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Differentiating Among Prefrontal Substrates in Psychopathy: Neuropsychological Test Findings

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Frontal lobe and consequent executive dysfunction have long been related to psychopathy. More recently, there have been suggestions that specific regions of frontal cortex, rather than all of frontal cortex, may be implicated in psychopathy. To examine this issue, the authors presented 25 individuals with psychopathy and 30 comparison individuals with measures preferentially indexing the orbitofrontal cortex (OFC; object alternation task), dorsolateral prefrontal cortex (DLPFC; spatial alternation task), and anterior cingulate cortex (ACC; number-Stroop reading and counting tasks). The individuals with psychopathy showed significant impairment on the measure preferentially sensitive to OFC functioning. In contrast, the 2 groups did not show impairment on the measures preferentially sensitive to the functioning of the DLPFC or ACC. These results are interpreted with reference to executive dysfunction accounts of the disorder.

Keywords: psychopathy, orbitofrontal cortex (OFC), dorsolateral prefrontal cortex (DLPFC), anterior cingulate cortex (ACC)

Psychopathy is characterized by a callous, shallow, and manipulative affective-interpersonal style combined with antisocial and reckless behavior (Hare, 1991). Individuals with psychopathy not only show little concern about the effects of their actions on other individuals but also appear to show little regard for the impact of actions on themselves. Thus, they often commit impulsive, poorly planned crimes for which the likelihood of being caught is high, and they do not avoid behaviors for which they have previously been punished (Hare, 1991).

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Frontal lobe impairment and consequent executive dysfunction have long been related to impulsivity and antisocial behavior (Barratt, 1994; Elliot, 1978; Gorenstein, 1982; Moffitt, 1993a; Raine, 1997, 2002). Indeed, a series of brain imaging studies of aggressive individuals have supported the suggestion of reduced frontal functioning in aggressive individuals (Raine et al., 1994; Raine, Buchsbaum, & LaCasse, 1997; Raine, Lencz, Bihrle, LaCasse, & Colletti, 2000; Raine, Meloy, et al., 1998; Raine, Phil, Stoddard, Bihrle, & Buchsbaum, 1998; Volkow et al., 1995; Volkow & Tancredi, 1987). Moreover, there is ample evidence that individuals with antisocial behavior show impaired performance on measures of executive functioning (Kandel & Freed, 1989; Moffitt, 1993b; Morgan & Lilienfield, 2000). However, it should be noted that the frontal lobe positions are relatively underspecified; typically, they do not distinguish between different forms of executive dysfunction or different regions of the prefrontal cortex. In addition, it remains unclear whether the executive dysfunction relates to antisocial behavior or problems that are comorbid with the executive dysfunction; specifically, there are strong suggestions of executive dysfunction in attention deficit hyperactivity disorder (ADHD). Children with ADHD are highly comorbid for conduct disorder and even psychopathic tendencies (Biederman, Newcorn, & Sprich, 1991; Colledge & Blair, 2001; Hinshaw, 1987; Taylor, Schachar, Thorley, & Wieselberg, 1986). In their review of the literature, Pennington and Ozonoff (1996) concluded that executive dysfunction was related to ADHD symptomatology; they argued that children with conduct disorder who are not comorbid for ADHD do not present with executive dysfunction.

One antisocial population that has shown no indications of impairment on measures of executive function linked to a main region of the frontal cortex, the dorsolateral prefrontal cortex (DLPFC), are individuals with psychopathy (Kandel & Freed, 1989; LaPierre, Braun, & Hodgins, 1995; Mitchell, Colledge, Leonard, & Blair, 2002). Thus, individuals with psychopathy have been found to show no impairment on the Wisconsin Card Sorting Test (WCST; Grant & Berg, 1948; Hare, 1984; Heaton, Chelune, Talley, Kay, & Curtis, 1993; LaPierre et al., 1995), the Controlled Oral Word Association Test (COWAT; Benton & Hamsher, 1989; Hart, Forth, & Hare, 1990; Smith, Arnett, & Newman, 1992; Roussy & Toupin, 2000), or the extradimensional-shift component of the intradimensional/extradimensional (ID/ED) task (Mitchell, et al., 2002). However, individuals with psychopathy do appear to show executive dysfunction on measures linked to ventrolateral/orbitofrontal cortex (OFC) dysfunction, for example, the Porteus Maze Test (Porteus, 1915/1965), motor go/no-go tasks, and measures of response reversal/extinction such as the ID/ED task and the one-pack card playing task (LaPierre et al., 1995; Roussy & Toupin, 2000; Mitchell et al., 2002). Moreover, reduced OFC functioning has been reported in individuals with psychopathy during an imaging study involving an aversive conditioning task (Veit et al., 2002). Thus, individuals with psychopathy do present with frontal lobe dysfunction albeit dysfunction that is selective to those executive functions mediated by the ventrolateral/OFC rather than the DLPFC.

Antisocial or impulsive behavior has also been linked to the medial frontal/anterior cingulate (ACC) dysfunction (Foster, Hillbrand, & Silverstein, 1993; Bush et al., 1999; Teichner, Golden, Van Hasselt, & Peterson, 2001). Very little is known about the possible contribution of medial frontal/ACC pathology in psychopathy. Recently, however, reduced ACC activation (both in its rostral and caudal divisions as well as the posterior cingulate) was observed in individuals with psychopathy during an emotional memory and an aversive conditioning task (Kiehl et al., 2001; Veit et al., 2002). From their results, Kiehl et al. (2001) concluded that some aspects of psychopathy may be related to abnormal function in the ACC.

The Stroop task is a task that has been consistently shown to recruit the ACC (and other frontal regions, particularly regions of the DLPFC) on functional imaging (Bench et al., 1993; Bush et al., 1998; Carter, Mintun, & Cohen, 1995; Derbyshire, Vogt, & Jones, 1998; Fan, Flombaum, McCandliss, Thomas, & Posner, 2003; MacLeod & MacDonald, 2000; Pardo, Pardo, Janer, & Raichle, 1990; Ravnkilde, Videbech, Rosenberg, Gjedde, & Gade, 2002; for reviews, see Botvinick, Cohen, & Carter, 2004, and MacLeod & McDonald, 2000). Crucially, human lesion studies have shown that the ACC is necessary for Stroop performance; patients with lesions of the ACC present with profound increases in the level of interference that they show during incongruent Stroop trials (Stuss, Floden, Alexander, Levine, & Katz, 2001; Swick & Jovanovic, 2002).

Only two previous studies have used the classic word-color Stroop task to test individuals with psychopathy (Hiatt, Schmitt, & Newman, 2004; Smith, Arnett, & Newman, 1992). Both these studies found that individuals with psychopathy performed similarly to comparison individuals in terms of the number of errors and the level of interference (Hiatt et al., 2004, Experiment 1; Smith et al., 1992). In addition, Brinkley, Schmitt, and Newman (2006) examined the level of interference in a Stroop task as a function of semantic relatedness of the target response to the distractor and also reported that individuals with psychopathy and comparison individuals displayed comparable interference.

