latency of the P300, though they did observe a late positive wave (at 600 msec) in psychopaths' waveforms for target stimuli (phonemes) during a dual task procedure (playing video games and making phonemic discriminations). Visual inspection of the waveforms in their study indicated that the P300 amplitude was smaller in the

psychopaths than in nonpsychopaths. It should be noted that Jutai et al did not record from parietal electrodes, usually the optimal site for detection of P300. In contrast, Raine and Venables (1988) reported that the amplitude of parietal P300 to target stimuli in the visual modality was greater in psychopaths than in nonpsychopaths.

In the remaining three studies that reported information about P300, there was no evidence indicating that P300 amplitude was abnormal in psychopaths; however, these studies did not employ paradigms that manipulated the salience of the stimuli. Overall, the findings do not provide unequivocal information about the nature of P300 in psychopathy. The only study (Raine and Venables 1988) that reported significant P300 differences found larger P300s in psychopaths than in nonpsychopaths. This finding was contrary to the expectation that psychopaths would have abnormally low P300 amplitude to oddball stimuli, as is observed in other patient groups with impaired ability to allocate attentional resources (Blackwood et al 1987; see Pfefferbaum et al 1995 for a review). It should be noted that Raine and Venables (1988) used visual stimuli, whereas many of the studies in other disorders employed auditory stimuli. The unexpected result obtained by Raine and Venables (1988) justifies further exploration of the P300 elicited by visual stimuli.

With regard to the P300 elicited by nonsalient stimuli, all the studies that have reported relevant data (Jutai et al 1987; Forth and Hare 1989; Raine and Venables 1988) have found that psychopaths do not differ from nonpsychopaths. This effect is consistent with the observation that psychopaths have a normal, or enhanced, ability to ignore irrelevant material (Jutai 1989; Jutai and Hare 1983).

Several studies have reported that long-latency ERPs (later than P300) are different in psychopaths than in nonpsychopaths, especially during visual language tasks. The most consistent feature is the appearance in psychopaths of a large frontally distributed negative wave with a latency of approximately 500 msec. Williamson et al (1991) reported that psychopaths exhibited a larger centrofrontal N500 to word stimuli during a lexical decision task than nonpsychopaths. The task employed by Williamson et al required a Go/No-go decision, raising the possibility that the prominent N500 of the psychopaths was related to poor response inhibition; however, Kiehl et al (in press) reported that psychopaths exhibited a large centrofrontal negative wave with latency about 350 msec during three different language tasks, all of which employed a Go/Go design. It is unlikely, therefore, that the abnormal late centrofrontal negative wave exhibited by psychopaths can be attributed entirely to difficulties in response inhibition. Although both Williamson et al (1991) and Kiehl et al (in press) employed tasks that

demanded linguistic processing, 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 in press], raising the possibility that it is independent of stimulus content.

Overall, the results of studies of ERPs with a latency of 300 msec or longer in psychopaths raise two major questions. First, does the visual P300 elicited by oddball stimuli have abnormally low amplitude and long latency in psychopaths, as would be expected from the evidence that impaired allocation of attentional resources is a characteristic of the condition? Second, can the late centrofrontal negative waves reported by Williamson et al (1991) and Kiehl et al (in press) be elicited by visual stimuli that do not involve linguistic processing? In this paper we report a study using an oddball paradigm with visual, nonlinguistic stimuli to address these issues. Specifically, we tested the following predictions: 1) the P300 elicited by the salient (oddball) stimuli will be smaller and will have longer latencies in psychopaths than in nonpsychopaths; 2) the amplitude and latency of the P300 elicited by the nonsalient stimuli will be the same in psychopaths as in nonpsychopaths; and 3) psychopaths, but not nonpsychopaths, will exhibit a late centrofrontal negative wave even though the stimuli do not require linguistic processing.

