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Somatic Markers and Response Reversal: Is There Orbitofrontal Cortex Dysfunction in Boys With Psychopathic Tendencies?

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This study investigated the performance of boys with psychopathic tendencies and comparison boys, aged 9 to 17 years, on two tasks believed to be sensitive to amygdala and orbitofrontal cortex functioning. Fifty-one boys were divided into two groups according to the Psychopathy Screening Device (PSD, P. J. Frick & R. D. Hare, in press) and presented with two tasks. The tasks were the gambling task (A. Bechara, A. R. Damasio, H. Damasio, & S. W. Anderson, 1994) and the Intradimensional/Extradimensional (ID/ED) shift task (R. Dias, T. W. Robbins, & A. C. Roberts, 1996). The boys with psychopathic tendencies showed impaired performance on the gambling task. However, there were no group differences on the ID/ED task either for response reversal or extradimensional set shifting. The implications of these results for models of psychopathy are discussed.

KEY WORDS: amygdala; orbitofrontal cortex; psychopathic tendencies; psychopathy.

Psychopathy is a disorder characterized in part by callousness, a diminished capacity for remorse, superficial charm, proneness to boredom, and poor behavioral controls (Cleckley, 1967; Hare, 1991). Psychopathic criminals commit a disproportionate amount of crime, habitually fail to fulfill societal obligations, appear to lack any sense of loyalty, and are unperturbed when confronted with the destructive nature of their behavior (Cleckley, 1967; Hare, 1991). It is thought that psychopathy can be indexed behaviorally in children using the Psychopathy Screening Device (PSD; Frick & Hare, in press) and in adults by using the Revised Psychopathy Checklist (PCL-R; Hare, 1991). Both scales index a similar syndrome. Factor analysis of both the PSD and PCL-R reveal a two-factor structure. First, an Impulsivity/Conduct Problems (I/CP) factor that comprises overt behavioral characteristics such as impulsivity, poor impulse control (e.g., becomes angry when corrected), and delinquent behavior (Frick, O'Brien, Wootton, & McBurnett, 1994; Hare, 1991). As regards the PSD, this factor is highly correlated with traditional measures of conduct problems, such as the *DSM-IV* definition of Conduct Disorder (Frick, 1995). Secondly, the Callous/Unemotional (C/UN) factor captures such characteristics as lack of guilt, lack of empathy, and superficial charm, which are considered primary in the clinical description of psychopathy (Cleckley, 1967). However, despite the similarities between the PSD and PCL-R it is premature to suggest the two are isomorphic. There are some content differences. For example, some PCL-R items have no PSD counterparts (parasitic lifestyle and lack of realistic, long-term goals). Likewise some PSD items have no PCL-R counterparts (concerned about schoolwork, keeps the same friends, teases other people). However, it is important to note that the neurocognitive impairments that have been found in adult psychopathic individuals are also being found in children with psychopathic tendencies (Blair, 1999; Fisher & Blair, 1998; O'Brien & Frick, 1996).

Currently, three loci of impairment at the anatomical level have been suggested as causes of psychopathy. These are the septo-hippocampal system (Gorenstein &

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Newman, 1980); the amygdala (Blair & Frith, 2000; Blair, Morris, Frith, Perrett, & Dolan, 1999; Patrick, 1994); and the orbitofrontal cortex (Damasio, 1994; LaPierre, Braun, & Hodgins, 1995). The septo-hippocampal position was prompted by Gray's Behavioral Inhibition System theory of fear and anxiety (Gray, 1971, 1987). Septo-hippocampal lesions have been found to induce impairments in passive avoidance and aversive conditioning (see, for reviews, Gorenstein & Newman, 1980; Gray, 1971). However, the mechanisms thought to be impaired by these lesions are not those of Gray's conceptualization. Septo-hippocampal lesions are no longer thought to damage a Behavioral Inhibition System crucial for emotional learning (Gray, 1971) but rather a system that is crucial for the representation of context (i.e., a representation of the individual's immediate environment; LeDoux, 1995, 1998; O'Keefe, 1991). The organism may use representations of context to aid passive avoidance and aversive conditioning, but such representations are not necessary for emotional learning to occur (see LeDoux, 1995). Thus, the individual may need to represent a particular environment in order to learn to avoid that environment; this will require appropriate functioning of septo-hippocampal neurons. However, if the individual has to learn which lever to avoid pressing in an environment, a representation of that environment will not aid decision making.

As regards the amygdala position, there are striking similarities between the performance of psychopathic individuals and patients with amygdala lesions on neurocognitive measures. Thus, psychopathic individuals show reduced potentiation of the startle reflex by visual threat primes (Patrick, Bradley, & Lang, 1993) and impairments in aversive conditioning (Hare, 1998; Lykken, 1957, 1995). Patients with amygdala lesions also show both these impairments (Angrilli et al., 1996; Bechara et al., 1995; LaBar, LeDoux, Spencer, & Phelps, 1995). Moreover, psychopathic individuals, like most patients with amygdala lesions, show impairments in processing fearful expressions (Adolphs et al., 1999; Blair, Colledge, Murray, & Mitchell, 2001; Blair & Coles, 2000; Fine & Blair, 2000; Stevens, Charman & Blair, 2001).

As regards the orbitofrontal cortex position, reference has been made to apparent behavioral similarities between patients with orbitofrontal cortex lesions and psychopathic individuals (Blumer & Benson, 1975; Damasio, 1994). Thus, for example, both groups show heightened risk for aggression (Grafman, Schwab, Warden, Pridgen, & Brown, 1996; Hare & Jutai, 1983). However, care must be taken when considering this apparent similarity. Patients with orbitofrontal cortex lesions show primarily reactive aggression; their aggression is a consequence of frustration or perceived threat (Anderson, Bechara, Damasio, Tranel, & Damasio, 1999; Blair & Cipolotti, 2000; Grafman et al., 1996). In contrast, the aggression shown by psychopathic individuals is instrumental; it is directed towards a goal, for example, financial reward or increased social respect (Cornell et al., 1996; Williamson, Hare, & Wong, 1987).