In contrast to Hiatt et al. (2004; Experiment 1), Smith et al. (1992) and Brinkley et al. (2006), Newman, Schmidt, and Voss (1997) reported that individuals with psychopathy showed an abnormal pattern of interference (less interference) relative to comparison individuals on a Stroop-type interference task (see also Hiatt et al., 2004, Experiment 2, for a partial replication). In this task, which is based on methodology introduced by Gernsbacher and Faust (1991), participants are presented with two consecutive pictures or words and are instructed to indicate whether the two pictures (or words) are conceptually related. On word trials, the first word was presented with a superimposed picture. On picture trials, the first picture was presented with a superimposed word. In each case, the participants were instructed to ignore this distractor stimulus. However, on half the trials (the incongruent trials) in which the consecutively presented stimuli were unrelated, the distractor stimulus was conceptually related to the first stimulus (e.g., the words *soup* and *rain* were presented with the superimposed picture of an umbrella). Although healthy individuals were found to be slower to respond to the incongruent trials than to the congruent trials (Gernsbacher & Faust, 1991), the individuals with psychopathy were not (Newman et al., 1997). In addition, Hiatt et al. (2004, Experiment 3) using a color-word Stroop task in which the color information was spatially separated from the word information also found reduced interference. Reduced interference could reflect either superior ACC functioning in individuals with psychopathy or a reduction in the strength of the pathways mediating the responses.

One difficulty with previous investigations of interference in Stroop-type paradigms is that they are not very sensitive; they do not typically allow parametric manipulation of the level of interference. This makes the detection of subtle effects difficult. However, the number-Stroop task does allow a parametric assessment of cognitive interference (see Figure 1). In this task, the participant is presented with numbers on the screen (e.g., three 4s) and has to either enumerate (i.e., three) or identify (i.e., 4) the numbers presented to them. Task difficulty can be manipulated by altering the symbolic number line distance between the numerosity and the

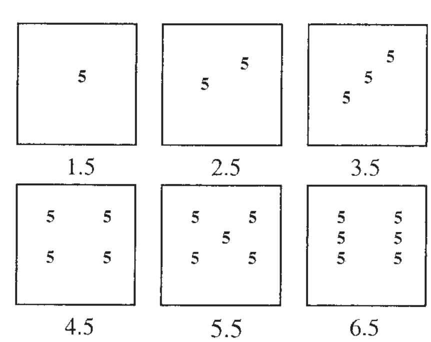

Figure 1. Example stimuli involving the numeral 5.

identity of the numbers presented (i.e., three 4s represent a symbolic number line distance of 1, whereas two 4s would represent a symbolic number line distance of 2). Specifically, task difficulty is a function of the symbolic number line distance; that is, task difficulty or cognitive interference increases as symbolic number line distance decreases (Pavese & Umilta, 1998, 1999; K. S. Blair, Morton, & Blair, 2006a).

The number-Stroop paradigm is particularly interesting because although participants are considerably faster at reading numerals rather than at counting them, the interference in this paradigm is reciprocal; that is, reading numerals interferes with counting numerals and counting numerals interferes with reading numerals (K. S. Blair, Morton, & Blair, 2006a). With respect to the number line distance interference effect, recent functional MRI (fMRI) work has shown that this effect is reflected in ACC activation; that is, ACC activation increases as the symbolic number line distance decreases. In addition, this ACC activation is seen regardless of whether the reading response or the counting response is the distractor stimulus (K. S. Blair, Morton, Maratos, et al., 2006b). In short, even subtle impairment should be evidenced by performance on the number-Stroop task.

At the cognitive level, executive dysfunction in psychopathy has been linked to impulsivity (Miller, Flory, Lynam, & Leukefeld, 2003; Whiteside & Lynam, 2001), conceptualized as (lack of) premeditation and (lack of) perseverance. Lack of premeditation is likened to the "inability to inhibit previously rewarded behavior when presented with changing contingencies" (Whiteside & Lynam, 2001, p. 687) and lack of perseverance "may be related to disorders that involve the inability to ignore distracting stimuli or to remain focused on a particular task" (Whiteside & Lynam, 2001, p. 687). Executive dysfunction in psychopathy has also been linked to impaired response modulation—the "rapid and relatively automatic (i.e., noneffortful or involuntary) shift of attention from the effortful organization and implementation of goal-directed behavior to its evaluation" (Newman et al., 1997, p. 564).

From these accounts, it could be expected that individuals with psychopathy would be impaired on a broad range of tasks, indeed on tasks that could be speculated to recruit the ventrolateral/OFC, DLPFC, and ACC. Thus, let us consider the ID/ED task. In this task, there are two principal measures: First, the number of response reversal errors (e.g., when choosing between the two shapes, the participant continues to respond to the shape that had resulted in reward but that now, when responded to, results in punishment). Second, the number of ED errors (e.g., when the participant responds by choosing one or another shape despite the fact that the reward contingency is based on the lines that accompany the shapes). Both response reversal and ED shifting would appear to require the inhibition of a previously rewarded behavior or response modulation. During response reversal, the participant can be considered to inhibit the response to the previously rewarded shape and shift attention to the new contingency information. During ED shifting, the participant can be considered to inhibit the response to the previously rewarded class of stimuli (shape rather than lines) and shift attention to the new contingency information. However, whereas inhibition or response modulation accounts can explain the response reversal impairment shown by individuals with psychopathy on the ID/ED task, these accounts have more difficulty explaining the lack of an impairment in ED shifting shown by the same individuals on this task (Mitchell, Colledge, et al., 2002). Yet an account of this data can be provided from the perspective of cognitive neuroscience. Thus, individuals with psychopathy present with impairment to those processes, mediated by the OFC, that allow the alternation of responding to different objects as a function of contingency change (Shape 1 vs. Shape 2). However, they do not present with impairment to those processes, mediated by the DLPFC, that allow the alternation of responding to different semantic categories (shapes vs. lines) as a function of contingency change. In short, the claim would be that even if a characterization of the impairment in individuals with psychopathy in terms of inhibition or response modulation was correct, it would be necessary to constrain such accounts such that they were not domain general but rather specific to particular neurocognitive systems.

Of course, given the implications for the domain general accounts of the ability of individuals with psychopathy to perform attentional shifts mediated by the DLPFC rather than response reversal mediated by the ventrolateral/OFC, it would be useful if the results from the ID/ED task (Mitchell et al., 2002) could be replicated and extended. To examine this issue, we presented individuals with psychopathy with three different tasks: object alternation (OA), spatial alternation (SA; also known as delayed alternation), and the number-Stroop task. Although all of these tasks recruit regions beyond the frontal cortex, they are interesting in that they differentially tax regions within the frontal cortex.

In the OA task, the participant has to modulate his or her response to objects as a function of contingency change. Neuroimaging data indicate that both the OFC and DLPFC show responses during OA (Curtis, Zald, Lee, & Pardo, 2000; Zald, Curtis, Folley, & Pardo, 2002). However, the neuropsychological literature indicates that only OFC damage, not DLPFC damage, disrupts performance on the OA task (Freedman, Black, Ebert, & Binns, 1998; Mishkin, Vest, Waxler, & Rosvold, 1969; Pribram & Mishkin, 1956). In other words, although there may be associated activity in the DLPFC during OA, this does not appear to be necessary for task performance.

In the SA task, the participant has to modulate his or her responses to different spatial locations as a function of contingency change. Neuroimaging studies have shown a neural response in the DLPFC but in not the OFC during performance of the SA task (Curtis et al., 2000; Zald et al., 2002). Damage to the DLPFC, but not to the OFC, disrupts performance on the SA task (Brutkowski, Mishkin, & Rosevold, 1963; Mishkin et al., 1969). Both the OA and SA tasks have been used extensively to assess probable prefrontal dysfunction in psychiatric disorders, including major depressive disorder, obsessive compulsive disorder and schizophrenia (Abbruzzese, Ferri, & Scarone, 1997; Cavedini, Ferri, Scarone, & Bellodi, 1998; Freedman, 1994).

