Electrophysiology of Dampening of

Emotional Reactivity in Psychopathic Personality

by

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Abstract

Diminished emotional and empathic capacity is a core characteristic of psychopathic personality. The current study examines the effect of the condition on neural reactivity to emotional content with the use of high-density electroencephalography (EEG). Seventeen high-trait and 15 low-trait healthy individuals identified with a self-report measure of psychopathy participated in an emotional Stroop task in which they responded to negative and positive valence blocks of emotionally charged and emotionally neutral images. The high-trait group showed less reactivity to emotional stimuli than neutral stimuli with faster Stroop reaction times, reduced amplitude of two emotional processing event-related potentials (ERPs), the Early Anterior Positivity, and the Late Positive Potential, and less affective amplification of the P1 attentional ERP. Diminished processing of emotional content may reflect a top-down, learned inhibition of emotional processing, whereas reduced early emotional reorienting of attention also suggests an additional bottom-up, biologically based deficit in affective reactivity.

Keywords: Event Related Potentials; Psychopathy; Emotion; Late Positive Potential; Early Anterior Positivity; P1

To my parents and sister,

for the unwavering love, dedication, belief and support (both emotionally and financially!) that made this document, and my dreams possible,

And to the North Shore gang,

for keeping me out of my ivory tower

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Introduction

Psychopathic personality, a subcategory of the DSM-IV diagnosis of Antisocial Personality Disorder (APD), is characterised not only by the APD tendency to engage in impulsive, antisocial, and self-destructive behaviours (American Psychiatric Association, 2000), but also a core deficit in emotional and empathic capacity (Cleckley, 1976; Hare, 1991). Most models of psychpathy incorporate a two-factor structure in which interpersonal problems are parsed into either blunted affect, or reckless impulsivity categories (e.g. see Fowles & Dindo, 2006). The Psychopathy Checklist-Revised (PCL-R; Hare, 1991), the definitive and most widely recognized measure of psychopathy, places a strong emphasis on this division, identifying two distinct factors. PCL-R Factor 1 traits comprise a number of affective and relational dysfunctions including superficial charm, grandiosity, and absence of guilt, while PCL-R Factor 2 traits relate to destructive lifestyle and risky behaviours, such as irresponsibility, proneness to boredom and lack of long-term planning (Hare et al., 1990).

Psychopathic personality is a widely acknowledged predictor of criminal violence and recidivism, and a noted risk factor in professional risk assessment tools such as the Historical-Clinical-Risk Management 20 scale (HCR-20; Webster, Douglas, Eaves, & Hart, 1997). Increasingly however, the personality disorder is being recognized as a spectrum condition existing in varying degrees throughout the adult population. Indeed, there may be “successful psychopaths” who are capable of adapting to social norms, functioning within community settings, and avoiding confrontation with the criminal justice system (Benning, Patrick, Hicks, Blonigen, & Kruegar, 2003). As a result, interest in exploring psychopathy within non-criminal, normative populations has increased, and several attempts have been made to develop efficient self-report assessment methods for psychopathy that do not rely heavily on information gleaned from criminal records.

The electrophysiological study of psychopathy

Electrophysiological examinations of the condition employing event-related potentials (ERPs) have focused primarily on attentional dysfunctions. For example, in a seminal study conducted by Kiehl and colleagues (Kiehl, Hare, McDonald, & Liddle, 1999), reductions in P3 amplitude were found in a group of high psychopathy criminal offenders relative to a low psychopathy criminal comparison group. The P3 component is a large positive wave that occurs across parietal regions of the scalp, beginning approximately 300ms following the presentation of both visual and auditory target stimuli (Comechero & Polich, 1999; Conroy & Polich, 2007). This sensory modality independent response is thought to index attentional focus on salient task relevant information. Its reduction in psychopaths suggests impairment of their higher-level attentional processes, and may be the key to their self-destructive and antisocial behaviours (Kiehl, Hare, McDonald, & Liddle, 1999). But support for this interpretation was initially mixed, as some earlier ERP investigations of the condition found *increased* P3 amplitudes amongst criminal psychopaths and antisocial youths (see Raine, 1988). This had led some researchers to conclude that the condition was actually characterized by an augmentation of information processing, and impairment of early physiological arousal mechanisms. Though this issue remained largely unresolved for a great deal of time, more recent work has linked reductions of the P3 component to increased psychopathic impulsivity (Carlson, Thai, & McLarnon, 2009), and augmentation of the wave to increased fearlessness (Carlson & Thai, 2010). This potentially explains the inconsistent findings of past studies; conflicting results may have been due to varying levels of impulsivity and fearlessness in each sample.

Electrophysiological research examining the link between psychopathy and learning has shown evidence that high psychopathy offenders exhibit diminished Error Related Negativity (ERN) when confronted with emotional faces (Munro, Dywan, Harris, McKee, Unsal, & Segalowitz, 2007). The ERN is elicited from the caudal anterior cingulated cortex (ACC), across frontocentral regions of the scalp, approximately 200ms following an incorrect response. It indexes performance monitoring and reinforcement learning, and is sensitive to motivation, showing augmentation in high reward tasks amongst healthy individuals (see Munro et al., 2007). It also shows a generalized increase in patients with anxiety sensitivity conditions such as obsessive-compulsive disorder (see Olvet & Hajcak, 2008). The ERN is a reflexive, automatic response. This led Munro et al. (2007) to argued that because psychopaths in their sample displayed less ERN for emotional faces, though not for semantic stimuli, the condition was associated with an inability to engage in normal learning from visceral, bottom-up emotional cues, and that psychopaths must rely instead on top-down emotional evaluations.

Ultimately, Munro's primary focus was on learning and not emotion, and similarly, most ERP research on psychopathy continues along attentional and cognitive lines. To date, only two studies have employed ERPs to directly assess affective deficits associated with the personality disorder. This is a serious area of concern, for although antisocial behaviours are the most likely reason for psychopaths to come into contact with the criminal justice system, it is deficits in emotional and empathic response that differentiate the condition from other subtypes of antisocial personality disorder, (American Psychiatric Association, 2000), and allow psychopaths to function as what Hare (1993) described as "remorseless intraspecies predators."

The first of these two ERP studies of emotion, conducted by Williamson, Harpur, and Hare (1991), found that although in non-psychopathic criminals responses to affective words during a lexical decision task were differentiated from those to neutral words by faster reaction times and greater voltage of a late positive component (LPC) distributed across the posterior scalp, psychopaths' responses showed no such discrimination. Psychopaths in the study also presented with increased voltage of a late frontocentral negativity (N500) for all lexical stimuli, and evidence of abnormal language lateralization. Given the distribution and latency of the LPC—which peaked 613ms following stimulus presentation (Williamson et al., 1991)—the authors speculated that this component may have been a combination of P3 response and semantic processing. They cautiously suggested that its reduction may have resulted from the reduced salience and motivational value of emotional content to their psychopaths. However, abnormalities in the N500 also supported alterative explanations, such as a gross disorganisation of semantic and conceptual systems in psychopaths. Results may even have been due to the unusual lateralization of language observed in the group (Williamson et al., 1991). Thus, the data remained open to interpretation due to the limited research conducted on the topic prior to the study.

The second study, conducted by Kiehl, Hare, McDonald and Brinks (1999) was designed to reassess the linguistic abnormalities found in the first by testing psychopaths' ability to respond to abstract versus concrete, and negative versus positive valence words. Psychopathic criminals displayed increased negativities across the frontocentral scalp peaking at 350ms post stimulus presentation (N350) for all lexical stimuli, and reduced differentiation of this component for abstract versus concrete, and negative versus positive emotion words when compared to non-psychopathic criminals. Because the N350 appeared to be functionally analogues to the N500, and because no differentiation of abstract and concrete words, *or* negative and positive words was observed, the authors concluded that the results elucidated the ambiguities of Williamson et al. (1991) and supported the generalized language processing deficit model of psychopathy (Kiehl, Hare, McDonald & Brinks, 1999).

But while these two papers tested semantic aspects of psychopathic affective deficits, their emphasis on language processing may have confounded the study of more visceral emotional reactivity. In recent years, well validated picture stimuli assessed for overall valence and arousal across a wide variety of populations have become readily available (see Hajcak & Weinburg, 2010; Lang, Bradley, & Cuthbert, 2005). Much work has been done to identify strong ERP correlates of emotional processes too (see below). And although Kiehl, Hare, McDonald and Brinks (1999), and Williamson et al. (1991) assessed response to stimuli across the dorsal scalp, due to the limited ability to assess voltages across the wider scalp at the time of their studies, few measures were taken for occipital region sites in the former, and none were take in the latter. Therefore, fresh examination of emotional deficits using more modern ERP recording techniques, conducted within the frame work of dominant emotional ERPs may shed greater light on the affective deficits associated with psychopathic personality disorder.

Emotional ERP components and their implications for psychopathy research

The Late Positive Potential is perhaps the most critical component in ERP investigations of emotion. The latency and distribution of Late Positive Potential (LPP) bear similarities to those of the posterior P3 wave. In experimental situations, the P3 response is elicited by task specific targets made salient to participants artificially by virtue of a researcher's instruction; emotional stimuli, however, are salient by their very nature, and, logically should evoke responses similar to those induced by task relevant targets (Hajcak & MacNamara, 2010). Consistent with this reasoning, previous research has found that relative to neutral stimuli, emotionally evocative stimuli of both positive and negative valence elicit greater positive potentials across parietal regions of the scalp, beginning approximately 300ms after stimulus presentation and lasting for up to several seconds (Hajcak & MacNamara). This differential response to emotional content is the LPP. In some ways it can be conceptualised as an emotional P3, though its duration is typically much longer than the standard attentional component. It is theorised that the LPP reflects an affect driven reorientation of cognitive processing to salient emotional stimuli (Hajcak & MacNamara). It can be influenced by several top-down processes of emotion regulation, such as redirection of attention, emotional suppression and emotional reappraisal, each of which has been shown to decrease evoked response to emotional stimuli (Hajcak & MacNamara, 2010; Hajcak & Nieuwenhuis, 2006; Moser, Hajcak, Bukay, & Simons, 2006). Additionally, the P3 in psychopaths has already been found to be is diminished (Kiehl, Hare, McDonald, & Liddle, 1999; Carlson et al., 2009) and potentially less differentiated for affective versus neutral stimuli (Williamson et al., 1991). If psychopathic affective dysfunctions have a basis in top-down regulatory processes, it seemed probable that emotional ERP investigation of the disorder would find reductions in LPP amplitude to be one of the personality disorder's defining electrophysiological characteristics.