Orbitofrontal cortex has been associated with at least three partially dissociable cognitive systems: the social response reversal system (Blair & Cipolotti, 2000), the somatic marker system (Damasio, 1994) and a nonsocial response reversal system (Rolls, 1997). The social response reversal system is conceptualized as a system that is activated by another's angry expressions. In addition, it is also activated by representations of situations that have been previously associated with another individual's angry responses or other negative valence expressions (e.g., the staring expressions of others that can precede a sense of embarrassment, and perhaps others' disgusted expressions). In these situations another's anger might be expected. The suggestion is that activation of this system results in the modulation of current behavioral responding, in particular the modulation of reactive aggression mediated by the hypothalamus and periaqueductal gray (and perhaps sexual behavior mediated by related systems). In line with this position, neuroimaging findings have indeed shown the involvement of right orbitofrontal cortex in processing angry, but not sad, facial expressions (Blair et al., 1999). Moreover, patients who present with reactive aggression following orbitofrontal cortex lesions have been found to be impaired in processing angry expressions and judging the appropriateness of behaviors in particular social contexts (Blair & Cipolotti, 2000). However, there are no indications that the social response reversal system is impaired in psychopathic individuals. Although adult psychopathic individuals and children with psychopathic tendencies show impairment in the processing of fearful facial expressions, they show no selective difficulties in processing angry expressions (Blair et al., 2001; Blair & Coles, 2000; Fine & Blair, 2000; Stevens et al., 2001). Moreover, although adult psychopathic individuals and children with psychopathic tendencies show impairment in distinguishing moral and conventional transgressions (Blair, 1995, 1997), they show no impairment in recognizing the inappropriateness of behaviors that result in another's anger (Blair & Cipolotti, 2000). Regarding the somatic marker hypothesis, according to Damasio and colleagues, the ventromedial frontal cortex (orbitofrontal and medial frontal cortex) acts as a repository, and is involved in the formation of recorded dispositional linkages between factual knowledge and bioregulatory states (Bechara, Damasio, & Damasio, 2000; Damasio, 1994). When individuals are faced with a situation for which some factual aspects have been previously categorized, the dispositional linkages are activated. This allows the individual to make appropriate decisions. The dispositional linkages are activated in either of two ways. They can be activated via a "body loop" in which a "somatic marker" (increased autonomic arousal) is conveyed to somatosensory cortices. Alternatively, this can occur via an "as-if body loop" in which the body is bypassed and reaction signals are conveyed to the somatosensory structures (i.e., no increased autonomic activity can be detected). Under either loop, the somatosensory structures then adopt an appropriate pattern that constrains option–outcome reasoning. In short, the somatosensory pattern marks the scenario as either good or bad, allowing the rapid rejection/endorsement of specific option–outcome pairs. In other words, the somatic marker indicates whether a particular choice would be advantageous or not. If there is damage to the somatic marker system, there will be no somatic marker to guide behavior. In line with this position, individuals with "acquired sociopathy" following orbitofrontal cortex lesions are less likely to show autonomic responses to visually presented social stimuli (scenes of social disaster, mutilation, and nudity; see, for a review, Bechara et al., 2000). In contrast, they are able to generate conditioned autonomic responses to visual stimuli paired with an aversive loud sound (Bechara, Damasio, Damasio, & Lee, 1999). In addition, such patients, unlike controls, are less likely to shift their behavior away from packs of cards associated with high risk (Bechara et al., 2000). Damasio and colleagues have suggested that early impairment of the somatic marker system might underlie developmental psychopathy (Damasio, 1994; Damasio, Tranel, & Damasio, 1990). However, it should be noted that psychopathic individuals are not less likely to show autonomic responses to visual threatening images although they are less responsive to the sad and fearful expressions of others (Aniskiewicz, 1979; Blair, 1999; Blair, Jones, Clark, & Smith, 1997; Patrick et al., 1993). Yet, psychopathic individuals are less likely to generate conditioned autonomic responses to conditioned stimuli (e.g., Lykken, 1957). In addition, in the first investigation of the performance of psychopathic adults on Bechara's four pack card playing task, psychopathic individuals performed similarly to comparison individuals (Schmitt, Brinkley, & Newman, 1999). However, it should be noted that the task instructions used by Schmitt et al. (1999) differed from those of Bechara et al. (2000). Indeed, in a second study, using the revised instructions provided by Bechara, adult psychopathic individuals did perform more poorly than comparison individuals (Mitchell, Colledge, Leonard, & Blair, Submitted, 2001).

As regards the response reversal system, there are considerable animal data suggesting that the orbitofrontal cortex is involved in altering previously acquired stimulus–reward associations when they are no longer adaptive (Dias et al., 1996; Rolls, 2000). In addition, Rolls and others have demonstrated that patients with OFC lesions have more difficulty in reacting to the valence change of the stimuli (i.e., when the reward values of the stimuli reversed) than patients with more dorsolateral or posterior lesions (Rahman, Sahakian, Hodges, Rogers, & Robbins, 1999; Rolls, Hornak, Wade, & McGrath, 1994). Two studies have found indications of a response reversal impairment in adult psychopathic individuals (LaPierre et al., 1995; Mitchell et al., Submitted, 2001). LaPierre et al. (1995) found that psychopathic individuals performed more poorly on a Go/No-Go task where they had initially formed a prepotent response tendency to a particular stimulus and then had to reverse this response. The psychopathic individuals were significantly more likely than the comparison individuals to continue to respond to the stimulus. Mitchell et al. (Submitted, 2001) explored performance of adult psychopathic individuals and controls on the Intradimensional/Extradimensional Discrimination (ID/ED) task. In the ID/ED task (described more fully below), the participant is taught to respond to one of two stimuli and then, having reached criterion, must reverse this response so that they respond to the other stimulus (Dias et al., 1996). The psychopathic individuals were significantly impaired in response reversal on this task.