In the number-Stroop task, the participant has to either enumerate or identify the numbers presented to them and inhibit responses to the competing numerical information. Neuroimaging work has shown that the ACC is involved in mediating the number-Stroop task (Bush et al., 1998; K. S. Blair, Morton, Maratos, et al., 2006b). If individuals with psychopathy have a frontal impairment specific to OFC, they could be expected to show impaired performance on the OA task but not on the number-Stroop task or the SA task. If individuals with psychopathy have ACC impairment, they could be expected to show increased interference on the number-Stroop task relative to comparison individuals. Finally, if individuals with psychopathy have a more generalized executive deficit relating to impulsivity or reduced response modulation, it might be hypothesized that they should show impairment on the number-Stroop task, the OA task, and the SA task. We tested these hypotheses.

Method

Participants

Participants were 55 men selected from a pool of individuals residing in Category B (second-highest security level) institutions in England. In accordance with the established criteria of the literature and the established guidelines of the Psychopathy Checklist–Revised (PCL-R; Hare, 1991), individuals with a PCL-R score of 30 or more were included in the psychopathic group, whereas individuals with a PCL-R score of 19 or less were included in the comparison group. Individuals with a PCL-R score between 20 and 29 were excluded from the study.

Although a total of 55 inmates participated in the study, inmate transfers prevented some individuals from participating in both testing sessions. Consequently, 20 individuals took part in both studies, 18 individuals took part in the OA/SA tasks only, and 17 individuals took part in the number-Stroop tasks only. Raven's Advanced Matrix-Set I (Raven, 1965) was used as an estimate of general intelligence, and the National Adult Reading Test (NART; Nelson & Willison, 1991) was used as an estimate of verbal intelligence. There were no significant group differences in age, Raven's scores, or NART scores for either task; see Table 1 for full participant details. The sample was made up of 44 Caucasian, 9 Afro-Caribbean, and 2 Asian participants (6 Afro-Caribbean participants in the psychopathic group, and 3 Afro-Caribbean and 2 Asian participants in the comparison group).

Measures

The Psychopathy Checklist–Revised (PCL-R). The PCL-R consists of 20 behavioral items, and individuals can score between 0 and 2 on each item. PCL-R scores are most often obtained on the basis of a file review and a semistructured interview but can also be reliably obtained from file notes alone (Hare, 1991; Wong, 1988). PCL-R scores of all participants in the study were determined independently by two raters, with one rater scoring the participant on the basis of a file review only and the second rater scoring the participant on the basis of both a file review and, when possible, a semistructured interview. In this study, 8 participants (5 psychopathic and 3 comparison) were unavailable for interview and so were scored on the basis of file notes only by both raters. Interrater reliability for those taking part in the study was established by means of a Spearman rank correlation. The correlation, $r_{\text{ranks}} = .96$, $p < .001$), is similar to that reported in the literature (e.g., Hare, 1991). The intraclass reliability for PCL-R ratings for participants taking part in the OA/SA and number-Stroop tasks was similarly high, $F(1, 35) = 124.92$, $p < .001$, and $F(1, 36) = 129.88$, $p < .001$, respectively.

The OA and SA Tasks. The OA and SA tasks were adapted from the noncomputerized tasks administrated in the Freedman et al. (1998) study. Two objects were presented to the participants on each trial, one on either side of the computer screen. For the OA task, one of the objects depicted a blue horse, and the second object depicted a green carrot. For the SA task, the objects depicted on both sides were identical red cars (i.e., the SA could not be solved by reference to a specific object). At the viewing distance of 60 cm, the two objects extended 22.91 arc min horizontally and 7.92 arc min vertically. The instructions to the participants for both tasks read

> In this task, two objects are going to appear on the screen. Behind one of them is a £20 note. I want you to try to get the £20 note every single time. Remember, your job is to get the £20 note every single time. There will always be a £20 note under one of the objects. There is a rule that you can use to get the money every time. You need to work out this rule. Any questions?

The participants were then informed that the task involved fictitious money and that they would not receive any form of payment for taking part in the task. For the OA task, the participants' task was to learn that the object behind which the £20 note was located was being alternated after each correct response. On the first trial of the OA task, both objects were baited with a £20 note. For the second trial, the £20 note was located behind the object not chosen on the first trial. On each subsequent trial following a correct response, the other object was baited. After an incorrect response, the £20 note remained behind one object until the participant made a correct response.

For the SA task, the participants' task was to learn that the side on which the £20 note was located was being alternated after each correct response. On the first SA trial, both objects were baited with a £20 note. For the second trial, the £20 note was located on the side not chosen on the preceding trial. On each subsequent trial following a correct response, the other side was baited. Following an incorrect response, the £20 note remained behind one side until the participant made a correct response. In the Freedman et al. (1998) study, a correction procedure was implemented in the program such that if a participant failed to find the £20 note after 12 consecutive responses, the £20 note was placed behind the other object (OA) or in the other location (SA). However, this correction procedure was never actually used in the present task because no participant chose the incorrect object on 12 consecutive trials. For both tasks, the time between response and next stimulus presentation was 1 s. The participant was considered to have learned the task after 12 consecutive correct responses, and after the participant achieved that goal, testing for the task was discontinued. If the participant had not reached 12 consecutive correct trials after 80 trials, testing for the task was discontinued. Responses were recorded by the means of a click with the mouse on top of the chosen

Table 1
Participants' Age and Scores on the Psychopathy Checklist–Revised and Intelligence Tests

Group	Age			PCL-R			Raven			NART		
	M	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
OA/SA tasks												
Psychopathic group ($n = 17$)	36.59	10.27	23–56	32.05	2.19	30–37	8.00	2.43	3–11	21.45	9.06	8–45
Comparison group ($n = 19$)	36.89	9.61	23–53	10.09	5.33	1.6–18.95	8.17	2.15	4–12	22.51	7.46	9–36
Number–Stroop tasks												
Psychopathic group ($n = 19$)	35.47	7.65	22–53	32.47	2.08	30–37	7.95	1.90	3–10	23.43	7.62	8–45
Comparison group ($n = 18$)	31.50	8.26	20–44	8.21	4.62	1.1–17.50	8.22	2.21	5–12	22.70	8.59	12–36

Note. PCL-R = Psychopathy Checklist–Revised (Hare, 1991); Raven = Raven's Advanced Matrix Set I (Raven, 1965); NART = National Adult Reading Test (Nelson & Willison, 1991); OA = object alternation; SA = spatial alternation.

object. Stimuli were controlled by the software VisualBasic (Version 5, Microsoft, Redmond, WA) and presented on a Dell Inspiron 8100 (Dell Computers, Round Rock, TX).