A previous ERP study examining the influence of anxiety sensitivity on an emotional variant of the traditional cognitive Stroop task found that threatening words relative to neutral words were characterized by a positive deflection of an early slow wave distributed across the frontal scalp 200-300ms following stimulus presentation (Taake, Jaspers-Fayer, & Liotti, 2009). The authors deemed this effect the Early Anterior Positivity (EAP), and noted that it was only present within threat versus neutral word blocks of the emotional Stroop task, and not positive versus neutral word blocks. As such the EAP likely reflects early emotional response to aversive stimuli.

Though it initially appeared that the effect was greater in high trait-anxiety subjects than low-trait anxiety subjects, the group by stimulus type interaction failed to approach significance (Taake et al., 2009). Exploratory analysis did reveal an interaction between group and very early modulations of the EAP. Moreover, these very early modulations were significantly correlated with variations of the EAP in the high anxiety group. They also noted a study which found that panic words evoked a positive deflection of slow waves across frontal regions, particularly among panic disorder patients (see Taake et al., 2009; Pauli, Amrhein, Muhlberger, Dengler, & Wiedemann, 2005). Thus, it is possible that the EAP represents a generalized early reflexive emotional threat response that varies as a function of anxiety sensitivity and personal salience of the stimuli. Psychopathic personality is strongly characterized by stress immunity, social dominance, and a general lack of anxiety in the face of menacing situations (Hare, 1991, 993; Lilienfeld & Widows, 1996). It was therefore likely that whereas typical individuals would show a large positive deflection across frontal regions for threatening, anxiety provoking stimuli relative to neutral stimuli, more psychopathic individuals will show little or no difference in their responses to each category of stimuli. No such effect was expected for positive stimuli as the

EAP seems to reflect threat response, unlike the more valence indiscriminate LPP.

Early attentional components may also be linked to emotion and emotional arousal. The P1 is a positivity evoked across lateral occipital regions of the scalp approximately 100ms following presentation of a visual stimulus. It most likely originates in the occipital lobe, though attempts at localization have been met with mixed results (Luck, 2005). The component can be influenced by top-down mechanisms if attention is shifted to or from the anticipated locations of an impending target, but on a trial by trial basis it occurs to early to be altered without a preceding cue. The effect can also be amplified by increases in a subject's overall level of arousal (Vogel & Luck, 2000). In their emotional Stoop task, Taake and colleagues (2009) found that greater P1s were elicited by threatening words than neutral words in high trait anxiety subjects relative to controls. When confronted with emotionally arousing images that would otherwise amplify P1 voltage in a typical population, it appeared plausible that psychopaths would show less amplification of this early, more physiologically based measure of attention due to their generalized lack of emotionality.

The current study

The current study was designed to examine the link between these three ERP components, the LPP, the EAP, and the P1, and psychopathic personality traits within a healthy undergraduate sample using an emotional variant of the traditional cognitive Stroop task and a between groups design. Six effects were predicted: (1) it was anticipated that high psychopathic personality trait participants relative to low psychopathic personality trait participants would show overall reductions in reaction time during the emotional Stroop task, and (2) no reaction time bias for positive versus negative valence emotional blocks, thus reflecting less emotional interference in the cognitive task; (3) the high-trait group was expected to display less LPP voltage increase for emotional stimuli relative to neutral stimuli than the low-trait group, reflecting reduced salience of emotional targets, and less direction of attentional resources to their processing; (4) less differentiation between potentials evoked by negative stimuli versus neutral stimuli during the time window of the EAP across frontal regions was expected in the high-trait group relative to the low trait group, tantamount to reduced reactivity to anxiety provoking content in more psychopathic subjects; (5) the high-trait group was expected to display reduced P1 voltage across all conditions of the task, as well as (6) less differentiation between positive and negative blocks, reflecting diminished overall affective arousal during an emotionally evocative situation, and lack of preference for emotional content of a particular valence respectively.

Methods

Measures

Psychopathic personality traits were rated using the Psychopathic Personality Inventory-Revised: Short Form (PPI-R: SF; Lilienfeld, 2004). The PPI-R: SF is a 56-item self-report measure. It was derived through principal axis factor analyses of community and prison sample data for its longer 154-item parent scale, the Psychopathic Personality Inventory-Revised. Participants endorse items regarding their interpersonal style, relationships, leisurely pursuits, goals, and reactions to empathy and fear inducing situation on a 4-point Likert-type scale: 1 ("False"), 2 ("Mostly False"), 3 ("Mostly True"), and 4 ("True"). Both the original measure and the shortened screening form contain eight subscales: Machiavellian Egocentricity, Social Influence, Fearlessness, Coldheartedness, Rebellious Nonconformity, Blame Externalization, Carefree Nonplanfulness, and Stress Immunity. The short form is made up of the seven questions of each subscale that loaded most heavily across samples, with the exception of Social Influence, for which the eighth item was included in order to reduce content repetition.

Factor analysis of the original iteration of the Psychopathic Personality Inventory suggested that a two-facture structure similar to that of the PCL-R underlies seven of the measure's eight content scales (Benning, Patrick, Hicks, Daniel, & Kruegar, 2003): Social Influence, Fearlessness and Stress Immunity correspond to a Fearless Dominance factor; Machiavellian Egocentricity, Rebellious Nonconformity, Blame Externalization, and Carefree Nonplanfulness relate to a Self-Centred Impulsivity factor; Coldheartedness loads onto neither. Fearless Dominance is thought to tap into the emotional deficits characteristic of psychopaths, and correlates with PCL-R Factor 1, while Self-Centred Impulsivity encapsulates their impulsive, antisocial, and self-destructive tendencies of PCL-R Factor 2. The original Psychopathic Personality Inventory was well validated across a variety of samples such as criminal, college, and the general community (Falkenbach, Poythress, Falki, & Manchak, 2007; Poythress, Edens, & Lilienfeld, 1998). Revisions of the measure were conducted to make it more accessible by lowering the required reading level, re-wording culturally specific items, and reducing its overall length (Lilienfeld & Widows, 2005). Less research has been conducted on the revised version of the questionnaire, and there is some debate regarding the applicability of the two-factor model to it, but the measure has great potential for the assessment of psychopathic personality traits within the overall population (Uzieblo, Verschuere, Van den Bussche & Crombez, 2010).

Participants

Participants were recruited via email from a pool of undergraduate students who completed an electronic battery of demographic information and self-report personality pre-screening measures that included the PPI-R: SF. Screening sessions were approximately 10 minutes in length. Eighteen individuals (8 male, 1 left-handed, mean age=20.12, mean education=13.82) with scores above the 90^{th} percentile (PPI-R: SF score>134, mean=141.76) were recruited for the high psychopathic personality trait group, and 16 individuals (5 male, 2 left-handed, mean age=20.40, mean education=14.27) with scores below the 25th percentile (PPI-R: SF score<106, mean=94.13) were selected for the low psychopathic personality trait group. No participants were colourblind, and all reported normal or corrected to normal vision. They were free of serious past head injury resulting in 10 or more minutes of unconsciousness, had no DSM-IV Axis I diagnosis, and were not currently on any form of prescription medication for a neurological or psychiatric condition. Each participated in a 2 hour ERP session that included the emotional Stroop task (see below) for which they were compensated 4% course credit. The project was conducted to Simon Fraser University ethical standards.

Paradigm

An emotional variant of the traditional Stroop task was used to assess the influence of psychopathic personality traits on affective response and processing. Whereas in the cognitive Stroop participants view colour words and respond to the colour in which they are written, in the emotional Stroop participants view emotionally salient stimuli and respond to coloured targets. Conflict in the emotional Stroop, reflected in the form of increased reaction time to emotional targets, is caused by the greater affective processing requirements of such stimuli. The emotional Stroop has been used in several studies to explore emotional biases in various populations (eg. Taake et al., 2009). Stimuli consisted of images acquired from the International Affective Picture System database (IAPS; Lang et al., 2005), matched for content (see appendix 4.4), and scaled to 12 x 8cm, with a central 1 x 1cm coloured square target superimposed.

Stimuli were displayed on a black computer screen. The IAPS database is an extensive collection of images rated for valence and arousal and well validated in a number of experiments (see Lang et al., 2005). Four hundred trials were presented over eight blocks separated by breaks. Within each block, all stimuli presented were unique, with 25 being emotionally neutral, and 25 being highly emotionally evocative. Four “negative emotion blocks” featured images of negative valence and both high and low arousal (eg. injured/threatening animals, scenes of violence/sadness, aimed weapons). Four “positive emotion blocks” featured images of positive valence and both high and low arousal (healthy/cute animals, scenes of love/joy, exciting sports, money). Across block, positive and negative emotional images were matched for valence and arousal. Each stimulus was presented for 500ms, followed by a 1500-2000ms jittered interstimulus interval during which a 1 x 1cm white fixation cross was displayed at the centre of the screen. Participants were seated 55cm from the screen in a soundproof booth and responded to the colour of the superimposed square targets (red, blue, green, or yellow) with the index and middle figures of each hand using a custom designed response box. Stimuli were pseudorandomized such that no more than three images of the same valence, nor three targets of the same colour appeared in a row.