As far as we are aware, this paper is the first to investigate orbitofrontal cortex functioning in children with psychopathic tendencies. Two tasks will be used (see Method for task details). The first is the four-pack card playing task of Bechara et al. (1994). This task is interesting because patients with both amygdala and orbitofrontal cortex, but not dorsolateral prefrontal cortex, lesions show impairment on this task (Bechara et al., 1999; Bechara, Damasio, Tranel, & Anderson, 1998). Thus, both the amygdala and orbitofrontal cortex positions would predict that children with psychopathic tendencies should show impairment on this task. The second task is the Intradimensional/Extradimensional Discrimination (ID/ED) task. This task is interesting because it assesses two dissociable abilities. First, it assesses the ability to perform response reversals; the participant is initially rewarded for one behavioral choice and then must reverse his/her behavior when this stimulus is no longer associated with reward. Second, it assesses the ability of the participant to perform extradimensional shifts; to shift their response set from one stimulus property to another (for example, shifting attention from the stimulus's shape to the type of lines covering it). Lesions of dorsolateral prefrontal cortex are associated with impairments in extradimensional shift learning, but not in reversal learning, whereas lesions of the orbital prefrontal cortex produce impairments in the reversal learning, but not in the extradimensional shift learning (Dias et al., 1996). Although functional imaging work has indicated that the reversal learning component of this task is associated with amygdala activation (Rogers, personal communication), temporal lobe lesions, including lesions of the hippocampus, do not result in impairment on any component of this task (Owen, Roberts, Polkey, Sahakian, & Robbins, 1991). Recent work also indicates that these different forms of shift learning depend on distinct and dissociable neurochemical substrates (Dias et al., 1996; Rahman et al., 1999; Rogers et al., 1999). Although the amygdala position would predict no impairment on this task, it would be expected that if there was generalised orbitofrontal dysfunction, children with psychopathic tendencies should show impairment on this task.

Thus, in summary, the amygdala position predicts impairment on the four-pack card playing task but not the ID/ED task. In contrast, the orbitofrontal cortex position predicts impairment on the four pack card playing task and a reversal learning impairment on the ID/ED task. This study tests these predictions.

METHOD

Participants

The participants were recruited from three schools for boys with emotional and behavioral difficulties. All of these children had received statements under the Education Act of 1993 as being too problematic for mainstream education. In addition, there was a further pool of children attending a comprehensive school in an area with high unemployment who all also have received statements under the Education Act of 1993. Consent was obtained from all the parents of the children who were approached regarding this work. The children were also free to withdraw from the study at any time.

Initially, 183 boys were screened using the Psychopathy Screening Device. Almost all of the participants were from homes of low socioeconomic status. In line with previous work (Blair, 1997, 1999; Fisher & Blair, 1998), participants with a PSD score above 25 formed the psychopathic tendencies group. Participants with a PSD score below 20 formed the comparison group. Fifty-one boys meeting the inclusion criteria participated in the study. It was not possible to test the same sample on both tasks because of children leaving school during the course of the study and thus not being available for a second testing session. Thus, 32 boys received both tasks, 11 boys received only the four-pack card playing task, whereas 10 boys received only the ID/ED task; see Table I for full participant details divided by task.

The British Picture Vocabulary Scale (Dunn, Wheklan, & Pintillie, 1982) was administered to provide an estimate of intelligence. The groups did not differ significantly in either age or estimated verbal IQ. The sample was made up of 50 Caucasian and 1 Afro-Caribbean participants.

Table I. Participant Characteristics

	The gambling task		The ID/ED task	
	Children with PT ($N = 20$)	Comparison group ($N = 23$)	Children with PT ($N = 19$)	Comparison group ($N = 23$)
PSD	31.00 (3.07)** [26 to 37]	6.89 (4.50) [0 to 18]	30.87** (3.17) [26 to 37]	8.14 (5.21) [0 to 18]
C/U	8.48 (1.39)** [6 to 11]	1.86 (1.79) [0 to 6]	8.21** (1.69) [5 to 11]	2.14 (1.91) [0 to 6]
I/CP	15.83 (1.91)** [13 to 20]	3.52 (2.95) [0 to 9]	16.13** (1.74) [13.5 to 20]	4.39 (3.40) [0 to 10]
Age	13.17 (1.86) [9–8 to 16–0 yrs]	12.75 (0.83) [10–5 to 13–9 yrs]	12.98 (2.17) [9–9 to 17–1 yrs]	12.91 (0.88) [10–4 to 14–0 yrs]
IQ	85.70 (10.09) [68 to 108]	91.43 (11.02) [76 to 116]	85.37 (9.47) [68 to 96]	90.17 (11.46) [77 to 116]

Note. PSD: Psychopathy Screening Device; C/U: The callous and unemotional component of psychopathy (e.g., a lack of guilt); I/CP: the impulsive and conduct problems component of psychopathy (e.g., engaging in crime); IQ: Intelligence quotient; N: Number of participants. Standard deviations are in parentheses and ranges in square brackets.