The Number-Stroop Counting Task. The number-Stroop counting task was adapted from the task administrated in Pavese and Umilta's (1999) study. Stimuli were patterns of one-, two-, three-, four-, five-, or six-numeral 1s, 2s, 3s, 4s, 5s, and 6s. Patterns resembled those on a die. All possible combinations of numerosities and digits occurred. So, for example, one digit 5 was depicted in one event (1.5), two digit 5s in another event (2.5), three 5s in a third event (3.5), four 5s in a fourth event (4.5), five 5s in a fifth (5.5), and finally six 5s in a last event (6.5; see Figure 1, e.g., stimuli involving the digit 5). The digits 1, 2, 3, 4, and 6 were similarly presented in six different patterns. Thus, the final stimuli set consisted of (6×5) 30 different events. Of these, 6 events represented a symbolic number line distance of 0 (1.1, 2.2, 3.3, 4.4, 5.5, and 6.6), 10 represented a distance of 1 (1.2, 2.1, 2.3, 3.2, 3.4, 4.3, 4.5, 5.4, 5.6, and 6.5), 8 a distance of 2 (1.3, 2.4, 3.1, 3.5, 4.2, 4.6, 5.3, and 6.4), and 6 a distance of 3 (1.4, 2.5, 3.6, 4.1, 5.2, and 6.3).

The instructions read, "In this task, you are going to see numbers on the screen. You must press the button that corresponds to the number of numbers on the screen. So, if there are three 4s, you must press the *3* button. Try to do this as quickly as possible without making errors." Stimuli appeared in black against a white background and were presented in the center of the screen in font type Times (type size = 48 points) on a Macintosh system (Apple Computer, Cupertino, CA). Each trial began with a fixation point (+) presented for 500 ms in the middle of the screen. When the fixation point was extinguished, it was replaced immediately with the Stroop stimulus for that trial. The Stroop stimulus was exposed until a response from the participant was registered, at which point the screen went blank before the presentation of a new fixation point initiating the next trial. Participants did not receive feedback on their performance either before or after the study. Trials were presented randomly within each block, and all 36 trials were presented in every block. The entire run consisted of 10 blocks. Thus, a total of 360 trials were presented to each participant. Responses were recorded by means of six keys, with key *E* denoting response number 1, *R* denoting 2, *T* denoting 3, *U* denoting 4, *I* denoting 5, and *O* denoting 6. Participants responded with their index, middle, and ring fingers of both hands. At the viewing distance of 50 cm, the visual angle ranged from 4.66 arc min horizontally and 4.92 arc min vertically (for numerosity 6 displays) to 0.42 arc min horizontally and 0.75 arc min vertically (for numerosity 1 displays). Stimuli were developed and controlled by the software SuperLab Pro (Version 2.0, Cedrus Corp., San Pedro, CA) and were presented on a Macintosh G3 (Apple Computer).

The Number-Stroop Reading Task. The experimental design and presentation of the number-Stroop reading task were identical to those of the number-Stroop counting task with the one crucial exception that participants were now asked to respond to the number on the screen rather than the number of numbers on the screen. Accordingly, instructions for the number-Stroop reading task read, "In this task, you are going to see numbers on the screen. You must press the button that corresponds to the number on the screen. So, if there are three 4s, you must press the *4* button. Try to do this as quickly as possible without making errors."

Procedure

Each participant was tested individually in a quiet interview room. After giving written consent, each participant was presented with the four tasks as part of a larger neuropsychological test battery. The data collection for the number-Stroop counting and reading tasks was initiated following the completion of the data collection for the OA and SA tasks. Therefore, participants who participated in the OA and SA tasks as well as in the Stroop tasks always first participated in the OA and SA tasks. The OA and SA tasks were always presented within the same session and were counterbalanced so that half of the group with psychopathic scores and half of the comparison group were presented with the OA task first, and the other half were presented with the SA task first. Likewise, the number-Stroop counting and reading tasks were always presented within the same session and were counterbalanced so that half of the psychopathic group and half of the comparison group were presented with the number-Stroop counting task first, and the other half were presented with the number-Stroop reading task first. Participants received no financial or other compensation for taking part in the study.

Results

OA/SA Tasks

For the purpose of the analyses, on any trial, choosing the object behind which the £20 note was located was scored as correct. In addition, the learning criterion was 12 consecutive correct responses, and the failure criterion was 80 trials.

An initial 2 (group: psychopathic vs. comparison) × 2 (performance: pass vs. fail) chi-square test was conducted on the OA data. This revealed a significant group difference, $\chi^2(2, N = 36) = 9.92$, $p < .01$; a significantly higher number of individuals with psychopathy failed the task relative to comparison individuals: fail (psychopathic group) = 13, pass (psychopathic group) = 4, fail (comparison group) = 6, pass (comparison group) = 13. All 36 participants passed the SA task; thus no analysis was conducted on failure rates for the SA task. Next, a 2 (group: psychopathic vs. comparison) × 2 (task: OA vs. SA) analysis of variance (ANOVA) was conducted on the error data. This revealed a main effect of task, $F(1, 34) = 91.20$, $p < .001$, $\eta_p^2 = .73$; there was a significantly greater number of errors on the OA trials than on the SA trials, *M* (OA trials) = 27.31, *SE* = 2.55; *M* (SA trials) = 3.27, *SE* = 0.66. There was also a main effect of group, $F(1, 34) = 5.37$, $p < .05$, $\eta_p^2 = .14$; individuals with psychopathy committed more errors than did comparison individuals, *M* (psychopathic group) = 18.47, *SE* = 1.96, *M* (comparison group) = 12.11, *SE* = 1.96. However, there was a significant Group × Task interaction, $F(1, 34) = 3.61$, $p < .05$, one-tailed; $\eta_p^2 = .10$). As can be seen in Table 2, although the two groups committed a comparable number of errors on the SA task, the individuals with psychopathy presented with an increased number of errors on the OA task. A follow-up *t* test confirmed that the difference between the psychopathic and comparison groups on the OA task was significant, $t(34) = -2.19$, $p < .05$, Cohen's $d = 0.73$, *M* (psychopathic group) = 32.88, *SE* = 3.24; *M* (comparison group) = 21.74, *SE* = 3.85. Moreover, 82% (14/17) of the individuals with psychopathy performed beyond the range of scores of healthy participants in the study by Freedman et al. (1998), indicating marked impairment on this task. The *t* test performed on the two groups for the SA task was not significant ($t = -1.19$, *ns*). Moreover, only 12% (2/17) of the individuals with psychopathy

Table 2
Mean Error Rates and Standard Deviations for the Object Alternation (OA) and Spatial Alternation (SA) Tasks

	OA task		SA task	
Group	*M*	*SD*	*M*	*SD*
Psychopathic (*n* = 17)	32.88	3.24	4.06	1.28
Comparison (*n* = 19)	21.74	3.85	2.47	0.52

and 5% (1/19) of the comparison individuals performed beyond the range of scores of healthy participants in the study by Freedman et al. (1998). In short, the individuals with psychopathy performed comparably to comparison individuals on the SA task but were significantly impaired relative to comparison individuals on the OA task.

The Number-Stroop Tasks

Trials in which the reaction times (RTs) exceeded 1,800 ms or were less than 250 ms were excluded from further analysis. RTs and error rates were then entered into ANOVAs to examine the effect of group on congruence and error rates. Only RTs for correct responses were entered into the analyses.