EEG recording

High density electroencephalographic (EEG) scalp potentials were recorded using a 64-channel Ag/AgCl electrode cap at sites FP1 FPz, FP2, AF3, AF4, AFz, AF7, AF8, F7, F5, F3, F1, Fz, F2, F4, F6, F8, FT7, FC5, FC3, FC1, FCz, FC2, FC4, FC6, FT8, T7, C5, C3, C1, Cz, C2, C4, C6, T8, TP7, CP5, CP3, CP1, CPz, CP2, CP4, CP6, TP8, P9, P7, P5, P3, P1, Pz, P2, P4, P6, P8, P10, PO7, PO3, POz, PO4, PO8, O1, Oz, O2, Iz, , plus six externals including M1 and M2, and four nonstandard facial sites. Voltages were recorded against a common mode sense (CMS) rejection active electrode. Bipolar horizontal electrooculogram (HEOG) was recorded with electrodes placed on the external canthi to monitor eye movements, and blinks were tracked with FP1, FP2, FPz and external electrodes centered under the pupils 1cm below each eye. Offline, a 0.01 Hz highpass and a 30 Hz lowpass filter, (zero phase, slope=12dB/octave), were applied digitally, and electrodes were re-referenced to average mastoid. Data was sampled at a rate of 512Hz (amplifier: Biosemi Actiview Two, Amsterdam). A semiautomatic artifact rejection procedure combined with visual inspection of the EEG over 200ms pre-stimulus to 800ms post-stimulus epochs removed trials contaminated by eye movements, blinks and amplifier blocking. One subject was dropped from each group (Low-trait: male, left-handed; High-trait: female, right-handed) due to excessive blink and alpha wave artifacts.

ERPs were selectively grand averaged within subjects over a 800ms epoch for each condition by time-locking to positive, negative, positive block-neutral, and negative block-neutral stimuli onset for all trials in which a correct response was made. Amplitudes were aligned to a 200ms pre-stimulus baseline period.

Behavioural analysis

Behavioural data analysis of emotional Stroop performance was conducted using an omnibus repeated measures ANOVA on Reaction Times for trials in which a correct response was made to the target, with one between factor of Group (high-trait; low-trait) and two within factors of Block Valence (negative; positive), and Stimulus Valence (emotional; neutral). This design allowed for testing of whether reaction time modulation between groups occurred as a “fast” within block effect for individual trials, or as a “slow” between block effect (Taake et al., 2009). Subsequent restricted within-group analyses were then conducted for both the high-trait and low-trait groups using two within factors of Block Valence (negative; positive), and Stimulus Valence (emotional; neutral) to determine if observed and *a priori* predicted reaction time effects were only present in one group or the other.

Phaf and Kan (2007) have argued that in contrast to the traditional cognitive Stroop, where semantic processing interferes with individual trials, in the emotional Stroop, affective interference slows *subsequent* trials, builds up over time, and culminates in an overall block level “slow” effect. As such, relative to the low psychopathic personality trait group, the high psychopathic personality trait group was anticipated to show overall reductions in reaction time during the emotional Stroop task, reflecting diminished response to and processing of emotional stimuli. Previous research has also shown that such block level effects show a bias for negative valence and threat related stimuli (Pratto & John, 1991; Taake et. al., 2009). Therefore, a “slow” Block by Group interaction, with greater differentiation of reaction times during the positive and negative valence blocks for the low-trait group than the high-trait group was also expected

ERP analysis

Each ERP component of interest was analysed first with an omnibus between-groups ANCOVA, and subsequently with restricted ANCOVAs within the low-trait and high-trait groups to clarify significant and *a priori* predicted group interactions. For each component, repeated measures ANCOVA assessed mean voltage during epochs of the grand average waves for individual subjects, across regions of interest (ROIs) calculated from mean voltages of neighbouring electrode sites. Epochs and electrode sites were selected on the basis of prior specifications in the literature, and visual inspection of ERP waveforms and topographic distributions. The Bonferonni correction for multiple comparisons was employed to ensure a Family-wise error rate of $\alpha<0.1$.

LPP

The LPP was assessed over a 400-600ms post stimulus epoch. Separate analyses were conducted on midline and lateral posterior ROIs (midline: CPz, Pz, POz; lateral: CP2, CP4, P2, P4, CP1, CP3, P1, P3. The global between-group repeated measures ANCOVA design contained one between factor of Group (high-trait; low-trait), two within factors of Block Valence (negative; positive), and Stimulus Valence (emotional; neutral), and a covariate of Gender (male; female) due to the gender imbalance between the high and low psychopathic personality trait groups. An additional factor of Hemisphere (right:

even numbered sites; left: odd numbered sites) was included for the lateral analysis. Planned analyses for the low-trait and high-trait groups contained two within factors of Block Valence (negative; positive), and Stimulus Valence (emotional; neutral), a covariate of Gender (male; female), plus an additional factor of Hemisphere (right: even numbered sites; left: odd numbered sites) for the lateral analyses.

An interaction of Stimulus Valence by Group was expected. Whereas the low-trait group was expected to show greater response for emotional stimuli than neutral stimuli during the 400-600ms window of the LPP, the high-trait group was expected to display no such differentiation.

EAP

The EAP component was assessed over a 200-300ms post stimulus epoch. Separate analyses were conducted on midline and lateral anterior ROIs (midline: AFz, Fz, FCz; lateral: F3, F5, F7, F4, F6, F8). The between-group design contained one between factor of Group (high-trait; low-trait), two within factors of Block Valence (negative; positive), and Stimulus Valence (emotional; neutral), and a covariate of Gender (male; female). An additional factor of Hemisphere (right: even numbered sites; left: odd numbered sites) was included for the lateral analysis. Within-group analyses employed two within factors of Block Valence (negative; positive), and Stimulus Valence (emotional; neutral), a covariate of Gender (male; female), plus an additional factor of Hemisphere (right: even numbered sites; left: odd numbered sites) for lateral analyses.

A significant Block Valence by Stimulus Valence by Group interaction was expected for the EAP. The low-trait group was expected to show greater positive deflections of the component for emotional stimuli than neutral stimuli during the negative block, whereas the high-trait group was expected to present with little differentiation.

P1

The P1 component was assessed over an 85-135ms post stimulus epoch for lateral parietal-occipital ROIs (P8, PO8, O2, P7, PO7, O1). Global repeated measures ANCOVA design contained one between factor of Group (high-trait; low-trait), three within factors of Block Valence (negative; positive), Stimulus Valence (emotional; neutral), and Hemisphere (right: even numbered sites; left: odd numbered sites), and a covariate of Gender (male; female). Within-group analyses contained three within factors of Block Valence (negative; positive), Stimulus Valence (emotional; neutral), and Hemisphere (right: even numbered sites; left: odd numbered sites), and a covariate of Gender (male; female).

The P1 is largely unaffected by top-down control mechanisms on a trial by trial basis. Instead, it is modulated by stimulus characteristics and individual level of arousal (Vogel & Luck, 2000), and pre-stimulus deployment of attention. Given that the high-trait group should be less aroused during an emotionally evocative situation, they were expected to show an overall Group effect of reduced P1 response throughout the task. Additionally, while differential reactivity to positive and negative blocks—an indication of aversion or preference for emotional content of a specific valence—was predicted for the low-trait group, an absence of this effect was expected for the high-trait group.

Power profile

For α=0.05, df=1, 29, F_{crit}=4.18, and magnitudes of effect given by Cohen's (1992) recommendation of φ'=0.1, 0.25, and 0.4, the power profile for all between-groups tests is as follows:

φ'	λ	1-β
0.1	0.32	0.085
0.25	2.0	0.277
0.4	5.12	0.590

For FW α=0.1, df=1, 13, F_{crit}=4.67, and magnitudes of effect given by Cohen's recommendation of φ'=0.1, 0.25, and 0.4, the power profile for all low-trait within-group tests is as follows:

φ'	λ	1-β
0.1	0.15	0.064
0.25	0.9375	0.146
0.4	2.4	0.300

For FW α=0.1, df=1, 15, F_{crit}=4.54, and magnitudes of effect given by Cohen's recommendation of φ'=0.1, 0.25, and 0.4, the power profile for all high-trait within-group tests is as follows:

φ'	λ	1-β
0.1	0.17	0.064
0.25	1.0625	0.156
0.4	2.72	0.329

The above power profiles indicate that all tests have low power to detect small, medium and large effect sizes.

Results

Demographic variables

Independent t-tests revealed that the high and low-trait groups did not differ significantly in terms of age, t(30)=.252, p=0.803, or years of education, t(30)=.722, p=0.459. The high-trait group scored significantly higher on the PPI-R: SF than the low-trait group, t(30)=-16.760, p=0.000.

Behavioural effects

Between-block and within-block accuracy ratings can be found in figure 1.2. There were no significant differences between groups for accuracy in any conditions. Mean reaction times can be found in figures 1.3, and 1.4 respectively. Repeated measures ANOVA revealed a significant main effect of Block Valence, $F(1,30)=13.597$, p=0.001, with reaction times greater during negative blocks than positive blocks. No significant main effect of Stimulus Valence was found, $F(1,30)=2.037$, p=0.164. There was no significant between Group effect, $F(1,30)=1.129$, p=0.297, and no significant interactions.

Subsequent planned repeated measures ANOVA within the low-trait group found a significant main effect of Block Valence, $F(1,14)=21.876$, p=0.000, no significant main effect of Stimulus Valence, $F(1,14)=2.822$, p=0.115, and no significant interaction of Block Valence by Stimulus Valence, $F(1,14)=3.394$, p=0.087. Within the high-trait group, reaction times were slower during the negative emotion block than the positive emotion block, but this did not produce a significant main effect of Block Valence, $F(1,16)=2.605$, $p=0.126$. The was no significant main effect of Stimulus Valence, $F(1,16)=0.115$, $p=0.739$, and no significant interaction of Block Valence by Stimulus Valence, $F(1,16)=0.122$, $p=0.731$.