Methods and Materials

Participants

The participants were 21 male inmates from a federal forensic psychiatric facility near Vancouver, British Columbia. They were participants in a violent offender or sex-offender treatment program. Volunteers were selected for the study if they were between 18 and 55 years of age, had normal, or corrected-to-normal vision, were free from any reported serious head injury or neurological impairment, had no DSM-IV Axis I diagnosis (American Psychiatric Association 1994), and were right-handed (Annett 1970). Volunteers participated in two sessions: a videotaped semistructured interview and the experimental recording session. Information from the interview and an extensive review of institutional files were used by two clinicians to independently complete the PCL-R on each inmate. Each of the 20 items on the PCL-R is scored on a three-point scale (0–2) according to the extent to which it applies to the inmate. The mean and standard deviation of PCL-R total scores (which can range from 0 to 40) for the entire sample were 25.9 and 9.1, respectively. Because of the continuing debate as to whether psychopathy is a discrete condition or a dimension of personality (e.g., Cooke and Michie 1997), we performed both categorical and correlational analyses. For the purposes of categorical analyses, an approximate median split was used to create two groups. Inmates with a PCL-R score of 29 or above ($n = 11$) were defined as Psychopaths (mean = 33.2, standard deviation = 2.2), and those with a PCL-R score of 27 or below ($n = 10$) were defined as Nonpsychopaths (mean =

17.9, standard deviation = 6.8). Using this procedure all but 1 of the Psychopaths had a PCL-R score above 30 (the suggested cutoff point for psychopathy given by Hare 1991). Three of the Nonpsychopaths had scores above the recommended cutoff of 20 on the PCL-R (Hare 1991). The liberal cutoff point on the PCL-R for inclusion into the Nonpsychopathic group would, if anything, lend to a conservative bias to our experimental hypotheses. The kappa coefficient for two independent raters for classification into Psychopathic and Nonpsychopathic groups by PCL-R scores was 1.00. The interrater reliability for two raters for total PCL-R scores was .86.

Mean age and years of formal education were 27 and 33, and 10.5 and 10.8 years for Psychopaths and Nonpsychopaths, respectively. The two groups did not differ significantly on either of these measures ($p > .20$). Eighteen participants were Caucasian (9 Nonpsychopaths), 1 was African American (a Nonpsychopath), and 2 were North American Indian (both Psychopaths). Participants were rated as average to above average intelligence by a psychiatric screening interview completed for participation in the treatment programs. We paid each inmate \$5.00 for the PCL-R interview and \$10.00 for the experiment. The total of \$15.00 was equivalent to 2 days prison wage. As an additional incentive, we told the participants that the participant who had the best reaction time and accuracy would receive an extra \$10.00. The study was conducted in accordance with Institutional and University ethical standards.

Stimuli

Each stimulus, displayed on a computer monitor, consisted of a white square on a black background. The target stimulus was a 4×4 cm square and the nontarget stimulus was a 6×6 cm square. The larger stimuli subtended a visual angle of 8.5 by 8.5 degrees, and the smaller stimuli subtended an angle of 3.8 by 3.8 degrees.

Physiological Recording

We recorded scalp potentials from tin electrodes (ElectroCap International) placed over prefrontal (F7, Fpz, F8), frontal (F3, Fz, F4), temporal (T3, T4), central (C3, Cz, C4), and parietal (P3, Pz, P4) sites according to the International 10/20 system of electrode placement. Vertical eye movements were monitored from an electrode on the supraorbital ridge of the right eye. All electrodes were referenced to an electrode located at the right mastoid process. One additional channel, left mastoid to right mastoid, was recorded for the purposes of allowing digital rereferencing to an average of left and right mastoids (Nunez 1981, 1990). Electrical impedance was checked before and after the experiment. In all cases, the electrode impedances were below 5 k Ω .

The electroencephalographic channels (Grass Model 8-18C) were amplified with a bandpass of 0.1–70 Hz, digitized on-line at a rate of 256 samples per second, and recorded on computer hard disk. The sampling epoch was 1300 msec, beginning with a 100-msec prestimulus baseline period. Artifact rejection was performed before averaging to eliminate trials contaminated by blinks (greater than 50 μ V) or amplifier blocking. These rejected

trials did not exceed 5% of trials in any condition, and there were no group differences in the number of trials averaged in any condition. The ERPs were then digitally filtered with a zero-phase shift 20-Hz low-pass filter to reduce electromyographic noise.