The design of the number-Stroop tasks allowed not only a general examination of participant performance according to congruence (i.e., congruent vs. incongruent trials) but also a more finely detailed analysis of sensitivity to interference according to symbolic number line distance. Thus, some trials represented a symbolic number line distance of 0 (e.g., 1.1, 2.2), 10 represented a distance of 1 (e.g., 1.2, 2.1), 8 a distance of 2 (e.g., 1.3, 2.4) and 6 a distance of 3 (e.g., 1.4, 2.5). According to our hypothesis, interference should vary as a function of the symbolic number line distance. We conducted an analysis on the data examining the impact of symbolic number line distance on group RT data. This involved a 2 (group: psychopathic vs. comparison) × 2 (task: counting vs. reading) × 4 (Distance: 0, 1, 2, and 3) ANOVA being conducted on the RT data. The analysis revealed, first, that there was a significant main effect of task, $F(1, 35) = 15.99$, $p < .001$, $\eta_p^2 = .31$; RTs to reading trials were faster than RTs to counting trials: *M* (reading trials) = 823.08, *SE* = 22.26; *M* (counting trials) = 892.22, *SE* = 23.46. Second, there was a main effect of distance, $F(3, 105) = 22.91$, $p < .001$, $\eta_p^2 = .58$, with the linear contrast being significant, $F(1, 35) = 39.25$, $p < .001$, $\eta_p^2 = .53$; RTs increased as a function of decreased symbolic number line distance, *M* (Distance 3) = 873.05, *SE* = 20.52; *M* (Distance 2) = 872.06, *SE* = 21.16; *M* (Distance 1) = 862.80, *SE* = 22.18; *M* (Distance 0) = 822.70, *SE* = 22.49. Third, there was a main effect of group, $F(1, 35) = 5.26$, $p < .05$, $\eta_p^2 = .13$; the psychopathic group was slower to respond to the stimuli than was the comparison group, *M* (psychopathic group) = 906.05, *SE* = 29.53; *M* (comparison group) = 809.26, *SE* = 30.3; see Table 3 for participant RTs on the number-Stroop tasks. However, there was no significant Distance × Group, Task × Group, or Task × Distance × Group interaction. In short, although individuals with psychopathy were slower overall at responding to the stimuli, they showed task and distance effects comparable to those of the comparison individuals (see Table 3 for participant RTs on the number-Stroop tasks overall).

Inspection of the means in Table 3 might indicate that the distance effect in the present study was carried by the congruent condition. We thus conducted a second analysis on the data examining the impact of symbolic number line distance on group RT data not involving the Distance 0 congruent condition. This involved a 2 (group: psychopathic vs. comparison) × 2 (task: counting vs. reading) × 3 (Distance: 1, 2, and 3) ANOVA being conducted on the RT data. The analysis revealed, first, that there was a significant main effect of task, $F(1, 35) = 13.09$, $p < .001$; $\eta_p^2 = .27$; RTs to reading trials were faster than RTs to counting trials, *M* (reading trials) = 835.48, *SE* = 22.26; *M* (counting trials) = 892.22, *SE* = 23.46. Second, the linear contrast for distance was again significant, $F(1, 35) = 3.51$, $p < .05$, one-tailed; $\eta_p^2 = .10$. RTs increased as a function of decreased symbolic number line distance, *M* (Distance 3) = 873.05, *SE* = 20.52; *M* (Distance 2) = 872.06, *SE* = 21.16; *M* (Distance 1) = 862.80, *SE* = 22.18. However, there was no significant Distance × Group, Task × Group, or Task × Distance × Group interaction. In short, although individuals with psychopathy were slower overall at responding to the stimuli, they showed task and distance effects comparable to those of comparison individuals. In addition, the distance effect in the present paradigm was present for distances involving incongruent data only (i.e., Distances 1, 2, and 3; see Table 3).

Next we wanted to examine the effect of group on congruence on the number-Stroop counting and reading tasks separately. A 2 (group: psychopathic vs. comparison) × 2 (congruence: congruent vs. incongruent) ANOVA was first conducted on the counting data. The analysis revealed, first, that there was a main effect of congruence, $F(1, 35) = 18.06$, $p < .001$, $\eta_p^2 = 0.34$; RTs to

Table 3
Participants' Reaction Times, Error Rate, and Standard Error on the Number-Stroop Tasks Overall, the Number-Stroop Counting Task, and the Number-Stroop Reading Task

		Number-Stroop											
		Overall RT				Counting RT				Reading RT			
Group	Symbolic number line distance	*M*	*SE*	Error rate		*M*	*SE*	Error rate		*M*	*SE*	Error rate	
Psychopathic (n = 19)	1	917.34	28.63	5.05	0.67	953.89	34.06	3.32	0.65	880.79	33.86	4.53	1.32
	2	920.79	29.52	4.46	0.54	956.32	38.20	2.89	0.69	885.26	35.94	3.53	0.82
	3	904.90	30.94	4.55	0.71	940.16	39.29	2.11	0.64	869.16	34.28	2.11	0.63
	0	881.16	31.38	2.08	0.66	914.74	39.33	0.58	0.23	847.58	36.76	0.68	0.23
Comparison (n = 18)	1	828.75	29.41	6.54	1.46	860.94	34.06	2.33	0.49	797.00	29.08	3.72	0.57
	2	823.33	30.32	6.68	1.33	856.94	28.78	2.17	0.43	789.72	26.86	2.11	0.35
	3	820.69	31.78	5.85	1.42	850.94	31.54	1.50	0.32	790.44	30.77	1.78	0.31
	0	764.25	32.24	1.75	0.56	804.28	27.66	0.56	0.15	724.22	29.40	0.94	0.38

Note. RT = reaction time.

congruent trials were faster than RTs to incongruent trials, *M* (congruent trials) = 859.51, *SE* = 24.29; *M* (incongruent trials) = 903.13, *SE* = 23.75. The analysis also revealed that there was a significant main effect of group, $F(1, 35) = 4.75$, $p < .05$, $\eta_p^2 = 0.12$; the psychopathic group was slower at responding to the trials than was the comparison group, *M* (psychopathic group) = 932.43, *SE* = 32.63; *M* (comparison group) = 830.30; *SE* = 33.63. However, the Congruence × Group interaction was not significant ($F < 1$, *ns*). In other words, although individuals with psychopathy were slower at responding to the trials overall, they did show the same congruence effect as comparison individuals (see Table 3 for participant RTs on the number-Stroop counting task).

A 2 (group: psychopathic vs. comparison) × 2 (congruence: congruent vs. incongruent) ANOVA was now conducted on the reading data. The analysis revealed, first, that there was a main effect of congruence, $F(1, 35) = 28.23$, $p < .001$, $\eta_p^2 = .45$; RTs to congruent trials were faster than RTs to incongruent trials, *M* (congruent trials) = 785.90, *SE* = 23.69; *M* (incongruent trials) = 835.48, *SE* = 22.25. The analysis also revealed that there was a significant main effect of group, $F(1, 35) = 5.42$, $p < .05$; $\eta_p^2 = .13$; the psychopathic group was slower at responding to the trials than the comparison group, *M* (psychopathic group) = 863.07, *SE* = 31.39; *M* (comparison group) = 758.31, *SE* = 32.25. In addition, the Congruence × Group interaction was significant, $F(1, 35) = 3.97$, $p < .05$ one-tailed, $\eta_p^2 = .10$. In other words, the psychopathic group showed less interference relative to comparison individuals on the number-Stroop reading task (see Table 3 for participant RTs on the number-Stroop reading task).