ERP effects

Mean voltages by condition for all ERP effects can be seen in charts 2.3-2.8. Results for repeated measures ANCOVAs can be seen in charts 2.9-2.14. Only results that survived the Greenhouse-Geisser correction for non-Sphericity are reported.

LPP (400-600ms)

For the midline analysis of the LPP, no significant main effect of Block Valence was found, $F(1,29)=0.745$, $p=0.395$, and the main effect for Stimulus Valence approached, but failed to reach significance, $F(1,29)=3.787$, $p=0.061$. The only significant interaction was Stimulus Valence by Group, $F(1,29)=4.315$, $p=0.047$. No significant effect was found for Group or Gender. Subsequent within-group analysis of the low-trait group found no significant main effect of Block Valence, $F(1,13)=2.617$, $p=0.130$, but did find a significant main effect of Stimulus Valence, $F(1,13)=7.463$, $p=0.017$, with ERPs to emotionally evocative stimuli being far more positive than those to emotionally neutral stimuli. No significant interactions were found. Within the high-trait group, no significant effect was found for Block Valence, $F(1,15)=0.104$, $p=0.751$, or Stimulus Valence, $F(1,15)=0.338$, $p=0.569$, nor were there any significant interactions.

Lateral between-group LPP analysis found no significant main effect of Block Valence, $F(1,29)=0.537$, $p=0.469$, but did find significant main effects of Stimulus Valence, $F(1,29)=6.823$, $p=0.014$, with greater positivities to emotional stimuli, and Hemisphere, $F(1,29)=4.483$, $p=0.043$, with greater voltages across left lateralized sites. No significant effect was found for Group or Gender. Lateral LPP analysis within the low-trait group found no main effects of Block Valence, $F(1,13)=2.578$, $p=0.132$, or Hemisphere, $F(1,13)=3.895$, $p=0.231$, but did find a significant main effect of Stimulus Valence, $F(1,13)=9.683$, $p=0.008$, with higher voltages for emotion stimuli than neutral stimuli. Within the high-trait group no significant main effects were found for Block Valence, $F(1,15)=0.026$, $p=0.875$, Stimulus Valence, 0.912, $p=0.355$, or Hemisphere, $F(1,15)=1.99$, $p=0.178$, nor were there any significant interactions. In conclusion, LPP modulations were comparable over midline or lateral sites.

EAP (200-300ms)

Midline analysis of the EAP component between-group using repeated measures ANCOVA found no main effect of Block Valence, $F(1,29)=0.429$, $p=0.518$, or Stimulus Valence, $F(1,29)=2.498$, $p=0.125$, and no significant effects of Group or Gender. The predicted three-way interaction of Block Valence by Stimulus Valence by Group failed to reach significance, $F(1,29)=1.561$, $p=0.221$. As per the *a priori* prediction of a group interaction, within-group analyses were conducted. Within the low-trait group, the main effect of Block Valence was not significant, $F(1,13)=0.539$, $p=0.476$, though Stimulus Valence was, $F(1,13)=6.525$, $p=0.024$, with emotional stimuli producing a more positive deflection than neutral stimuli. There were no significant interactions. Within the high-trait group, no main effects were found, Block Valence, $F(1,15)=0.084$, $p=0.776$, Stimulus Valence, $F(1,15)=0.088$, $p=0.770$, nor were there any significant interactions.

Lateral analysis of the EAP found no significant effect of Block Valence, $F(1,29)=0.216$, $p=0.646$, Stimulus Valence, $F(1,29)=0.007$, $p=0.935$, or Hemisphere, $F(1,29)=0.179$, $p=0.676$. Significant two-way interactions of Stimulus Valence by Gender, $F(1,29)=4.508$, $p=0.047$, and Stimulus Valence by Hemisphere, $F(1,29)=9.591$, $p=0.004$ were observed, and Stimulus Valence by Group approached, but failed to reach significance, $F(1,29)=3.943$, $p=0.057$. The three-way interaction of Block Valence by Stimulus Valence by Group also approached but failed to reach significance, $F(1,29)=3.828$, $p=0.060$. As per the *a priori* prediction of a group interaction, within-group analyses were conducted. Within the low group, there were no significant main effects, though Stimulus Valence approached significance, $F(1,13)=4.076$, $p=0.056$, Block Valence, $F(1,13)=0.467$, $p=0.506$, Hemisphere, $F(1,13)=1.724$, $p=0.212$, and no significant interactions. Within the high group, there were no significant main effects, Block Valence, $F(1,15)=0.004$, $p=0.950$, Stimulus Valence, $F(1,15)=2.663$, $p=0.124$, Hemisphere, $F(1,15)=0.217$, $p=0.648$. Significant two-way interactions were Stimulus Valence by Gender, $F(1,15)=5.5565$, $p=0.032$, and Stimulus Valence by Hemisphere, $F(1,15)=10.542$, $p=0.005$.

P1 (85-135ms)

Between-group repeated measures ANCOVA for the P1 component found a significant main effect of Block Valence, $F(1,29)=4.740$, $p=0.038$, with voltages greater during the positive emotion block than the negative emotion block, and no significant main effect of Stimulus Valence, $F(1,29)=0.747$, $p=0.394$, or Hemisphere, 0.347, $p=0.561$. There was also a significant two-way interaction of Stimulus Valence by Group, $F(1,29)=4.256$, $p=0.048$. There was no effect of Gender, and while overall mean voltage was reduced for the high-trait group across conditions, the Group effect was not significant, $F(1,29)=1.003$, $p=0.325$. Within-group ANCOVA of the low-trait group found a significant effect of Block Valence, $F(1,13)=6.289$, $p=0.026$, with mean voltages higher during the positive emotion block, but no significant effect of Stimulus Valence, $F(1,13)=3.071$, $p=0.103$, or Hemisphere, $F(1,13)=0.009$, $p=0.928$. A significant two-way interaction of Block Valence by Hemisphere, $F(1,13)=4.828$, $p=0.047$ was also observed. Within the high-trait group there were no main effects for Block Valence, $F(1,15)=0.741$, $p=0.403$, Stimulus Valence, $F(1,15)=0.324$, $p=0.578$, or Hemisphere, $F(1,15)=1.128$, $p=0.303$, and no significant interactions.

Exploratory analysis

In Taake and colleagues' (2009) emotional Stroop investigation of trait anxiety, reaction time differences between threat and non-threat blocks of the task correlated with between block differences of negative voltages distributed across lateral regions of the anterior scalp, peaking at approximately 380ms following stimulus presentation for the high trait-anxiety group. The authors hypothesised that this AN380 effect was the electrophysiological correlate of the negative block reaction time bias produced by the emotional Stroop (Taake et al., 2009). To explore the AN380 in the current task, Repeated Measures ANCOVA on mean voltage for 350-450ms epochs of grand averaged waves for individual subjects were conducted within both the low-trait and high-trait groups across lateral ROIs (right: FC6, F4, AF4, F8; FC5, left: F3, AF3, F7). The design contained three within factors of Block Valence (negative; positive), Stimulus Valence (emotional; neutral), and Hemisphere, and a covariate of Gender (male; female).

Within the low psychopathy trait group, significant main effects were found for Block Valence, $F(1,13)=5.769$, $p=0.032$, with greater voltage during the negative block, and Stimulus Valence, $F(1,13)=7.689$, $p=0.016$, with greater voltage to emotional stimuli. There was no significant effect of Hemisphere, $F(1,13)=0.924$, $p=0.354$, nor any significant interactions, though Hemisphere by Gender did approach significance, $F(1,13)=4.578$, $p=0.052$. No significant main effects were found for the high trait group, nor were there any significant interactions, Block Valence, $F(1,15)=0.299$, $p=0.593$, Stimulus Valence, $F(1,15)=0.276$, $p=0.607$, Hemisphere, $F(1,15)=0.139$, $p=0.714$.

The block effect observed within the low group was subsequently tested to determine the AN380's relation to the emotional Stroop reaction time effect. Negative block minus positive block difference scores were computed for each subject for both reaction time, and for left and right ROI voltage during the 350-450ms time window. Pearson Product Moment correlation coefficients were calculated for difference scores. Block voltage differences were weakly negatively correlated with reaction time block differences in both hemispheres, but this effect was not significant, left: r=-0.277, p=0.317; right r=0.234, p=0.400.

Discussion

Behavioural effects

Despite reduced reaction times overall for the high-trait group during the emotional Stroop task, this effect was not significant, contrary to the first prediction for reaction time. It is possible that this effect was simply too small to detect with the current sample size, as observed power was 0.177. With regards to the second prediction of a negative block bias for the low-trait group only, repeated measures analysis of reaction times during the Stroop task found a significant effect of Block Valence across all participants, regardless of PPI-R: SF score. Responses during the negative emotion block showed an overall slowing in comparison to the positive block, but there was no significant interaction of this effect with Group. However, when mean reaction times were tested within groups, repeated measures ANOVA found that although reaction times were slower in both groups during the negative emotion block, this difference was only significant for the low-trait group. The fact that the trend in reaction times was the same in both groups may explain why no significant interaction between Block Valence and Group was found: the response pattern is similar in both groups, but far stronger in the low-trait group. This difference thus supports the second prediction for reaction time of a slow effect, negative emotion bias in the low group, with less differentiation in the high group.

That both groups show similar behavioural response patterns is actually quite intriguing. Psychopathy is increasingly viewed as a spectrum condition, with associated personality traits existing to varying degrees throughout the population (Carlson et al., 2009). This model is particularly emphasized in the purpose and structure of the PPI-R: SF, and other scales derived from the PPI, measures designed to facilitate assessment of the condition in non-criminal populations (Lilienfeld & Andrews, 1996; Lilienfeld & Widows, 2005). Though individuals selected for the high psychopathy personality trait group did score highly on the PPI-R: SF, they were chosen from a non-clinical sample, and thus it is not unreasonable that they displayed a similar trend in response patterns to other members of the population. Here it seems that high-trait individuals were responding in a similar manner to low-trait individuals, but their higher levels of psychopathic personality led to less emotional conflict, and thus resulted in augmentation of their reaction time performance on the emotional Stroop task.