Procedure

The experiment was conducted in a dimly lit room in a quiet part of the institution. After attachment of the electrodes the inmate sat in a comfortable chair approximately 60 cm from the computer monitor. He previewed the stimuli and was told to respond as quickly and accurately as possible, by pressing a designated button on a computer keyboard whenever a small square (the target) appeared, but not to respond when a large square (nontarget) appeared. The hand used to respond was counterbalanced across participants. The stimulus duration was 50 msec, with a random 750–1250 interstimulus interval. Two hundred trials were presented in two blocks of 100. Within each block 25% of the trials were the target stimuli and 75% of the trials were nontarget stimuli. The participant performed a block of 10 practice trials, repeated twice, to insure he understood the instructions before beginning the experiment.

Data Analysis

We performed separate *t* tests on the reaction time, percentage of correct hits, and errors of commission. Analyses of variance (ANOVAs) were performed on the ERP data, one for lateral sites and one for midline sites. These analyses included factors of Group (psychopath vs. nonpsychopath) \times Condition (target vs. nontarget) \times Site (prefrontal, frontal, central, parietal, and temporal for lateral analyses; prefrontal, frontal, central, and parietal for midline analyses). For lateral sites, there also was a factor for Hemisphere (left and right). Two ERP components were measured (relative to the 100-msec prestimulus baseline): the P300 and the N550. For the P300 we performed both peak amplitude and latency measurements. To reduce the effect of latency jitter on the P300 peak amplitude measurement, we also quantified the P300 as the mean amplitude in the 325–425-msec window. Analysis of the mean amplitude measurement of the P300 largely confirmed the peak amplitude analysis (detailed analyses of the mean amplitude measures are available upon request from the corresponding author). The amplitude of the N550 was quantified as the mean value in the 550–650-msec window. Following the ANOVA, planned comparisons were performed on the predicted effects. Type I error rate was maintained below .05 by using the Dunn–Bonferroni correction. Other effects of interest were tested using simple effects analyses or Tukey's multiple comparisons. The Geisser–Greenhouse correction was used for any repeated measures that contained more than one degree of freedom in the numerator (Geisser and Greenhouse 1958). All probability levels are reported using epsilon-adjusted degrees of freedom. The McCarthy and Wood (1985) correction was applied to any Group \times Site or Group \times Hemisphere interaction. In all cases, this correction did not decrease the probability level below significance.

We also performed correlation analyses comparing the P300

Table 1. Behavioral Data for Psychopaths and Nonpsychopaths for the Oddball Task

	Reaction times (msec)	Percentage of correct hits	Errors of commission
Psychopaths	416 (45.9)	96.2 (1.1)	0.54 (0.7)
Nonpsychopaths	403 (30.5)	94.0 (5.1)	1.80 (1.9)

Values are mean (SD).

amplitude and the amplitude of the N550 with PCL-R total scores. All participants were included in these analyses.

Results

Behavioral Data

Participants had no difficulty correctly responding to or correctly classifying the two stimuli. There were no group differences in any of the three conditions (all *ps* > .05). The behavioral results are presented in Table 1.

Event-Related Potentials

Grand mean ERPs for the Psychopaths and Nonpsychopaths are presented in Figure 1 and Figure 2 for the target and nontarget stimuli, respectively.

P300 Peak Amplitude

Analyses of the lateral sites yielded a main effect of Group [$F(1,19) = 5.75, p < .03$] and a Group \times Condition interaction [$F(1,19) = 4.82, p < .05$]. This pattern of results indicated four things: 1) the P300 to target stimuli was larger for nonpsychopaths than for psychopaths; 2) the P300 was larger for targets than for nontargets for nonpsychopaths; but 3) this latter effect was not significant for psychopaths; and 4) there were no ERP differences between psychopaths and nonpsychopaths for the nontarget stimuli. P300 amplitude measurements for Psychopaths and Nonpsychopaths are summarized in Table 2.