According to our hypothesis, symbolic number line effects should be evident not only in RT but also in error data. That is, the number of errors should increase as the symbolic number line distance decreases. We thus conducted an analysis on the data examining the impact of symbolic number line distance on group error data. This involved a 2 (group: psychopathic vs. comparison) × 2 (task: counting vs. reading) × 4 (Distance: 0, 1, 2, and 3) ANOVA being conducted on the error data. The analysis revealed that there was a significant main effect of distance, $F(3, 105) = 20.49$, $p < .001$, $\eta_p^2 = .48$, with the linear contrast being significant, $F(1, 35) = 32.67$, $p < .001$, $\eta_p^2 = .56$. The number of errors increased as a function of decreased symbolic number line distance, *M* (Distance 3) = 5.20, *SE* = 0.81; *M* (Distance 2) = 5.57, *SE* = 0.73; *M* (Distance 1) = 5.79, *SE* = 0.82; *M* (Distance 0) = 1.92, *SE* = 0.43 (see Table 3 for participant error rates on the number-Stroop tasks). The main effect of task and the Task × Congruence interaction were not significant. In addition, there was no significant main effect of group. In addition, the Distance × Group, Task × Group, or Task × Distance × Group interactions were not significant. In short, the impact of symbolic number line distance on error rates was comparable for the psychopathic and comparison groups (see Table 3 for participant error rates on the number-Stroop tasks overall).

As we had with the RT data, we wanted to examine whether the distance effect was also present when error data for the congruent Distance 0 was excluded. We thus conducted an analysis on the data examining the impact of symbolic number line distance on group error data involving incongruent data only. This involved a 2 (group: psychopathic vs. comparison) × 2 (task: counting vs. reading) × 4 (Distance: 1, 2, and 3) ANOVA being conducted on the error data. The analysis revealed that there was a significant main effect of distance, $F(2, 70) = 21.56$, $p < .001$, $\eta_p^2 = .38$, with the linear contrast being significant, $F(1, 35) = 30.01$, $p < .001$, $\eta_p^2 = .46$; the number of errors increased as a function of decreased symbolic number line distance, *M* (Distance 3) = 5.20, *SE* = 0.81; *M* (Distance 2) = 5.57, *SE* = 0.73; *M* (Distance 1) = 5.79, *SE* = 0.82. The main effect of task and the Task × Congruence interaction were not significant. In addition, there was no significant main effect of group. In addition, the Distance × Group, Task × Group, and Task × Distance × Group interactions were not significant. In short, the impact of symbolic number line distance on error rates as well as RTs was comparable for the psychopathic and comparison groups (see Table 3).

As with the RT data, we wanted to examine the effect of group on congruence for the number-Stroop counting and reading tasks separately. A 2 (group: psychopathic vs. comparison) × 2 (congruence: congruent vs. incongruent) ANOVA was first conducted on the counting data. The analysis revealed, first, that there was a main effect of congruence, $F(1, 35) = 47.15$, $p < .001$, $\eta_p^2 = .58$; participants committed more errors on the incongruent than on the congruent trials, *M* (congruent trials) = 0.57, *SE* = 0.14; *M* (incongruent trials) = 2.39, *SE* = 0.36. There was no significant main effect of group or Congruence × Group interaction. In short, as with the RT data, the impact of congruence on the number-Stroop counting task was comparable for the psychopathic and comparison groups (see Table 3 for participant error rates on the number-Stroop counting task).

A 2 (group: psychopathic vs. comparison) × 2 (congruence: congruent vs. incongruent) was then conducted on the number-Stroop reading data. The analysis revealed, first, that there was a main effect of congruence, $F(1, 35) = 18.09$, $p < .001$, $\eta_p^2 = .34$; participants committed more errors on the incongruent than on the congruent trials, *M* (congruent trials) = 0.81, *SE* = 0.22; *M* (incongruent trials) = 2.96, *SE* = 0.48. There was no significant main effect of group and no significant Congruence × Group interaction. In other words, in terms of error rates, the impact of congruence on the number-Stroop reading task was comparable for the psychopathic and comparison groups (see Table 3 for participant error rates on the number-Stroop reading task).

Correlational Analyses With PCL-R Factor 1, PCL-R Factor 2, and Total PCL-R Score

Next, we used a series of correlational analyses to examine the interrelationships between performance on the OA, SA, and number-Stroop tasks and score on the PCL-R and its constituent factors (see Table 4).

The correlational analysis for the OA and SA tasks revealed that performance (number of errors) on the OA task was significantly related to PCL-R Factor 1 ($r = .40$, $p < .01$) and total PCL-R ($r = .33$, $p = .05$) scores. Performance on the OA task was not significantly related to PCL-R Factor 2 score. In other words, whereas the ability to perform well on the OA task was significantly associated with PCL-R Factor 1 and total PCL-R scores, it was not associated with PCL-R Factor 2 scores (see Table 4). In contrast, there was no significant correlation between performance on the SA task and PCL-R Factor 1, PCL-R Factor 2, or total PCL-R score (see Table 4).

Table 4
Correlations Between the Performance on the Tasks Used in the Study and on the Psychopathy Checklist–Revised and Its Constituent Parts

Task	PCL-R Score		
	Factor 1	Factor 2	Total
OA	0.40**	0.24	0.33*
SA	0.18	0.15	0.19
Number-Stroop			
Overall	0.22	0.32*	0.30#
Counting	0.14	0.16	0.15
Reading	0.19	0.32*	0.31#

Note. PCL-R = Psychopathy Checklist-Revised; OA = object alternation; SA = spatial alternation.
# $p < .10$. * $p < .05$. ** $p < .01$.

For the number-Stroop tasks, we first considered performance in RTs overall. This analysis revealed that interference (RT difference between the incongruent and congruent conditions) was significantly and inversely related to PCL-R Factor 2 ($r = -.32$, $p < .05$) and total PCL-R ($r = -.30$, $p < .05$, one-tailed) scores. Level of interference was not significantly related to PCL-R Factor 1. In other words, whereas the level of interference was significantly and inversely associated with PCL-R Factor 2 and total PCL-R scores, it was not associated with PCL-R Factor 1 scores (see Table 4). We then considered performance on the number-Stroop counting and reading tasks separately. This analysis revealed no significant correlations between level of interference on the number-Stroop counting task and PCL-R Factor 1, PCL-R Factor 2, or total PCL-R score. In contrast, level of interference on the number-Stroop reading task was significantly and negatively related to PCL-R Factor 2 ($r = -.32$, $p < .05$) and total PCL-R ($r = -.31$, $p < .05$, one-tailed) scores. There was no significant correlation between performance on the number-Stroop reading task and PCL-R Factor 1 (see Table 4).

Next, we considered performance on the number-Stroop tasks in terms of error rates. None of these correlations was significant. In other words, in contrast to error rates on the OA and SA tasks and RT interference on the number-Stroop tasks, error rates on the number-Stroop tasks were not significantly associated with PCL-R Factor 1, PCL-R Factor 2, or total PCL-R score (see Table 4).

Discussion

In this study, we investigated the performance of individuals with psychopathy on targeted neuropsychological tasks. This study revealed that individuals with psychopathy did not present with a general prefrontal dysfunction. Thus, individuals with psychopathy performed comparably to comparison individuals on the SA task. They also performed comparably to comparison individuals on the number-Stroop counting task. However, they showed decreased interference relative to comparison individuals on the number-Stroop reading task. Finally, the individuals with psychopathy presented with impairment on the OA task relative to the comparison individuals.