It should also be noted that significant behavioural effects were found only at the block level, and not as an individual stimulus effects within blocks, thus concurring with Phaf and Kan (2007), and Taake et al. (2009). Additionally, while no significant effect of stimulus valence was found, there was a trend of slower reaction times to neutral stimuli than emotional stimuli. While this may at first seem odd, it is important to consider that the design of the study and the pseudorandomization of stimuli increased the likelihood of emotional IAPS pictures preceding neutral ones. Thus, this peculiarity in reaction time to neutral stimuli further supports the notion that the emotional Stroop task produces a slow effect, with emotional interference impeding response on subsequent trials.

LPP

As predicted, the Late Positive Potential was reduced in the high-trait group, relative to the low-trait group for both midline and lateral regions of interest (ROIs). Lateral analyses found the effect to be stronger over the left hemisphere of the posterior scalp, but were ultimately comparable to those conducted along the midline. Whereas the low group responded much more strongly to emotional stimuli than neutral stimuli regardless of positive or negative valence, the high trait group responded equally to all neutral and emotional stimuli. This pattern of activity supports the notion that psychopathy is to some degree influenced by top-down emotional regulation. As previously discussed, amplitude of the LPP increase as a function of emotional salience, and the component is sensitive to various forms of voluntary top-down control (regulation, reappraisal and redirection) (Hajcak & Nieuwenhuis, 2006; Moser et al., 2006).

No interaction was found between Block Valence and Stimulus Valence for either group, indicating that positive and negative emotional stimuli both produced an LPP effect. While it has been argued that the LPP may show a negative bias, in a study examining the time course of ERPs to IAPS stimuli, Weinburg and Hajcak (2010) have recently shown that such biases may relate to the intrinsic evolutionary value of emotional stimuli. These authors postulated that categorical differences within broader valence classes can be used to hierarchically rank LPP response, and found that among positive emotional stimuli, erotica produced greater response than affiliative images, which in turn produced greater response than exciting images. For negative valence pictures, mutilation produced a greater response than threatening images, which produced a greater response than disgusting images. They argue that previously observed negativity biases in the LPP may have been due to a “dilution” of the positive response due to an over representation of exciting stimuli. In the current study, no images of mutilation or erotica were used, and across all valences (negative, positive and neutral), stimuli were matched for content. As such, the absence of a negativity bias in the current study appears to concur with the previous literature examining LPP to IAPS stimuli.

Because of the largely top-down nature of the LLP, observed abnormalities in the component imply that the emotional deficits of psychopathic personality have a strong learned, cognitive aspect. Criminal psychopaths are often viewed as “untreatable” by the criminal justice system. This view is based on studies that reported that psychopaths showed poor responsiveness to treatment, and in some cases may have even manipulate programs and staff to their own ends (Rice, Harris & Comier, 1992; Seto & Barbaree 1999). Evidence of the condition may be used to exclude individuals from treatment programs, or to justify the pre-emptive imposition of indefinite incarceration of convicts who have served their time but pose a risk to vulnerable groups in Canadian jurisdictions (Criminal Code of Canada, 1985). But, if psychopathic emotional down-regulation is at least in part a learned phenomenon, rather than a purely physiological responsivity issue, this may imply that it can be unlearned, and that psychopaths may in fact be more receptive to treatment than has previously been assumed. This could potentially lead to treatments better designed to target their specific affective dysfunctions. It could also be used to guide early intervention strategies for children viewed as at risk by parents and teachers. Further research along these lines should focus on identifying factors that contribute to the development of this emotional response pattern. In particular, one study identified a cluster of “fearful psychopaths” from a high Antisocial Personality Disorder offender sample that display increased anxiety sensitivity and harm avoidance relative to other psychopaths, and were distinguishable by a markedly increased self-reported history of childhood abuse (Poythress et al., 2010)

EAP

The Early Anterior Positivity effects observed in this study did not match initial predictions. It was anticipated that EAP voltages would be less differentiated for negative emotional stimuli and neutral emotional stimuli within the high-trait group than the low-trait group. Midline analysis failed to find a significant interaction of Block Valence by Stimulus Valence in either the low-trait or the high-trait groups, though for the low trait group, there was an overall effect of Stimulus Valence, with emotional stimuli producing a greater positive deflection across the anterior scalp. This interaction approached, but failed to reach significance in the lateral analysis. It is possible that this test lacked adequate power to detect an effect of this magnitude, as observed power of the lateral interaction was 0.473. Within group analysis of the low-trait group found that emotional stimuli tended to produce a greater response along the midline ROI, and a similar trend was found at lateral sites. No such effect was found for the high group, though unexpectedly, Stimulus Valence was found to interact with both Hemisphere and Gender for lateral regions. Neither group appeared to show an interaction of Block Valence and Stimulus Valence. These results thus suggest a generalized effect of the EAP for individuals low in psychopathic personality, with emotional stimuli resulting in greater positive activation across anterior regions of the scalp, whereas those high in these personality trait show no such early emotional activation. In contrast, individuals with high trait-anxiety may show enhancements of the EAP to threat related images as per Taake et al. (2009).

Taake and colleagues (2009) view the EAP effect as an early positivity across the anterior scalp. However, other research groups have focus on the posterior scalp during this time window, where they have observed a negative enhancement of electrical potentials to emotional images, the Early Posterior Negativity (EPN; see Weinburg & Hajcak, 2010). In examining ERPs to IAPS stimuli, Weinburg and Hajcak (2010), found greater EPN for erotic than mutilation images, as well as an overall bias of the component toward positive valence versus negative valence images. In the current study, no such bias toward positive stimuli was observed. This could potentially be due to the fact that Weinburg and Hajcak (2010) found no overall difference between affiliative and threatening stimuli, and that positivity bias is only observed when mutilation and erotic stimuli are included in the broader valence categories, which was not the case in the current study. However, it is also possible that the EAP and the EPN represent distinct ERP components, with the former biased to negative and threat stimuli, and the latter biased to positive and reward stimuli. Future studies employing broader arrays of emotional stimuli, as well as ERP source localization of both components could potentially be used to determine if they share overlapping neural generators.

P1

Whereas decreases in LPP indicated clear cognitive, top-down disruption of affective response in psychopathy, the decreased P1 voltages observed in this study may point to additional bottom-up deficits. It was initially predicted that the high-trait group would show a generalized decrease in arousal throughout the entire experimental task, as indexed by diminished P1 voltage across all conditions; this was not the case. But although a clear between groups P1 difference across all stimuli was not found, the component was found to vary as a function of a Group by Stimulus Valence interaction. While the high-trait group displayed almost no difference between voltages to neutral and emotional stimuli, the low-trait group had a moderately more positive response to emotional stimuli. Though within group analyses failed to find a significant effect of Stimulus Valence for the low-trait group, there was a non-significant trend toward greater response to emotional stimuli than neutral stimuli. No such effect was found for the high group, thus it appears that higher levels of psychopathic personality traits were associated with at least some reduction of P1 amplitude to emotional stimuli. This within block effect is likely the result of a bottom-up response to emotionally evocative stimuli, where emotional content is eliciting a greater early response, before any type of top-town process may begin to interfere. It is unlikely that this effect is due to a top-down reorienting of attention, such as an attentional cueing effect, as it is occurring within blocks, and subjects had no way of know what type of images might be occurring next, and thus for which trials to redirect covert attention. This finding may still support the notion that higher levels of psychopathic personality traits are associated with less visceral response to emotion stimuli. While all images were matched for content, and negative and positive stimuli were matched for valence and arousal, both types of emotional stimuli were more arousing than neutral stimuli. Here, the absence of gut emotional response may have resulted in less redirection of attention to salient emotional stimuli. Admittedly, this explanation is limited by the fact that the current task featured only emotional blocks. Given that no blocks in the experiment were entirely emotionally neutral, it is impossible to say concretely whether the observed reductions in P1 voltage were due to the higher psychopathy individuals experiencing less emotional arousal, or simply because they inherently fail to reorient to novel or salient stimuli in general. Although psychopathy researchers have focused primarily on later attentional components, a recent study found *increased* N2—an early attentional component—for auditory stimuli in a high-psychopathy offender sample (Kiehl, Bates, Laurens, Hare, & Liddle, 2006). This indicates that psychopaths may actually possess enhanced early attention in some situations.

An unexpected effect of Block Valence was found for the P1 component, with voltages across groups greater during the positive emotion block than the negative emotion block. However, within group analyses helped clarify this finding, revealing significant increases in P1 voltages among low-trait individuals during the positive block. No such effect was found in the high-trait group, though there was a slight, non-significant tendency for greater responses during the positive emotion block, which may explain the lack of a Group interaction. Results thus supported the prediction of a between block bias in the low group, and less differentiation in the high group. The cause of this likely lies in the fact that P1 amplitude is increased when subjects actively attend to target locations before stimulus presentation (Vogel and Luck, 2000). It is possible that due to the aversive and threatening nature of stimuli presented in the negative block, low psychopathy trait participants indiscriminately directed covert attention away from potentially aversive images during the negative blocks, or focused more intently potentially rewarding images presented during positive blocks. By doing so, they may have caused a cuing effect that reduced P1 response to all stimuli throughout negative blocks, or amplified it throughout the positive blocks. If this is the case, it speaks to the idea that the high psychopathy trait group experienced less anxiety during the emotional Stroop task, and were able to perform equally well, regardless of the emotional content with which they were confronted. Further studies of the effects of emotion on the P1 should include non-emotional or no-response conditions to further explore the nature of basic emotional deficits and strengths in psychopathic populations, as well as to test whether exogenous and endogenous cueing effects can be observed within such groups.