There was a significant Group \times Hemisphere interaction [$F(1,19) = 4.54, p < .05$]. This effect indicated that the P300 was more lateralized (right hemisphere) in Nonpsychopaths than in Psychopaths.

At midline sites there was a significant Group \times Condition interaction [$F(1,19) = 5.66, p < .03$] and a Group \times Site interaction [$F(3,57) = 4.76, p < .006, \epsilon = .55$], and a Group \times Condition \times Site interaction [midline, $F(3,57) = 5.55, p < .002, \epsilon = .55$]. As with the lateral analyses, 1) Nonpsychopaths had a larger P300 for the target stimuli than did Psychopaths; and 2) Nonpsychopaths, relative to Psychopaths, showed greater central and posterior P300 differentiation between target and nontarget stimuli. There was no P300 difference between conditions for Nonpsychopaths at frontal sites. There was a

TARGET STIMULI

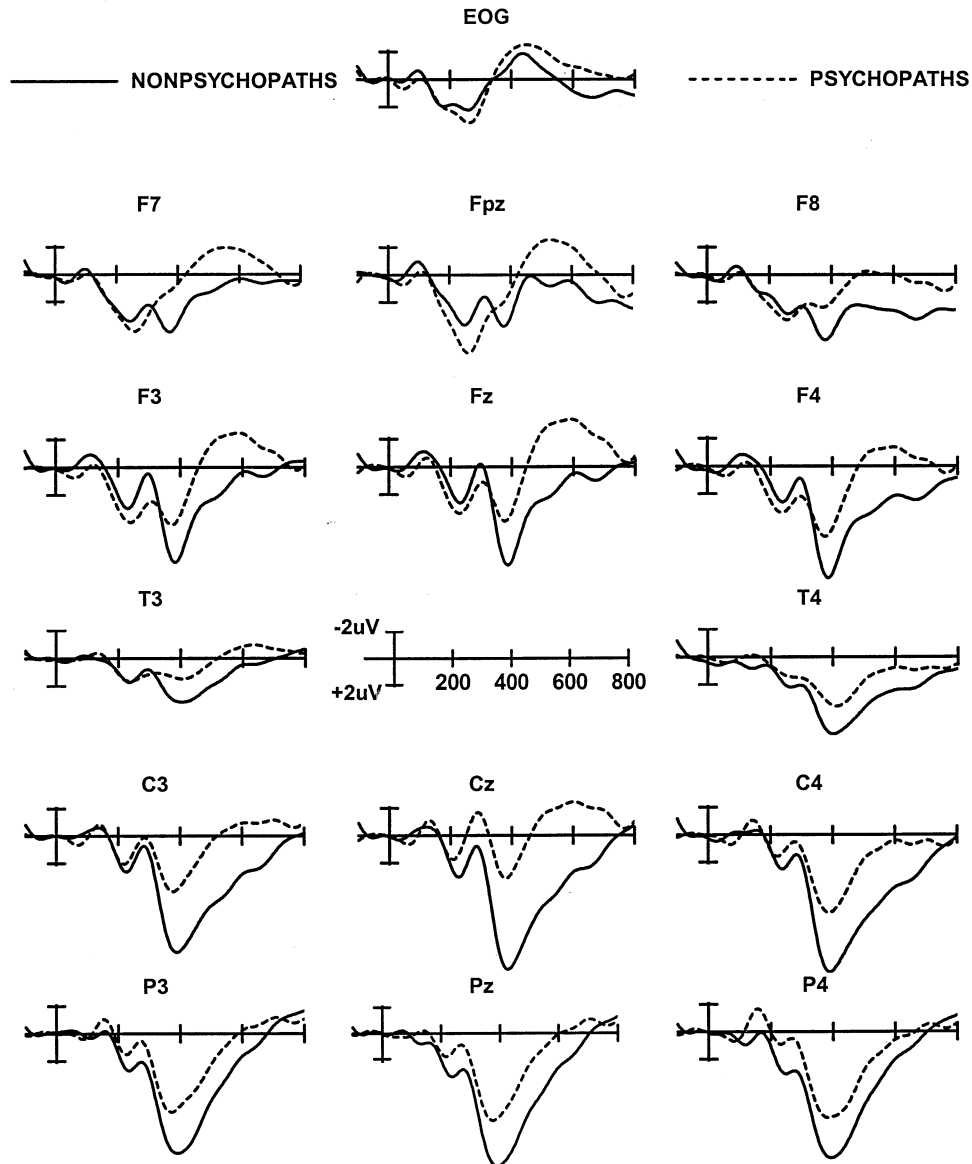


Figure 1. A comparison of the grand-averaged ERPs to target stimuli for Psychopaths and Nonpsychopaths. EOG, electro-oculogram.

trend for Psychopaths to show a slightly larger P300 to target than to nontarget stimuli at the anterior site (Fpz).

In general, the P300 was larger for target than for nontarget stimuli [main effect of Condition: lateral, $F(1,19) = 18.70, p < .00001$; midline, $F(1,19) = 5.66, p < .004$], with this effect being greater at right than left hemisphere central and parietal sites [Condition \times Site \times Hemisphere interaction: lateral, $F(4,76) = 5.73, p < .002, \epsilon = .68$; Condition \times Site interaction: midline, $F(3,57) = 4.75, p < .006, \epsilon = .55$]. Across stimulus types the P300

was larger at central and parietal sites than at anterior or temporal sites [main effect of Site: lateral, $F(4,76) = 23.36, p < .001, \epsilon = .40$; midline, $F(3,57) = 11.13, p < .001, \epsilon = .54$].

The results of the correlational analyses between PCL-R scores and the peak amplitude of the P300 to target stimuli are summarized in Table 3. Significant negative correlations were found at central and parietal sites, indicating that the smaller P300 to target stimuli was characteristic of psychopathy.