Antisocial and impulsive behavior has consistently been linked to frontal lobe dysfunction (Barratt, 1994; Elliot, 1978; Gorenstein, 1982; Moffitt 1993a; Raine, 1997, 2002). Indeed, considerable evidence links antisocial or impulsive behavior with impairment to the DLPFC, medial frontal cortex, and OFC (Kandel & Freed, 1989; Moffitt 1993b; Morgan & Lilienfield, 2000). However, the data for individuals with psychopathy have indicated a rather more selective form of impairment. In particular, individuals with psychopathy have been found to perform comparably to comparison individuals on tasks that require use of the DLPFC, such as the WCST, COWAT, and the ED-shift component of ID/ED task (Hare, 1984; Hart, Forth, & Hare, 1990; LaPierre et al., 1995; Mitchell et al., 2002; Roussy & Toupin, 2000; Smith et al., 1992). In contrast, individuals with psychopathy have been found to be impaired on tasks requiring the OFC such as the Porteus Maze Test, motor go/no-go tasks, and measures of response reversal/extinction such as the ID/ED task and the one-pack card-playing task (LaPierre et al., 1995; Mitchell et al., 2002; Newman, Patterson, & Kosson, 1987; Roussy & Toupin, 2000). In this study, we found that individuals with psychopathy performed comparably to comparison individuals on the SA task. Performance on this task has been related to the functional integrity of the DLPFC (Brutkowski et al., 1963; Mishkin et al., 1969). However, the individuals with psychopathy were impaired on the OA task. Performance on this task has been related to the functional integrity of the OFC (Freedman et al., 1998; Mishkin et al., 1969; Pribram & Mishkin, 1956). Of course, it could be argued, given our between-groups design, that the group difference was driven by superior OA performance of the comparison individuals rather than by impaired OA performance of the individuals with psychopathy. However, this appears unlikely. The comparison individuals in the present study performed slightly worse than the comparison individuals in the Freedman et al. (1998) study; that is, they showed no signs of superior performance. In contrast, the individuals with psychopathy performed comparably to the patients with OFC lesions in the Freedman et al. study. In short, these results support the suggestion of an intact DLPFC but an impaired OFC in individuals with psychopathy. More specifically, these results suggest that a principal function of the OFC, the alteration of motor responses to objects on the basis of reinforcement information (R. J. Blair, 2004), is impaired in individuals with psychopathy. In contrast, the role of the DLPFC in the alteration of motor responses to spatial locations on the basis of reinforcement information is not impaired in individuals with psychopathy (although it is possible that other functions of the DLPFC, yet to be discerned, may be impaired in individuals with psychopathy).

It is important to note here that individuals with psychopathy are not the only population presenting with ventrolateral/OFC dysfunction and elevated levels of aggression. Thus, patients with intermittent explosive disorder (Best, Williams, & Coccaro, 2002), childhood bipolar disorder (Gorrindo, Blair, Budhani, Pine, & Leibenluft, 2005), borderline personality disorder (Dowson et al., 2004; Soloff et al., 2003), or acquired sociopathy (Anderson, Bechara, Damasio, Tranel, & Damasio, 1999; R. J. R. Blair & Cipolotti, 2000; Grafman, Schwab, Warden, Pridgen, & Brown, 1996) all present with indications of OFC dysfunction and elevated levels of aggression. All of these patient populations present with elevated levels of frustration- and threat-based reactive aggression. We suggest that the OFC dysfunction observed in the individuals with psychopathy in the present study was more related to their presentation of reactive aggression rather than to their presentation of goal-directed instrumental aggression (R. J. R. Blair, 2003). Future work is needed to test this hypothesis.

Antisocial or impulsive behavior has also been linked to medial frontal/ACC dysfunction (Bush et al., 1999; Foster et al., 1993; Teichner et al., 2001). In addition, psychopathy has been suggested to involve ACC dysfunction (Kiehl et al., 2001). Support for this suggestion has come from two recent imaging studies reporting reduced ACC functioning in individuals with psychopathy (Kiehl et al., 2001; Veit et al., 2002). Neuropsychological studies have shown that the ACC is crucially involved in the performance of the Stroop task; damage to the ACC leads to increased interference on this task (Stuss et al., 2001; Swick & Jovanovic, 2002). In studies using the classic Stroop test, individuals with psychopathy have been found to perform like comparison individuals (Smith et al., 1992). In addition, Brinkley and colleagues (2006) examined the level of interference in a Stroop task as a function of semantic relatedness of the target response to the distractor and reported that individuals with psychopathy and comparison individuals displayed comparable interference. In contrast, there have been reports of reduced interference on incongruent trials in some Stroop-type interference tasks (Hiatt et al., 2004, Experiments 2 and 3; Newman et al., 1997). In the current study, we found that the individuals with psychopathy were generally slower to respond in both the number-Stroop counting and reading tasks, but although there was no significant difference in level of interference for the counting task, the individuals with psychopathy did show less interference for the reading task. In short, the current counting task results and the results of studies by Brinkley et al. (2006), Hiatt et al. (2004, Experiment 1), and Smith et al. (1992) suggest no impairment on Stroop measures in individuals with psychopathy. In contrast, the current reading task results and the results of studies by Hiatt et al. (2004, Experiments 2 and 3) and Newman et al. (1997) suggest reduced interference in individuals with psychopathy.

How can these inconsistent results be reconciled? The response set modulation hypothesis has been used to account for reduced interference in individuals with psychopathy on Stroop-type tasks (Hiatt et al., 2004; Newman et al., 1997). According to Lorenz and Newman (2002), individuals with psychopathy fail "to process the meaning of information that is peripheral or incidental to their deliberate focus of attention" (p. 92). Thus, according to the response set modulation hypothesis, in the Newman et al. (1997) study the distractor information was processed less by the individuals with psychopathy because it was incidental to the deliberate focus of attention. The current results from the number-Stroop counting task and those of Brinkley et al. (2006) and Smith et al. (1992) challenge this suggestion, however. In these studies, the incidental information was processed appropriately by the individuals with psychopathy. Recently, it has been suggested that individuals with psychopathy may only fail to process the meaning of information when it is spatially peripheral to their focus of attention (Hiatt et al., 2004). In the Newman et al. (1997) and Hiatt et al. (2004; Experiments 2 and 3) studies, the distractor information was spatially distinct from the target information. In both variants of the number-Stroop paradigm, the distractor information was spatially distinct from the target information. However, the individuals with psychopathy only showed reduced interference for the number-Stroop reading task and not the number-Stroop counting task. It is thus unclear that spatial distinctness is the crucial variable.

Probably the dominant current model of Stroop performance is the computational task context module model of Cohen and colleagues (Cohen, Botvinick, & Carter, 2000; Cohen, Dunbar, & McClelland, 1990; Cohen, Servan-Schreiber, & McClelland, 1992). In its simplest form, the model consists of two processing pathways, one for word reading and one for color naming. Processing occurs via activation spreading between units along the pathways. The strength of these pathways is determined by the degree of training that the model receives for a specific class of input. The model receives more extensive training on the word-reading task than on the color-naming task, because of the assumption that humans have more extensive experience with the former than with the latter. This asymmetry in training intensity leads to greater connection weights in the word-reading path compared with the color-naming path; that is, after training, word reading becomes the prepotent response. The task context module model stipulates the existence of executive features: the context module and, more recently, a system for conflict monitoring (Botvinick et al., 2004). The context module units become active-dependent on task instructions. In conditions of response competition (i.e., naming the color), the context module resolves the conflict by means of supporting the processing of the task-relevant information, so that it can out-compete information that is irrelevant to the task. Thus, the task context module model predicts that an individual's level of Stroop interference is a function of the training on the respective domains, the relative activation of these respective domains by a stimulus, and also the degree to which the context or conflict monitoring modules are functioning efficiently.