AN380 exploratory analysis

Exploratory analysis of lateral anterior voltages during the 350-450ms post stimulus window found significantly greater voltages in the negative emotion block than the positive emotion block, and to emotional stimuli than neutral stimuli within the low-trait group. Taake and colleagues (2009) argued that a ERP block effect peaking during this time window—the AN380—may in fact be the electrophysiological correlate of the emotional Stroop reaction time effect and found that increased negative block voltages during this time correlated with observed reaction time block effects (Taake et al.). As was the case in the previous study, for negative valence blocks of the task, more negative voltages across the lateral scalp were associated with increased reaction times. However, this effect was fairly weak, and did not approach significance. It is possible that with a greater sample size, this effect could be found to be significant. While a similar sample size was use by Taake et al., their observed correlation was much stronger for the high anxiety group, and no effect was found in the low anxiety group. Therefore, it is possible that the effect is simply too weak to observe reliably within a normal sample.

Limitations and future directions

A major limitation of the current study was the small sample size. The power profile conducted indicated that all statistical tests lacked acceptable power to detect even large effect sizes. Small sample size is often an issue in ERP research, and the number of subjects included in the current sample was fairly typical, though in future, the inclusion of more subjects will improve the ability to detect significant group differences and interactions.

A second limitation of the current study was the gender imbalance in the low psychopathic personality trait group. This was due in part to the method of participant selection employed, which was based on percentile rankings of a large mass screening of students. However, the PPI-R: SF appears to have a strong bias towards males. In a study recently completed in our lab, it was found that males score on average approximately 10 points higher on the scale than females (Carolan, Wilson, Sramko, Liotti, & Douglas, 2011), thus males were over represented above the 90^{th} percentile, and underrepresented below the 25^{th} percentile. Future research using the PPI-R: SF for between groups designs could use a median split procedure for subject selection, recruit males and females separately based on percentile rankings for each gender, or perhaps base selection on previously published population norms as these become more readily available.

A third limitation of the study was the lack IAPS images featuring erotica and mutilation. Weinburg and Hajcak (2010) found that of all positive and negative valence IAPS stimuli, these produce the greatest response for a number of emotional ERP components. Their absence may have influenced the inability to find Block Valence by Stimulus Valence interactions for the EAP, or a correlation between reaction time and AN380 voltage. However, the absence of such stimuli may have helped mitigate some of the gender imbalance in the study, as females typically report erotic IAPS as less arousing than males.

Regardless, overall experimental power could be increased in future studies by the inclusion of such stimuli.

Finally, participants in the current study were not given explicit instructions regarding how to approach the emotional and neutral images on which Stroop targets were superimposed. Rather, they were simply told to focus on fixation crosses during ISIs, and targets during stimulus presentations, so as not to interfere with the emotional Stroop effect. It is possible that one group more actively attended to the picture stimuli, or suppressed—or even enhanced—their emotional response to the images. This in turn may have altered ERP patterns, and could influence certain results, particularly the block effect of the P1 found in the low-trait group. This in itself would be intriguing, as such patterns might suggest fascination/desensitization for novelty and/or emotional content, desire to help or hinder the researcher in the case of participants who had discerned the nature of the task, or a number of other possibilities. For now, the existence of group differences is clear, but the exact direction of sensory gain modulation for components such as the P1 could be debated. Further studies on psychopathy and emotion could thus test the effects of explicit covert attention direction, emotional up or down regulation instructions, and passive observation blocks to test how such instructions influence ERP response.

Ultimately, by providing novel electrophysiological data in support of classic clinical observations, the current study appears to support the widely held view that increased psychopathic personality is characterized by a deficit in emotional response. Furthermore, results largely concur with established views of documented emotional ERP effects. In proceeding from here, psychopathy researchers will hopefully benefit from a clearer understanding of the physiological dysfunctions that underpin the condition, eventually leading to more effective treatments of the personality disorder, and better mitigation strategies. And in the tradition of neurology, perhaps EEG researchers of emotion in all its guises may benefit from the elucidation of the relationship between lack of empathic or emotional response, and reactivity of the EAP, LPP, and other emotional ERP components.