NONTARGET STIMULI

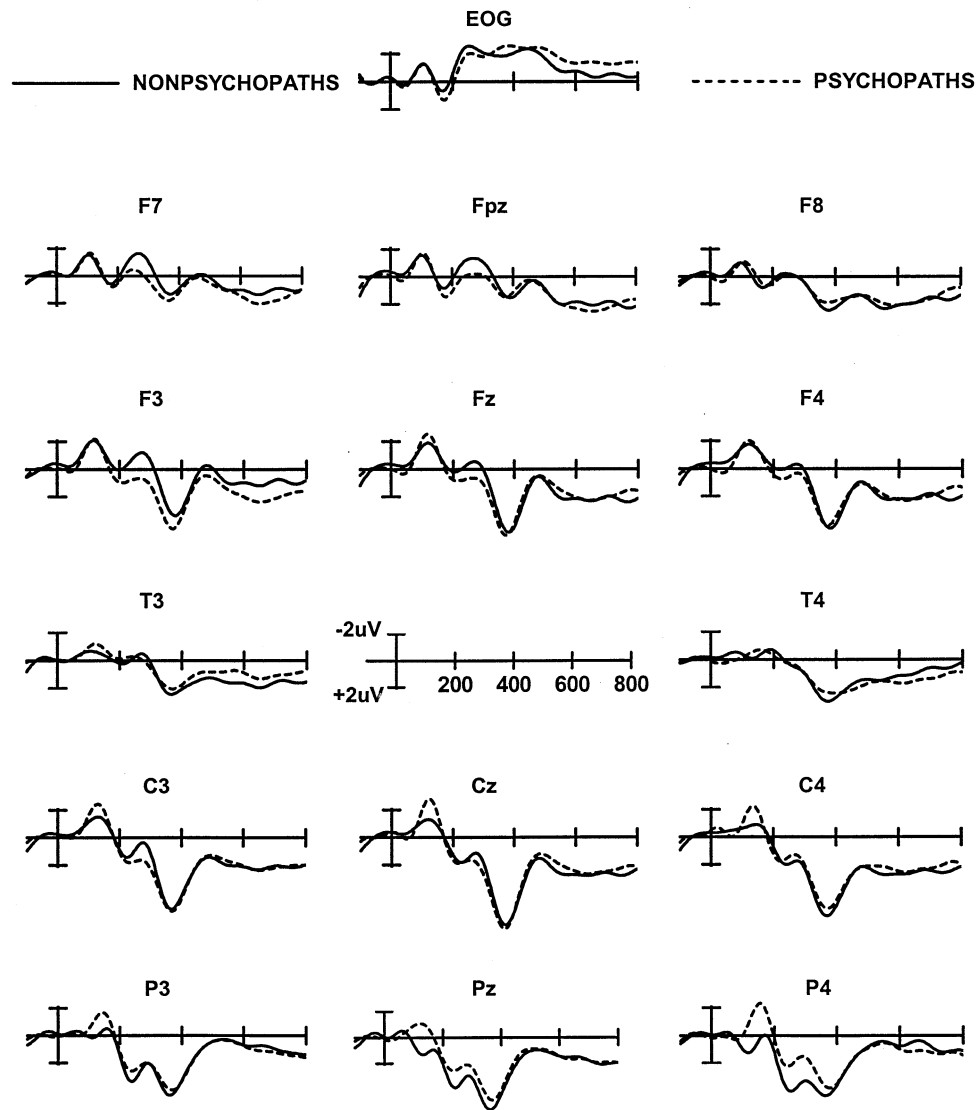


Figure 2. A comparison of the grand-averaged ERPs to nontarget stimuli for Psychopaths and Nonpsychopaths. EOG, electro-oculogram.

P300 Peak Latency

The P300 was earlier at prefrontal sites than at any other scalp site [main effect of Site: midline, $F(3,57) = 5.70$, $p < .01$; lateral, $F(4,76) = 10.67$, $p < .001$], an effect found only for the target condition and not the nontarget condition [Condition \times Site interactions: midline, $F(3,57) = 13.64$, $p < .0001$; lateral, $F(4,76) = 9.46$, $p < .001$]. Latency measurements also were faster over left hemisphere sites than at right hemisphere sites [main effect of Hemisphere: $F(1,19) = 8.68$, $p < .008$]. There were no P300 peak latency differences between Psychopaths and Nonpsychopaths.

N550 Mean Amplitude

Analyses of this time window confirmed that Psychopaths had a larger N550 than did Nonpsychopaths [main effect of Group: lateral, $F(1,19) = 9.43$, $p < .007$; midline, $F(1,19) = 14.04$, $p < .002$], an effect found for the target stimuli but not for the nontarget stimuli [Group \times Condition interactions: lateral, $F(1,19) = 7.20$, $p < .02$; midline, $F(1,19) = 10.01$, $p < .008$]. The N550 was more anterior than posterior [main effect of Site: lateral, $F(4,76) = 5.46$, $p < .006$, $\epsilon = .60$; midline, $F(3,57) = 7.26$, $p < .004$, $\epsilon = .56$; Condition \times Site interactions: lateral, $F(4,76) = 7.19$, $p < .002$, $\epsilon = .56$; midline, $F(3,57) =$

Table 2. Mean P300 and N550 Amplitude Measurements for Target and Nontarget Stimuli for Psychopaths and Nonpsychopaths at Prefrontal(F7, Fpz, F8), Frontal (F3, Fz, F4), Central (C3, Cz, C4), Parietal (P3, Pz, P4), and Temporal (T3, T4) Electrode Locations