If either the context or conflict monitoring modules operated inefficiently in individuals with psychopathy, heightened Stroop interference would be predicted (Cohen et al., 1990; 1992; 2000). If extreme, context or conflict monitoring dysfunction would result in the error not being detected or in the prepotent response being made and thus the individual making an incorrect response. If the dysfunction was less extreme, the error would be detected, but there would be insufficient top–down activation of the desired response to allow its rapid selection (it would be selected, just slowly; i.e., interference RTs would be high). Heightened interference in Stroop-type tasks has never been reported in individuals with psychopathy (Brinkley et al.; 2006; Hiatt et al., 2004; Newman et al., 1997; Smith et al., 1992) and was not observed in our study. According to the task demands model, reduced interference on Stroop-type tasks could be due to one of two factors.

1. *Superior functioning of the task demands module*. If the units of this module were elevated in their activation, they would boost the activation of the units representing task-relevant information, leading to less interference by units coding task-irrelevant information. This account would be consistent with the suggestion of superior ACC functioning in individuals with psychopathy, but it is inconsistent with findings reported in the current imaging literature (Kiehl et al., 2001; Veit et al., 2002).

2. *Reduced training (i.e., an education effect).* An abundance of data has shown the influence of training experience on Stroop interference levels; indeed, the Stroop effect can even be reversed with sufficient training of the nondominant response (for a review,

see Bush et al., 1998; MacLeod, 1991). Within the model, experience or training determines the strength of the processing pathways. Reduced training would mean weaker processing pathways. These weaker pathways would less strongly activate an automatic response. Instead, the response would be disproportionately determined by the task demand units. This account is consistent with the data obtained in the current study. First, according to the model, RT is determined by the activation level of the units coding the target response relative to the units coding the distractor. Generally reduced activation of these units, as must be predicted on the basis of reduced training (i.e., reduced interunit weights/connections), would generally increase RTs. Individuals with psychopathy do not always present with increased RTs relative to comparison individuals. Indeed, individuals with psychopathy may show comparable RTs (Kiehl, Hare, McDonald, & Brink, 1999; LaPierre et al., 1995) or even, under specific task conditions, reduced RTs relative to comparison individuals (Mitchell, Richell, Leonard, & Blair, 2006). However, the individuals with psychopathy were slower across conditions in the number-Stroop task.

Second, it is interesting to note that the individuals with psychopathy showed reduced interference on the reading rather than the counting task. In Stroop tasks, the reading response is regarded as prepotent (MacLeod, 1991). This prepotency is the explanation for the asymmetrical Stroop effect found with the classic color-word Stroop task. The number-Stroop task is particularly interesting because in healthy individuals and the comparison individuals in the current study, numeral reading was less (though it was still) prepotent relative to counting, and an atypical symmetrical Stroop effect was observed. If both responses are generally weaker because of reduced training or education in individuals with psychopathy, we would expect to see reduced interference in the individuals with psychopathy on the number-Stroop reading task; the response generated through counting would not be strong enough to effectively compete. However, the reading response would still be able to compete with the counting response on the number-Stroop counting task because it remains the relatively prepotent response. Although a training/education–based account is consistent with the current data and can be used to explain the results of most previous Stroop-type tasks (except Hiatt et al., 2004, Experiment 3), it should be noted that it cannot explain why reduced interference is seen in the spatially separated color-word Stroop (Hiatt et al., 2004, Experiment 3) but not the typical, nonspatially separated color-word Stroop (Hiatt et al., 2004; Experiment 1).

The current results have implications for suggestions that there is ACC dysfunction in individuals with psychopathy (Kiehl et al., 2001). They suggest that such claims must at least be qualified with respect to the division that has been made between regions of the ACC involved in emotional processing rather than conflict resolution (Bush, Luu, & Posner, 2000)—although reduced activation in both of these regions was reported by Kiehl et al. (2001). The current results, together with those of Smith et al. (1992) and Brinkley et al. (2006), suggest no dysfunction in those regions of the ACC involved in conflict resolution, although there may be dysfunction in those regions of the ACC involved in emotional processing. Of course, given the role of the proposed gating or modulatory role of the ACC (MacLeod & MacDonald, 2000), its level of activation is strictly contingent on the level of input it receives from other structures involved in the primary task processing. In emotional tasks, this is likely to include the amygdala. In the Kiehl et al. (2001) study, the activation of the amygdala in individuals with psychopathy was significantly reduced relative to comparison individuals. The reduced ACC activation reported in individuals with psychopathy in the two neuroimaging studies (Kiehl et al., 2001; Veit et al.) may therefore reflect reduced input from a dysfunctional amygdala (R. J. R. Blair, 2002) rather than ACC dysfunction per se.

At the cognitive level, executive dysfunction in psychopathy has been linked to impulsivity, conceptualized as lack of premeditation and lack of perseverance (Whiteside & Lynam, 2001). Executive dysfunction in psychopathy has also been linked to impaired response modulation—the "rapid and relatively automatic (i.e., noneffortful or involuntary) shift of attention from the effortful organization and implementation of goal-directed behavior to its evaluation" (Newman et al., 1997, p. 564). On the basis of these accounts, one might be expected to predict that individuals with psychopathy would be impaired on all the tasks presented in this study. Thus, the OA and SA tasks both required the inhibition of a previously rewarded behavior and normal performance on the number-Stroop task required some ability to ignore distracting stimuli. In addition, performance on all would have been influenced by processing "the meaning of information that is peripheral or incidental to their deliberate focus of attention" (Lorenz & Newman, 2002, p. 92). The current results thus suggest that domain-general inhibition/response set modulation accounts are at least in need of modification. Specifically, it would seem that although a description of the impairment in individuals with psychopathy in terms of an inhibition or response set modulation impairment may be possible, it should be a description that is tied to a particular processing domain (or possibly domains) rather than one that is domain general.

One caveat should be noted with respect to these results. Because of limitations in what was permissible to ask our participants, we could not obtain a full substance abuse history. It is possible that there were significant differences in substance abuse levels between the individuals with psychopathy and the comparison individuals. If there were group differences in substance abuse, these could have given rise to the OFC dysfunction apparent in the OA data. It is unlikely, however, that these could be related to the finding of reduced interference for the number-Stroop counting task. If these results were to reflect frontal functioning rather than educational history as we believe, they would indicate superior functioning of the ACC rather than ACC damage. This is an unlikely result of drug use.

In conclusion, in this study we found that individuals with psychopathy were impaired on the OA but not on the SA task and were generally slower on the number-Stroop tasks but showed reduced interference only for the number-Stroop reading task, not the number-Stroop counting task. This data is consistent with suggestions of OFC dysfunction in individuals with psychopathy but does not indicate DLPFC or ACC dysfunction, at least for those regions of DLPFC/ACC involved in Stroop performance. Of course, these data do not prove that all aspects of DLPFC/ACC functioning are intact in individuals with psychopathy. However, these data and those reported in the previous literature have currently failed to show a functional impairment related to activity in these regions.

It is interesting to note that all of our measures required response inhibition or response modulation—both of which are suggested to be impaired in individuals with psychopathy (Newman et al., 1997; Whiteside & Lynam, 2001). However, we only observed significant group difference for the OA and Stroop reading tasks. Our results therefore also suggest that although a description of the impairment in individuals with psychopathy in terms of an inhibition or response set modulation impairment may be possible, it should be a description that is tied to a particular processing domain (or possibly domains) rather than one that is domain general.

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