**$p < 0.001$.

Measures

Psychopathy Screening Device

The PSD consists of 20 behavioral items presented in a questionnaire format and scored by two teachers, or a teacher and care-worker. Factor analyses identify the existence of two highly interrelated behavioral factors (Frick et al., 1994). The Callous/Unemotional (C/UN) factor corresponds to affective and interpersonal traits whereas the Impulsivity/Conduct problems (I/CP) factor is defined by behaviors characteristic of conduct disorder (Frick, 1995; Frick et al., 1994). The C/UN factor items on the PSD include such characteristics as "acts charming in ways that seem insincere," "emotions seem shallow," "does not feel bad or guilty," and "is not concerned about the feelings of others," whereas the I/CP factor includes such items as "gets bored easily," "becomes angry when corrected," "acts without thinking," and "engages in risky or dangerous activities" (Frick & Hare, in press).

Participants were rated by two teachers, or in the case of boarding students by a teacher and a residential social worker. Pearson correlation of the ratings of the two raters were 0.699 for total PSD score, 0.582 for the C/UN factor, and 0.650 for the I/CP factor (all correlations are significant at the 0.01 level (two-tailed). Participants received the average score for each item of the two raters.

The Gambling Task (Bechara et al., 1994, 1999)

The gambling task was administered in the computerized format with a schedule of reinforcement as described in Bechara et al. (1999). The participant saw four decks of cards on a computer screen. At the top of each of these decks were the labels A, B, C, and D. Above these decks there was a green bar that changed according to the amount of money won or lost by the participant. A gain was indicated by a proportionate increase in the length of the green bar, and a loss was indicated by a proportionate decrease in the bar length. The participant clicked on a card from any of the four decks by using a mouse. The computer tracked the sequence of the cards selected from the various decks. Every time the participant picked a card by clicking on a deck, the computer generated a distinct sound (similar to a casino slot machine). The face of the card appeared on top of the deck (the color was either red or black), and a message was displayed on the screen indicating the amount of money the subject had won or lost. Once the money was added or subtracted, the face of the card disappeared, and the participant could select another card. The intertrial interval between making two consecutive card selections was set at 1 s. Each participant had 100 trials (card selections). After these trials, the program shut off automatically. The participant was not informed in advance how many trials there would be.

On the screen, the backs of the cards appeared identical, like real decks of cards. Whenever the participant picked from Packs A or B the computer displayed a $100 reward and whenever the participant picked from Packs C or D the computer displayed a $50 reward. The sequence of gains and losses for each card selection were based on the original version of this task (Bechara et al., 1994). When the schedule indicated that a card choice would be punished, the computer displayed a message: ". . . You have won X dollars, but you also have lost Y dollars . . ." (the Y amount corresponded to the negative number inside the square), and the net loss was reflected automatically on the green bar on the screen. In brief, every 10 cards from Deck A over the course of trials gained $1000, but there are also five unpredictable punishments ranging from $150 to $350, that brought the total loss to $1250. Every 10 cards from Deck B gained $1000, but there was also one big punishment for $1250. On the other hand, every 10 cards from Deck C or D only gained a total amount of $500, but the losses were also smaller, that is, $250 (ranging from $25 to $75 in Deck C and one $250 loss in Deck D), bringing a net gain of $250. In summary, decks A and B were equivalent in terms of overall net loss over trials. In a similar way, Decks C and D were equivalent in terms of overall net gains. However, Decks A and C had a higher frequency, but a lower magnitude, of punishment. In contrast, Decks B and D had a lower frequency, but a higher magnitude, of punishment. Thus, the participant should learn to avoid Decks A and B because they cost more in the long run and, instead, learn to respond to Decks C and D because they resulted in an overall gain in the long run. Full participant instructions are given in Bechara et al. (1999).

To score the performance of the subject on the gambling task, we added the number of cards picked from Decks A and B in each block of 10 cards.

The ID/ED Task (Dias et al., 1996)

The ID/ED task is a learning task, where the participant has to select one of two stimuli presented to them on a computer screen. The test stimuli can involve up to two dimensions; object shape and line shape. The shapes and lines are all novel stimuli. Each trial involves a discrimination that might involve the participant selecting between the stimuli Shape 1 + Line 2 and Shape 2 + Line 1, for example. The correct stimulus for a discrimination was always specified by one exemplar from one dimension (e.g., Shape 1 whether it is paired with Line 1 or 2).

On any one trial, the two test stimuli appeared randomly in two of four rectangles positioned toward the sides of the screen, and the participant was required to click with the mouse on the box containing the correct stimulus. If the participant chose correctly, the word CORRECT, written in green ink, appeared in the center of the screen. If the participant chose incorrectly, the word INCORRECT, written in red ink, appeared. The subject was considered to have learnt a given discrimination to criterion after choosing the correct stimulus eight times in succession.

The task consists of nine stages presented in the same fixed order. For all stages the criterion for progressing onto the next stage is a run of 8 correct choices within 50 trials. If this criterion is not achieved at a given stage, the test is discontinued. The nine stages are:

(1) *Simple discrimination* between two (pink) shapes (Shape 1 and Shape 2). The participant must learn to respond to Shape 1.
(2) *Simple reversal*, using the same stimuli but with the contingencies reversed. The participant must reverse his/her responding to Shape 1 and respond to Shape 2.
(3) *Compound discrimination-separate*. A pair of white line patterns is introduced (Line 1 and Line 2). However, the contingencies remain unchanged. The participant should maintain responding to Shape 2 irrespective of whether Shape 2 is paired with Line 1 or Line 2. The pink shapes and white line are kept separate to encourage the subject to perceive them as distinct. Pairing is pseudorandom: the same pairings (e.g., Shape 1–Line 1 and Shape 2–Line 2) appear in runs of no more than three trials.
(4) *Compound discrimination superimposed*. The white lines are superimposed on the pink forms for this and all subsequent stages, so that transfer learning cannot be attributed to locational learning. The contingencies remain the same. The participant should maintain responding to Shape 2.
(5) *Compound Reversal*. The same stimuli are used but the contingencies are reversed. The participant must reverse his/her responding to Shape 2 and respond to Shape 1. The lines remain without predictive power for deciding on a correct/incorrect response.
(6) *Intradimensional shift*. New shapes and lines are introduced (Shape 3 and Shape 4 and Line 3 and Line 4). The participant must learn to respond to Shape 3 irrespective of whether it is paired with Line 3 or Line 4.
(7) *Intradimensional reversal*. The contingencies are reversed. The participant must reverse his/her response to Shape 3 in favor of responding to Shape 4.
(8) *Extradimensional shift*. New shapes and lines are again introduced (Shape 5 and Shape 6 and Line 5 and Line 6). However, in this phase of the task the participant must shift attentional set from the shapes to the lines. Thus, the participant must learn to respond to Line 5 irrespective of whether it is paired with Shape 5 or Shape 6.
(9) *Extradimensional reversal*. The contingencies are reversed. The participant must reverse his/her response to Line 5 in favor of responding to Line 6.

The number of errors the participant makes for each stage are calculated by the computer.

Procedure

Each participant was tested individually in a quiet interview room allocated by the school. The tasks (ID/ED and the Gambling Task) were run on two separate testing sessions. Each task was described without informing the participant of the investigation's specific objectives and expectations. BPVS was used to test participants' IQ during one of the testing sessions.

RESULTS

The Gambling Task

Because of the broad range in age and IQ in our participants, an initial exploratory analysis investigated if either age or IQ predicted number of bad choices in any of the blocks of trials. This revealed no significant association between IQ and task performance in this population for any of the blocks (greatest r value for any block $= 0.17$; *ns*). However, there was a significant association between age and task performance (r for last block $= -0.39$; $p = 0.01$); the older children were more likely to avoid the bad packs by the end of the paradigm. Thus, despite the absence of group differences, an ANCOVA was conducted on the data, with age treated as a covariate.

Based on previous reports on adults (Bechara et al., 1994, 1999) and our preliminary data on adult psychopathic individuals (Mitchell et al., Submitted, 2001), we predicted that comparison children would sample randomly at first but then develop a preference for the less risky decks. In contrast, we predicted that children with psychopathic tendencies would be less likely to switch to the safer C and D packs. The two groups were initially compared on global performance by block using a mixed model 2 (comparison children vs. children with psychopathic tendencies) × 10 (blocks of 10 trials) ANCOVA. Mauchley's test of sphericity was significant (Mauchley's $W = 0.07$, $df = 44$, $p < 0.01$) thus the more conservative Greenhouse–Geisser test was used for the analyses. This revealed no significant main effect of block, $F(5, 215) = 1.51$, *ns*, but there was a significant effect of group, $F(1, 40) = 6.43$, $p < 0.05$; the children with psychopathic tendencies were more likely than the comparison group to play from the disadvantageous A and B packs. Crucially, the Block × Group interaction was also significant, $F(5, 215) = 2.32$, $p < 0.05$. As the task continued, the children with psychopathic tendencies failed to learn to avoid the A and B packs whereas the comparison children learnt to avoid these packs; see Fig. 1. There was a significant main effect of the covariate age, $F(1, 40) = 5.08$, $p < 0.05$. However, there was no significant Block × Age interaction.

A one-way ANCOVA was used to explore the prediction that the difference in responding was specifically related to the inability of children with psychopathic tendencies to shift away from the bad packs. We compared the difference in the number of times the children sampled from the bad pack in the last block. This revealed that children with psychopathic tendencies were significantly less likely to avoid the unfavourable packs than the comparison children, $F(1, 42) = 7.59$, $p < 0.01$. The covariate age was again significant, $F(1, 42) = 10.74$, $p < 0.01$.

ID/ED

Because of the broad range in age and IQ in our participants, an initial exploratory analysis investigated whether either age or IQ was associated with performance on either of the three core components of the task: learning (Phases 1 and 6); reversal learning (Phases 2, 5, 7, and 9); and the extradimensional shift stage (Phase 8). This revealed no significant associations between either age or IQ and performance on any of these three components. Thus, ANOVAs were used for data analysis.

Based on previous reports on adults (Dias et al., 1996; Rahman et al., 1999; Rogers et al., 1999) and our preliminary data on adult psychopathic individuals (Mitchell et al., Submitted, 2001), we predicted that there would be significant group differences for the reversal learning component of the task. The two groups were initially compared using a mixed-model 2 (comparison children vs. children with psychopathic tendencies) × 3 (component: learning, reversal learning, and extradimensional shift) ANOVA. Mauchly's test of sphericity was significant (Mauchley's $W = 0.643$, $df = 2$, $p < 0.01$) thus the more conservative Greenhouse–Geisser test was used for the analyses. This revealed a highly significant main effect of component,