PCL-R	F7	Fpz	F8	F3	Fz	F4	C3	Cz	C4	P3	Pz	P4	T3	T4
P300 peak amplitude														
Target stimuli														
Psychopaths	5.0	6.5	4.3	5.8	5.3	6.0	4.9	4.1	6.3	6.2	7.4	7.0	2.8	4.0
Nonpsychopaths	5.8	5.6	5.9	7.6	7.9	9.0	9.3	10.7	11.0	9.4	11.1	10.0	4.0	6.6
Nontarget stimuli														
Psychopaths	2.5	3.4	3.0	4.7	5.2	4.6	5.5	6.9	5.6	4.3	5.2	4.3	2.5	3.2
Nonpsychopaths	1.7	2.7	3.1	3.7	4.9	4.6	5.5	6.7	6.1	5.0	6.3	5.3	2.8	3.4
N550 mean amplitude														
Target stimuli														
Psychopaths	-1.8	-2.2	0.0	-2.3	-3.3	-1.2	-0.7	-2.2	-0.7	0.2	0.6	1.0	-0.7	0.9
Nonpsychopaths	0.5	0.7	2.6	0.8	1.0	2.5	3.4	3.3	4.3	2.3	3.4	2.7	0.8	2.6
Nontarget stimuli														
Psychopaths	1.3	2.2	2.0	1.8	1.8	2.1	1.9	2.3	2.4	0.6	1.3	0.8	0.9	1.7
Nonpsychopaths	1.0	1.9	2.2	1.0	2.1	2.2	2.1	2.7	2.7	0.5	1.3	0.6	1.6	1.3

10.51, $p < .002$, $\epsilon = .58$] and more prominent over the left hemisphere than the right hemisphere [main effect of Hemisphere: $F(1,19) = 20.53$, $p < .0001$; and Condition \times Hemisphere interaction: $F(1,19) = 11.10$, $p < .005$]. N550 amplitude measurements for Psychopaths and Nonpsychopaths are summarized in Table 2.

As for the P300 results, significant negative correlations were found between PCL-R scores and the N550 amplitude measurements at frontal and central sites (see Table 3).

Discussion

This study was designed to assess the topographic variation in the P300 response while psychopaths and nonpsychopaths performed a visual oddball task. We predicted that the P300 response to target stimuli would be smaller in psychopaths than in nonpsychopaths. The ERP results clearly supported this prediction. As Figure 1 illustrates, the P300 response to the target stimuli was significantly smaller for psychopaths than for nonpsychopaths. This effect was present despite the fact that there were no behavioral differences between groups. This finding may be due to the simplicity of the behavioral task (e.g., ceiling effects) or, more likely, representative of the greater

sensitivity of ERP measures to group differences in information processing. This latter conclusion is consistent with a number of other ERP studies on psychopathy (Jutai et al 1987; Raine and Venables 1988; Kiehl et al in press) that found ERP differentiation occurred with little or no behavioral differences between experimental conditions.

The reduced P300 amplitude for target stimuli in psychopaths apparently contradicts the finding by Raine and Venables (1988) of an enhanced P300 to visual target stimuli, making it necessary to examine the methodology of both studies. First, with regard to paradigm, Raine and Venables (1988) employed a visual continuous performance task (CPT), whereas in this study we employed a visual oddball task. In the CPT the participant must discriminate between multiple different nontarget stimuli, whereas in the oddball paradigm all nontargets are identical. With regard to participant classification, both studies distinguished psychopaths from nonpsychopaths by performing a median split on scores on the PCL (Raine and Venables 1988) or its revision, the PCL-R (present study) in a prison sample. Raine and Venables (1988) did not report the median score in their sample; however, if that sample was representative of the larger British prison population from which it was drawn (PCL-R mean score

Table 3. Correlations between Psychopathy (PCL-R Score) and P300 and N550 Amplitude Measurements for Target Stimuli at Prefrontal (F7, Fpz, F8), Frontal (F3, Fz, F4), Central (C3, Cz, C4), Parietal (P3, Pz, P4), and Temporal (T3, T4) Electrode Locations

PCL-R	F7	Fpz	F8	F3	Fz	F4	C3	Cz	C4	P3	Pz	P4	T3	T4
P300 peak amplitude														
<i>R</i>	-.10	.12	-.10	-.22	-.29	-.30	-.52	-.58	-.54	-.47	-.50	-.50	-.40	-.45
<i>p</i> value	.65	.60	.67	.34	.20	.18	.02	.007	.02	.03	.02	.02	.08	.05
N550 mean amplitude														
<i>R</i>	-.37	-.46	-.26	-.51	-.56	-.51	-.55	-.61	-.47	-.43	-.49	-.34	-.48	-.24
<i>p</i> value	.10	.04	.24	.02	.008	.02	.01	.003	.03	.05	.02	.14	.03	.29

17.8, standard deviation 8.6, as reported in Hare 1991), the median score was probably substantially lower than the median score of 29 in our study; however, the results of our correlational analysis suggest that differences between studies in the median values should not affect the findings.