Figures

Figure 1 Paradigm structure

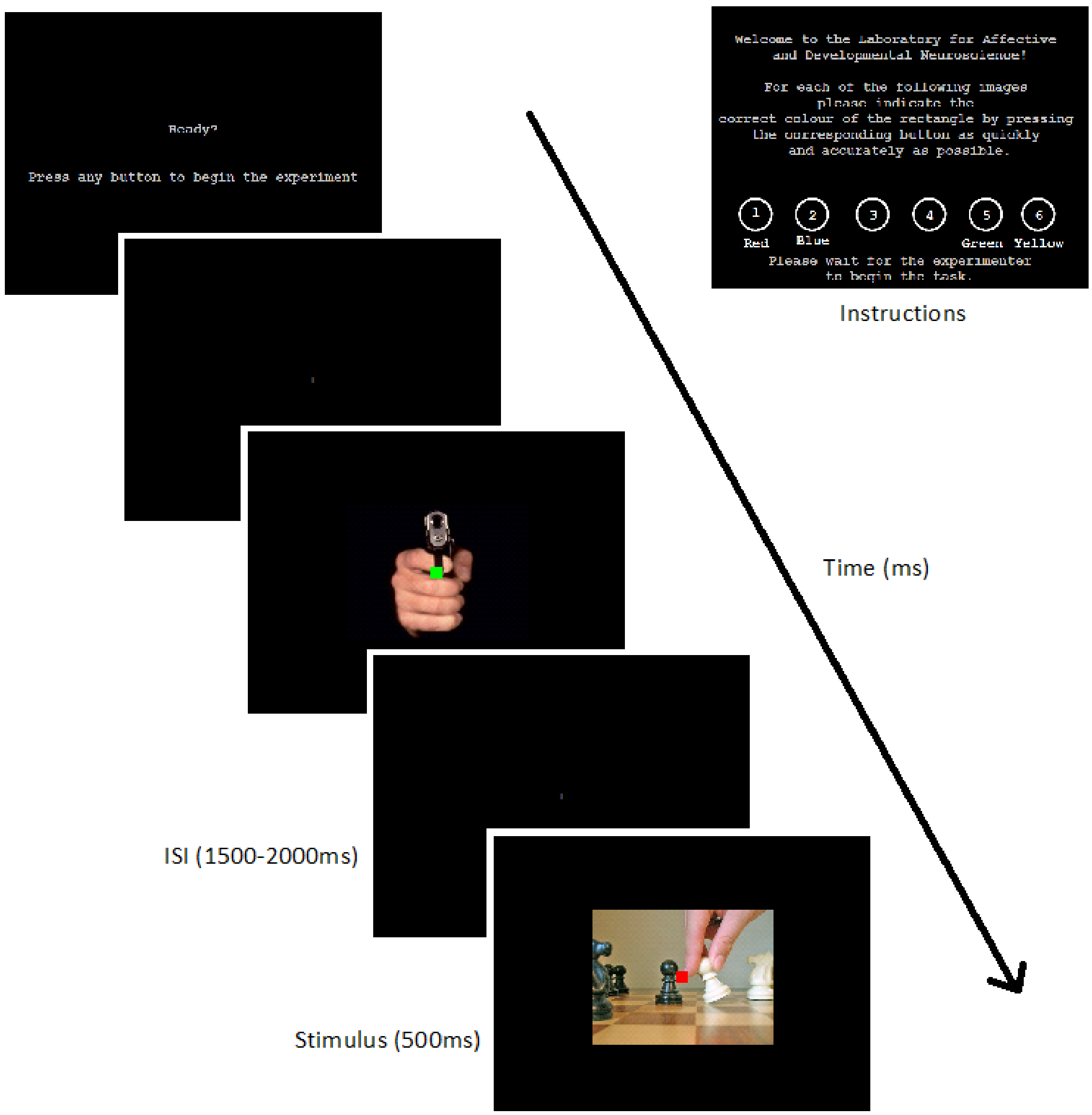

Figure 2 Response accuracy

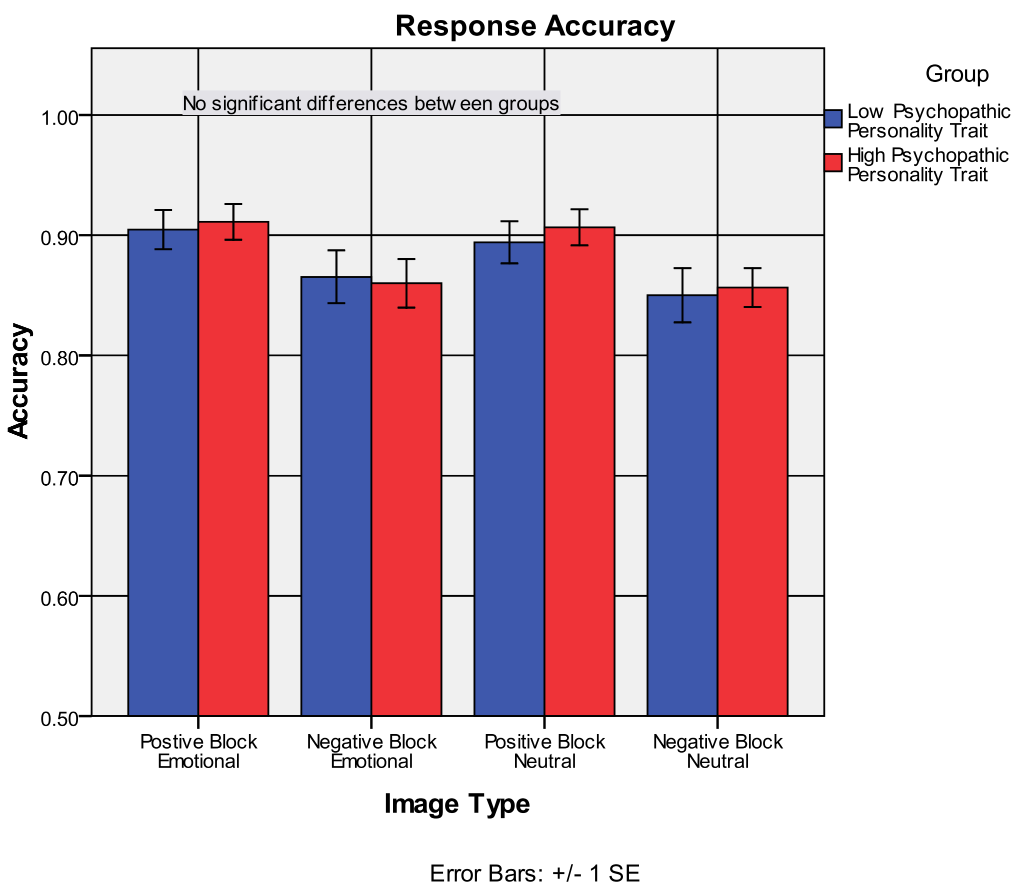

Figure 3 Between-block reaction time

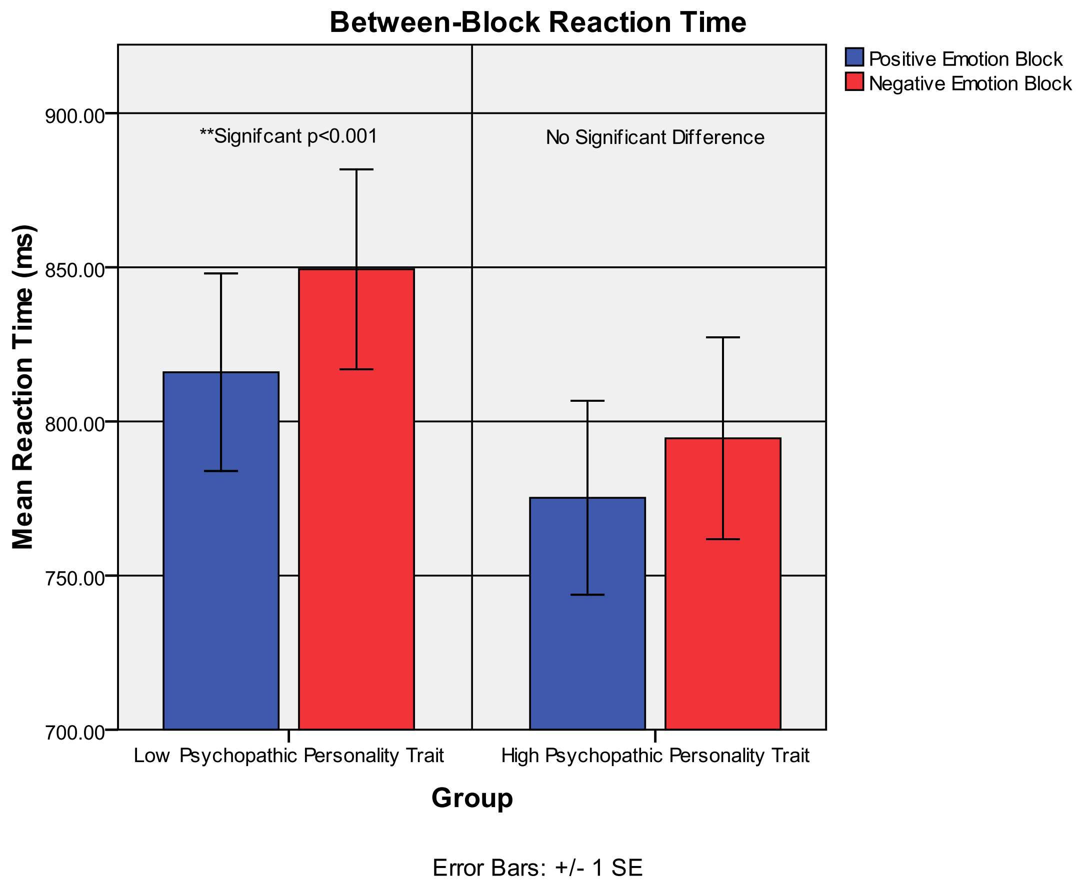

Figure 4 Within-block reaction time

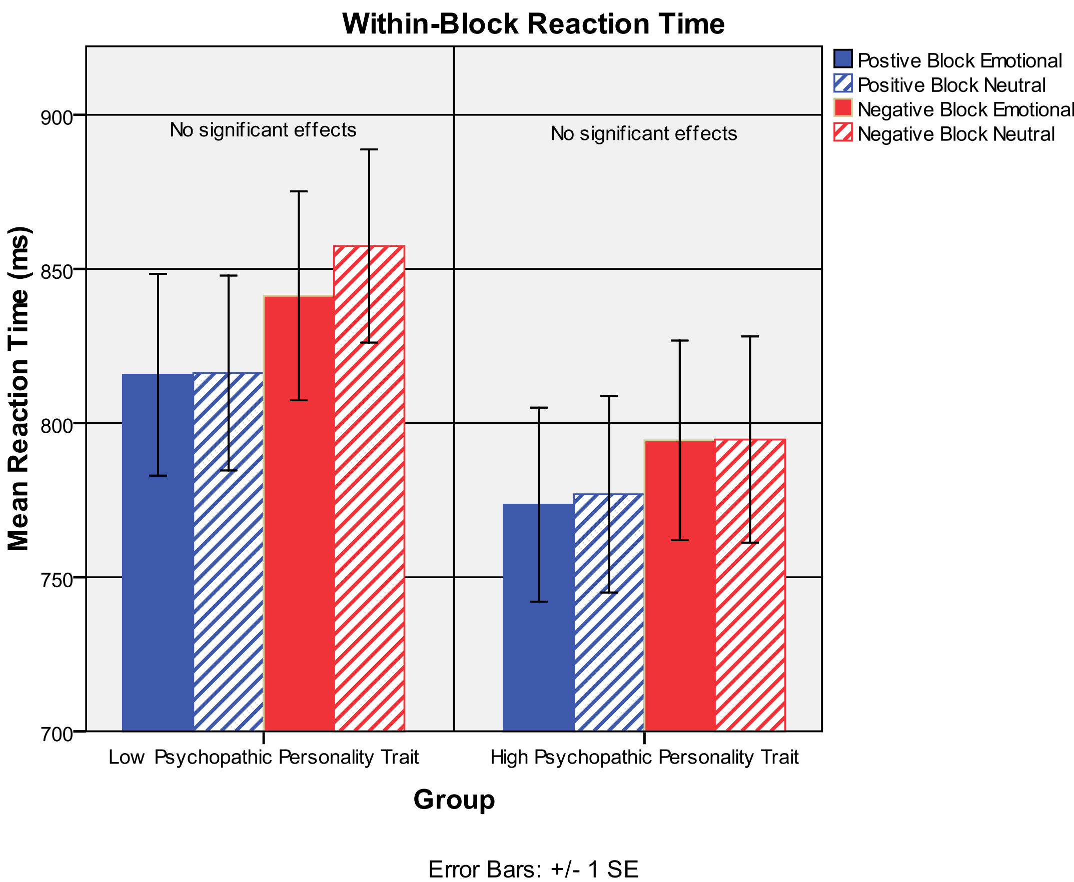

Figure 5 Between-block ERP effects

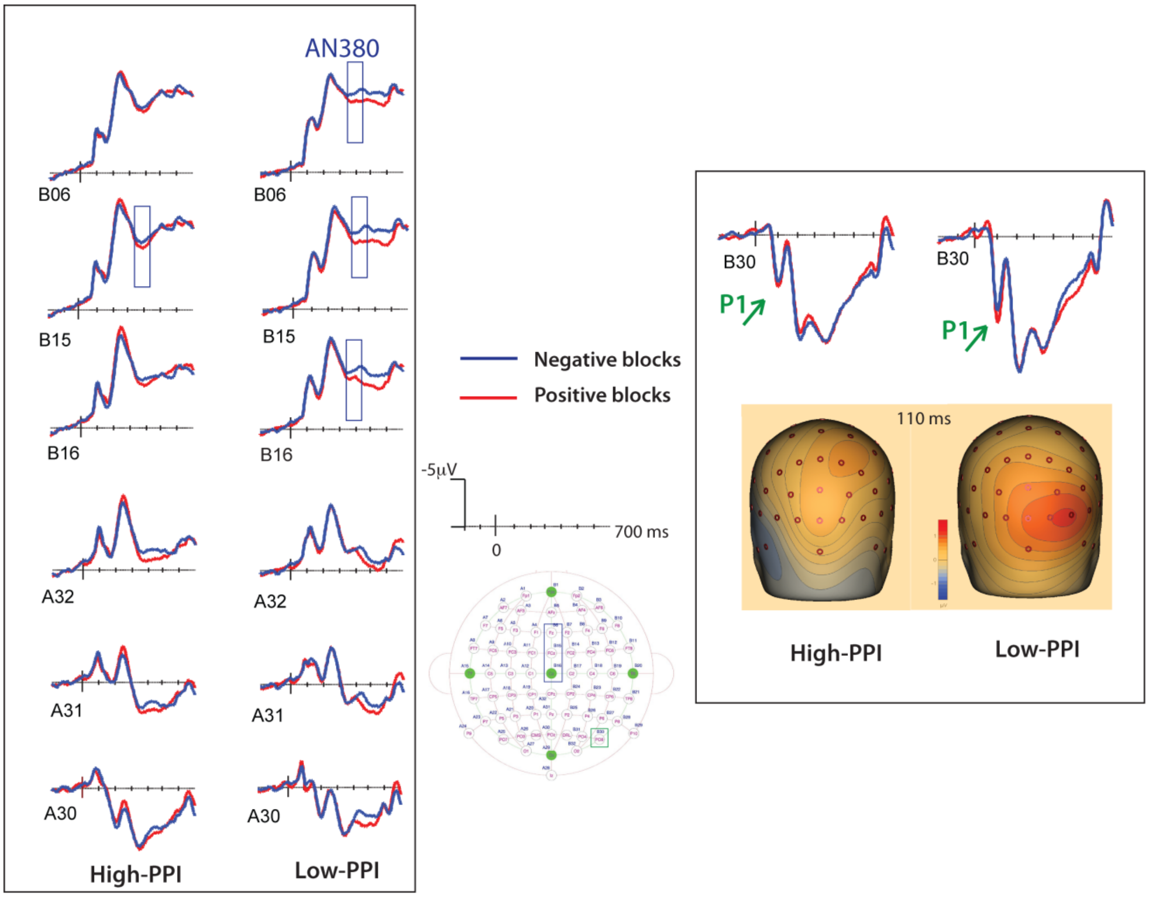

Figure 6 Within-block ERP effects

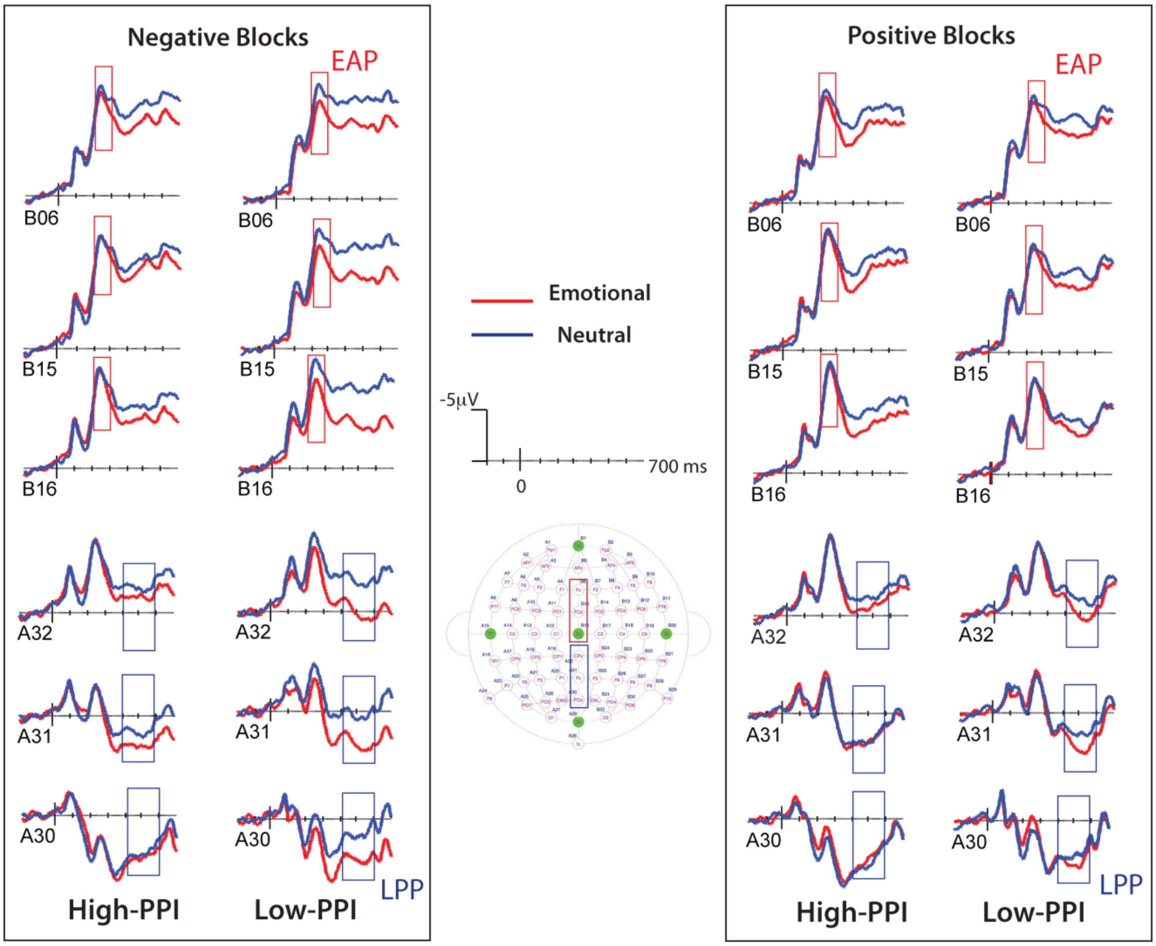

Figure 7 LPP midline ANCOVA results

LPP Midline	Between Groups (n=32)			Low-trait (n=15)			High-Trait (n=17)		
	df	F	Sig	df	F	Sig	df	F	Sig
Block Valence	1,29	0.745	0.395	1,13	2.617	0.13	1,15	0.104	0.751
Stimulus Valence	1,29	3.787	0.061	1,13	7.463	*0.017	1,15	0.338	0.569
Gender	1,29	0	0.992	1,13	0.571	0.463	1,15	0.424	0.525
Group	1,29	0.006	0.941	1,13	-	-	1,15	-	-
Block Valence * Gender	1,29	0.006	0.939	1,13	0.017	0.898	1,15	0.014	0.906
Block Valence * Group	1,29	0.173	0.681	1,13	-	-	1,15	-	-
Stimulus Valence * Gender	1,29	1.627	0.212	1,13	3.91	0.07	1,15	0.068	0.798
Stimulus Valence * Group	1,29	4.315	**0.047	1,13	-	-	1,15	-	-
Block Valence * Stimulus Valence	1,29	1.86	0.183	1,13	1.391	0.259	1,15	0.621	0.443
Block Valence * Stimulus Valence * Gender	1,29	0.122	0.73	1,13	0.008	0.929	1,15	0.256	0.62
Block Valence * Stimulus Valence * Group	1,29	252	0.619	1,13	-	-	1,15	-	-
	**significant at α<0.05				*significant at per test α<0.05				

Figure 8 LPP lateral ANCOVA results

LPP Lateral	Between Groups (n=32)			Low-trait (n=15)			High-Trait (n=17)		
	df	F	Sig	df	F	Sig	df	F	Sig
Block Valence	1,29	0.537	0.469	1,13	2.578	0.132	1,15	0.026	0.875
Stimulus Valence	1,29	6.823	**0.014	1,13	9.683	*0.008	1,15	0.912	0.355
Hemisphere	1,29	4.483	**0.043	1,13	3.895	0.07	1,15	1.999	0.178
Gender	1,29	0.302	0.587	1,13	0.879	0.366	1,15	0.009	0.926
Group	1,29	0.006	0.939	1,13	-	-	1,15	-	-
Block Valence * Gender	1,29	0.011	0.917	1,13	0.009	0.927	1,15	0.005	0.943
Block Valence * Group	1,29	0.258	0.616	1,13	-	-	1,15	-	-
Stimulus Valence * Gender	1,29	0.839	0.367	1,13	1.217	0.29	1,15	0.115	0.739
Stimulus Valence * Group	1,29	2.87	0.101	1,13	-	-	1,15	-	-