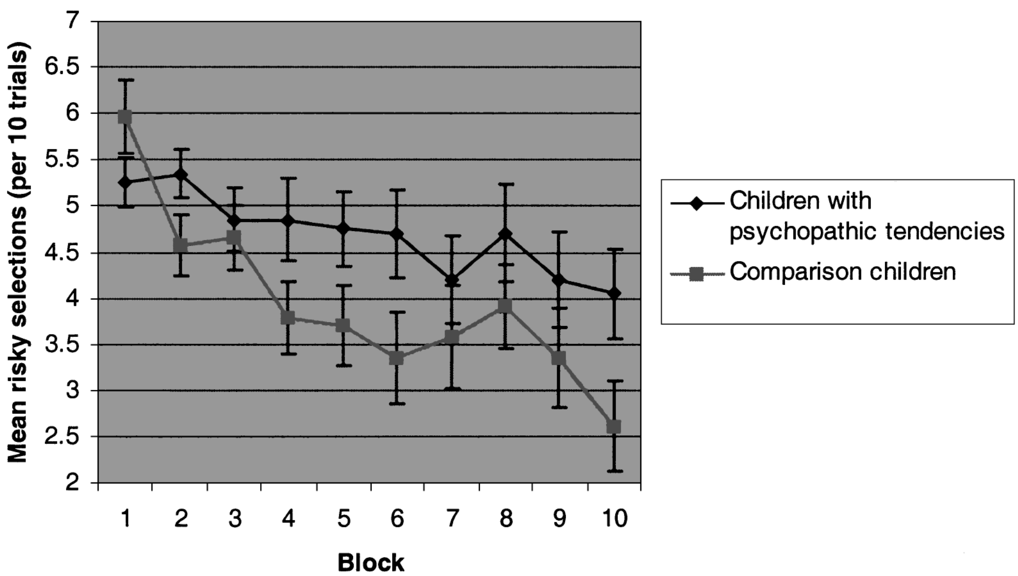

Fig. 1. The selections of boys with psychopathic tendencies and comparison boys from the risky packs across the 10 blocks of 10 trials. The boys with psychopathic tendencies were significantly more likely to pick from the risky packs than were the comparison boys. Points represent the mean number of selections from the risky decks per 10 selections; vertical lines depict standard errors of the means.

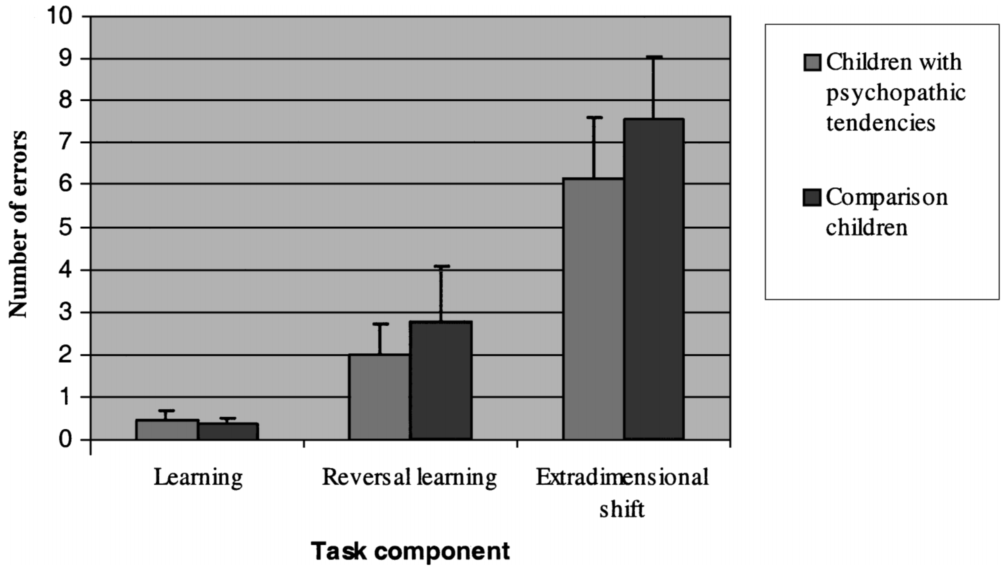

Fig. 2. The numbers of errors committed by boys with psychopathic tendencies and comparison boys on the three main components of the ID/ED task. The Extradimensional shift component was the most difficult component of the task. However, there were no significant group differences. Points represent the mean number of selections from the risky decks per 10 selections; vertical lines depict standard errors of the means.

$F(1.5, 59) = 18.27$; $p < 0.01$; the extradimensional shift component was indeed the most difficult component of the task; see Fig. 2. However, there was no significant group effect, $F(1, 40) = 0.673$; *ns*, or significant Group × Component interaction $F(1.5, 59) = 0.25$; *ns*.

DISCUSSION

As far as we are aware, this is the first study to specifically investigate orbitofrontal cortex functioning in children with psychopathic tendencies. In line with predictions, children with psychopathic tendencies were less likely than comparison children in the gambling task to avoid the risky packs. However, in contrast to predictions, the children with psychopathic tendencies did not show significantly more reversal errors on the ID/ED task.

Previous data investigating orbitofrontal cortex functioning in adult psychopathic individuals have indicated difficulties in response reversal (Mitchell et al., Submitted, 2001; LaPierre et al., 1995). In contrast, the present study found no indications of response reversal impairment in children with psychopathic tendencies. As regards performance on the gambling test, the data are more equivocal (Mitchell et al., Submitted, 2001; Blair & Cipolotti, 2000; Schmitt et al., 1999). Schmitt et al. (1999), and Blair & Cipolotti (2000) in a small group sample, found that adult psychopathic individuals were not less likely than the comparison individuals to avoid the risky packs. However, both of these studies used task instructions that differed from those of Bechara (Bechara et al., 1999). Specifically, there were no instructions categorically informing participants that some decks involve more loss than others and that participants could win more money overall if they avoid the costly decks. In the only study where such instructions have been used, the adult psychopathic individuals were significantly less likely than the comparison individuals to avoid the risky packs (Mitchell et al., Submitted, 2001). The current study, also using the Bechara et al. (1999) instructions, replicates this result in children with psychopathic tendencies.

It is interesting to compare the present results of the gambling and ID/ED tasks to those obtained with a related paradigm; the one-pack card playing task (Newman, Patterson, & Kosson, 1987). In this task, the participant has to decide whether to play a card. Initially, the participant's choices to play are reinforcing but as the number of trials increases, the probability of reward decreases. The participant should terminate responding before he receives greater levels of punishment than reward. Both children with psychopathic tendencies and adult psychopathic individuals fail to modulate their responding as the probability of punishment increases and perform more poorly than comparison individuals (Fisher & Blair, 1998; Newman et al., 1987; O'Brien & Frick, 1996). This task could be conceptualized as a response reversal task under partial reinforcement conditions (Blair & Cipolotti, 2000). However, the present results suggest that it should not be. The current data indicate that children with psychopathic tendencies show no apparent general impairment in response reversal.