The psychopaths' P300 deficit to target stimuli supports the long-standing idea that psychopathy is characterized by an inability or deficiency in sustaining attention or appropriately allocating attentional resources to task demands (Cleckley 1976; Hare 1993; Kosson 1996; Kosson and Newman 1986). Because this performance "deficit" was present only for the target condition and not the nontarget condition, it appears to indicate that it is a specific, rather than a global deficit in psychopathy. It might be that psychopaths are abnormal in their ability to mobilize and rapidly focus attention to stimuli to which they are required to respond. Once focused, it may be extremely difficult for them to remobilize and switch attentional resources (cf. Jutai and Hare 1983; Kosson 1996; Newman 1998).

We have provided further confirmation that psychopaths exhibit an abnormal late centrofrontal negativity in a task that requires a decision and response; however, in contrast to Williamson et al (1991) and Kiehl et al (in press), we observed this negativity for a task that places no explicit demands on linguistic processing. This raises the question of what aspect of processing is responsible for the negativity. Williamson et al employed a Go/No-go paradigm, indicating that the late negativity might be due at least in part to response inhibition. Our observation that the late negativity only occurred in response to the target stimuli indicates that it is unlikely to be due to response inhibition, confirming the conclusion of Kiehl et al. It remains to be determined what other processes these negative waves represent. It should be noted that the larger N550 in psychopaths than in nonpsychopaths may have been due, at least in part, to the psychopaths' reduced P300.

One additional interesting effect found in this study was that the peak amplitude of the P300 was greater over the right than over the left hemisphere electrode sites in nonpsychopaths but not in psychopaths. It is important to note that this reduced P300 asymmetry in psychopaths was present even after using the normalization procedure described in McCarthy and Woods (1985). There is a relatively large body of evidence that suggests psychopathy is associated with weakly or unusually lateralized cerebral hemispheres (Hare and McPherson 1984; Hare and Jutai 1988; and more recently, Day and Wong 1996). This hemispheric asymmetry in nonpsychopaths is very similar that found in healthy participants during a visual discrimination task (Alexander et al 1995). Indeed, the morphology and scalp distribution of the P300 for the

nonpsychopaths in our study very closely resembles that of healthy participants in Alexander et al's study. Interestingly, Alexander et al interpreted the right frontal-central asymmetry of the P300 to be reflective of processes involved in the sustained engagement of attentional focus. These findings suggest that future research examining the relationships among psychopathy, cerebral asymmetry, and attentional processes will be fruitful.

There is one additional interpretation of the P300 deficits in psychopaths that presents itself. Studies have shown that the auditory P300 is associated with formal thought disorder in schizophrenic patients and in healthy subjects (see McConaghy et al 1993, for a review). Ward et al (1992) reported a significant correlation between P300 amplitude reduction and scores on the Object Sorting Task (OST), a measure of thought disorder. There is growing evidence that the psychopathy is associated with formal thought disorder. For example, Williamson (1991) found that 20 of 21 psychopaths, assessed with the PCL-R; (Hare 1991), met the Thought, Language, and Communication (TLC; Andreasen 1979) criteria for thought disorder. More recently, Gillstrom (1994) found that psychopaths performed poorly on the Proverbs test, a test that reflects a breakdown in thought processes and is sensitive to the thought disorder associated with schizophrenia (Gorham 1956). These results suggest that future research on psychopathy and the P300 should employ both visual and auditory paradigms and assess formal thought disorder.

In conclusion, we have attempted to clarify the relationships between psychopathy and the P300 response during a visual oddball task. The present results are consistent with the clinical literature on psychopathy and support the hypothesis that psychopathy is associated with difficulties in the effective modulation and allocation of attentional resources and that these processing difficulties may be related to the presence of thought disorder.

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