The current data have specific implications for current neurocognitive models of psychopathy. First it appears that psychopathy, particularly when seen in children, is not associated with generalized orbitofrontal cortex dysfunction. Children with psychopathic tendencies show no impairment in social response reversal; they respond appropriately to angry expressions and can detect inappropriate social behavior that is likely to cause anger in others (Blair, 1999; Blair & Colledge, Submitted, 2001; Blair & Coles, 2000; Stevens et al., 2001). The current data indicate that they also show no impairment in nonsocial response reversal; they are sensitive to changes, at least if they are sudden, in reinforcement schedules and reverse their behavior accordingly.

There have been suggestions that psychopathy might be due to dysfunction in the somatic marker system, a system that is mediated by a circuit that includes the orbitofrontal cortex (Damasio, 1994; Damasio et al., 1990). The current data are in line with this position. However, the somatic marker hypothesis faces at least one major challenge when attempting to account for psychopathy. A core prediction of the hypothesis is that individuals with somatic marker impairment will not show autonomic responding to emotionally arousing stimuli (Damasio, 1994; Damasio et al., 1990). However, children with psychopathic tendencies and adult psychopaths do show arousal to such stimuli, as long as these stimuli are not sad or fearful expressions (Aniskiewicz, 1979; Blair, 1999; Blair et al., 1997; House & Milligan, 1976; Patrick et al., 1993). Thus, although the current data are compatible with the hypothesis, the hypothesis faces difficulties in providing a full account of psychopathy.

The current study was not designed to investigate the septo-hippocampal position on psychopathy (Gorenstein & Newman, 1980). Current formulations on the role of these systems do not suggest that they have a major role in either the form of decision making involved in the gambling task or the response reversal investigated with the ID/ED task (LeDoux, 1998; O'Keefe, 1991). However, the current results do have implications for the cognitive, response set modulation model that was developed from the septo-hippocampal position (Newman, 1998; Newman, Schmitt, & Voss, 1997; Patterson & Newman, 1993). Response modulation involves "a rapid and relatively automatic (i.e., non-effortful or involuntary) shift of attention from the effortful organisation and implementation of goal-directed behaviour to its evaluation" (Newman et al., 1997). Dysfunction within the system responsible for response modulation will result in impoverished performance under conditions where a salient stimulus should divert attention from ongoing behavior. This model specifically predicts that individuals with psychopathy will be more likely than nonpsychopathic individuals to persist in a previously rewarded response, even if the rate of punishment for this response increases. Support for this prediction comes from a series of studies employing the one-pack card playing task mentioned above (Fisher & Blair, 1998; Newman et al., 1987; O'Brien & Frick, 1996). However, the current data constrain the response set modulation hypothesis. The ID/ED task required shifts of attention during both response reversal and when shifting attention from the shape to the lines in the extradimensional shift. The children with psychopathic tendencies showed no impairment on either of these processes. However, there were indications of impairment in the Bechara task where the child had to shift away from Packs A and B, despite their high levels of reward, to Packs C and D. Perhaps, a crucial variable that must be considered is the frequency of punishment. In at least the beginning of the one-pack card playing task and the Bechara task, the punishments are infrequent. However, in the response reversal phases of the ID/ED task, the previously always rewarded stimulus suddenly becomes the always punished stimulus. The current data suggest that in conditions of certainty the children can alter response set. This suggests in turn that, if we are to adopt the response set modulation hypothesis, we should consider the impairment to be in detecting the altered contingencies rather than in shifting response. If the change in contingencies is easy to detect, as in the ID/ED task, there should be no problem. If it is not, then the problem may be quite severe.

An alternative way of conceptualizing the current results makes reference to the interconnections between basolateral amygdala and orbitofrontal cortex and their critical role in encoding and using associative information about the motivational significance of stimuli (Gallagher, McMahan, & Schoenbaum, 1999; Schoenbaum, Chiba, & Gallagher, 1998, 2000). Within this circuit, the amygdala has a critical role in forming associations between unconditioned and conditioned stimuli and between individual conditioned stimuli (Killcross, Robbins, & Everitt, 1997; LeDoux, 1998; Schoenbaum et al., 1998). Orbitofrontal cortex encodes the motivational significance of the cues and the incentive value of expected outcomes (Gallagher et al., 1999; Schoenbaum et al., 2000; Thorpe, Rolls, & Maddison, 1983). Thus, both the basolateral amygdala and orbitofrontal cortex are involved in encoding the value of a stimulus, and lesions to either system impair reversals in responding following changes in the value of reinforcement (Gallagher et al., 1999; Hatfield, Han, Conley, Gallagher, & Holland, 1996; Rolls, 1997). Indeed, both amygdala and orbitofrontal cortex dysfunction have been found to result in poor performance on the gambling task (Bechara et al., 1994, 1999). Moreover, there is certainly mounting evidence of amygdala dysfunction in psychopathic individuals (see, for a review, Blair & Frith, 2000).

It can be speculated that the functioning of the circuit is sensitive to the ease with which any change in reinforcement contingencies can be detected. Dysfunction within the amygdala alone may make the individual less sensitive to changes in reinforcement contingencies and thus only give rise to impairment on tasks such as the one-pack card playing task and the gambling task where the changes are less easy to detect. Of course, the above position is highly speculative. However, it is important to note that it gives rise to clear, testable predictions. While children with psychopathic tendencies are not impaired on the current version of the ID/ED task, if the above position is correct, it can be predicted that they will be impaired on a version of the task where changes in reinforcement schedules are less clearly indicated; for example, in Phase 1, if Shape 1 was rewarded and Shape 2 punished only 80% of the time and then, in Phase 2, Shape 1 punished and Shape 2 rewarded, only 80% of the time. Such predictions are currently under investigation.

It is important to note some interesting similarities and differences between adult psychopathic individuals and children with psychopathic tendencies. Previous work has shown strong similarities between the performance of children with psychopathic tendencies on many neurocognitive measures (Blair, Jones, Clark, & Smith, 1995; Fisher & Blair, 1998; Newman et al., 1987; O'Brien & Frick, 1996). Moreover, the current results echo previous findings showing an impairment on the gambling task in adult psychopathic individuals (Mitchell et al., Submitted, 2001). However, there are clear differences between the performance of children with psychopathic tendencies and adult psychopathic individuals on the ID/ED task. Although the current study revealed no difficulty for children with psychopathic tendencies on any phase of the task, adult psychopathic individuals showed significant impairment in response reversal. This suggests, following the argument developed above, that the dysfunction within the amygdala–orbitofrontal cortex circuit described above is more severe in adult psychopathic individuals. Such individuals have difficulties even when the change in contingencies is apparently very clear.

One brief caveat should be noted at this point: the population studied in this paper overlapped considerably with the population studied in two other papers (Blair et al., 2001; Blair & Colledge, Submitted, 2001). Given the relatively small sample sizes, it will be important to replicate these results in other settings. Moreover, it would be important to determine whether these results also extend to girls with psychopathic tendencies. It might also be useful to compare the performance of the two populations in the present study with a third population. However, it should be noted that the performance of the comparison population on the four-pack card playing task was within the range of healthy adult individuals (Bechara et al., 1998) and performance of both groups on response reversal and ED shift on the ID/ED task was within the range of healthy children of comparable age (Hughes, Russell, & Robbins, 1994). Interestingly, children with ADHD, even when medicated, show pronounced impairment on the ED shift, unlike the populations in the current study, an error pattern consistent with the suggestion that this disorder reflects dorsolateral prefrontal cortex dysfunction (Kempton et al., 1999).

An additional, interesting extension to this study would be to investigate the relationship between performance on the four-pack card playing task and the gambling task and scores on the two factors making up the PSD (i.e., C/UN and I/CP). In this study, there was no overlap between the children with psychopathic tendencies and the comparison children on either of these factors. However, it would be predicted that measures of amygdala dysfunction should be more highly associated with the C/UN factor of psychopathy rather than with I/CP. In contrast, it is possible to predict that some individuals with high levels of impulsive, reactive aggression who do not present with C/UN impairment, might be impaired on only the orbitofrontal cortex measures (see Blair & Cipolotti, 2000).

There are two main implications of the present results. First, the results have clear treatment implications. If psychopathic tendencies reflect amygdala dysfunction, as the current data suggest, neither empathy induction nor anger management techniques are likely to be effective. Empathy induction techniques will not be effective because the capacity to find the distress of others aversive will be disrupted by the amygdala dysfunction (see Blair & Frith, 2000). Anger management techniques will not be effective because the disorder does not reflect an inability to control reactive aggression (cf. Cornell et al., 1996). In contrast, it reflects a heightened willingness to engage in instrumental aggression. However, treatment regimes based on altering the individual's expectations that aggressive action will have beneficial consequences may prove useful (see Crick & Dodge, 1996). Second, the differences between the child with psychopathic tendencies and adult psychopaths, both showing impairment on measures of amygdala dysfunction but the adults showing far more pronounced impairment on measures reflecting the interaction of orbitofrontal cortex and the amygdala than children, have developmental implications. It is possible that because of the interconnections of the amygdala and orbitofrontal cortex, a reduction in afferent input from the amygdala (because of the primary amygdala dysfunction) may, over time, have a negative impact on the responsiveness of the orbitofrontal cortex. Accordingly, the long-term effects of this dysfunction may not be as apparent until later in the life span, thereby explaining the lack of evidence for response reversal deficits in children with psychopathic tendencies. A second possibility is that the greater orbitofrontal cortex dysfunction seen in the adults is a secondary consequence of some of the behavioral characteristics of psychopathy. For example, one of the criteria of psychopathy, stimulation seeking, is often associated with drug use (Hare, 1991). Studies suggest that psychopathy is associated with higher rates of drug abuse, dependence, and multiple drug use (e.g., Smith & Newman, 1990; Hemphill, Hart, & Hare, 1994). Using a novel decision-making task, Rogers et al. (1999) assessed the quality of decision making and deliberation time of individuals with focal orbitofrontal cortex damage, and individuals who abused amphetamine or opiates. All three groups showed impaired performance on the task relative to comparison groups. Furthermore, chronic amphetamine abusers showed a pattern of suboptimal decisionmaking that correlated with their years of abuse. Given the neuro-cognitive impairments associated with chronic drug abuse, and the data suggesting higher rates of abuse and dependence among psychopathic individuals, we cannot discount the possibility that some of the decision-making impairments seen in psychopathic individuals is acquired as a secondary consequence of the stimulus-seeking behavior characteristic of the disorder.

In conclusion, the current study found impaired performance in children with psychopathic tendencies on the gambling but not the ID/ED task. These data are in line with the suggestion that amygdala dysfunction is the core impairment in psychopathy (e.g., Blair & Frith, 2000). Because of this dysfunction, the system crucial for representing the motivational value of stimuli that is mediated by an integrated neural circuit, including the amygdala and orbitofrontal cortex, is disrupted. The dysfunction in this circuit is less than is seen in adult psychopathic individuals (Mitchell et al., Submitted, 2001).

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