Hemisphere * Gender	1,29	3.087	0.089	1,13	2.77	0.12	1,15	1.316	0.269
Hemisphere * Group	1,29	0.306	0.584	1,13	-	-	1,15	-	-
Block Valence * Stimulus Valence	1,29	2.735	0.109	1,13	2.089	0.172	1,15	0.9	0.358
Block Valence * Stimulus Valence * Gender	1,29	0.25	0.621	1,13	0.007	0.934	1,15	0.295	0.595
Block Valence * Stimulus Valence * Group	1,29	0.177	0.677	1,13	-	-	1,15	-	-
Block Valence * Hemisphere	1,29	0.525	0.475	1,13	1.424	0.254	1,15	0.07	0.795
Block Valence * Hemisphere * Gender	1,29	2.254	0.144	1,13	1.323	0.271	1,15	0.928	0.351
Block Valence * Hemisphere * Group	1,29	1.957	0.312	1,13	-	-	1,15	-	-
Stimulus Valence * Hemisphere	1,29	0.196	0.661	1,13	0.588	0.457	1,15	0.024	0.878
Stimulus Valence * Hemisphere * Gender	1,29	0.394	0.535	1,13	0.383	0.547	1,15	0.079	0.783
Stimulus Valence * Hemisphere * Group	1,29	0.33	0.57	1,13	-	-	1,15	-	-
Block Valence * Stimulus Valence * Hemisphere	1,29	0.003	0.958	1,13	2.118	0.169	1,15	0.345	0.566
Block Valence * Stimulus Valence * Hemisphere * Gender	1,29	0.01	0.923	1,13	0.014	0.909	1,15	0.022	0.884
Block Valence * Stimulus Valence * Hemisphere * Group	1,29	1.679	0.205	1,13	-	-	1,15	-	-
	**significant at α<0.05				*significant at per test α<0.05				

Figure 9 EAP midline ANCOVA results

EAP Midline	Between Groups (n=32)			Low-trait (n=15)			High-Trait (n=17)		
	df	F	Sig	df	F	Sig	df	F	Sig
Block Valence	1,29	0.429	0.518	1,13	0.539	0.476	1,15	0.084	0.776
Stimulus Valence	1,29	2.498	0.125	1,13	6.525	*0.024	1,15	0.088	0.77
Gender	1,29	0.091	0.766	1,13	0.128	0.726	1,15	0.505	0.488
Group	1,29	0.01	0.921	1,13	-	-	1,15	-	-
Block Valence * Gender	1,29	0.744	0.395	1,13	0.137	0.717	1,15	0.574	0.46
Block Valence * Group	1,29	0.203	0.656	1,13	-	-	1,15	-	-
Stimulus Valence * Gender	1,29	1.549	0.233	1,13	0.091	0.768	1,15	3.727	0.073
Stimulus Valence * Group	1,29	1.782	0.192	1,13	-	-	1,15	-	-
Block Valence * Stimulus Valence	1,29	0.039	0.844	1,13	0.307	0.589	1,15	0.288	0.6
Block Valence * Stimulus Valence * Gender	1,29	1.17	0.288	1,13	1.636	0.223	1,15	0.232	0.637
Block Valence * Stimulus Valence * Group	1,29	1.561	0.221	1,13	-	-	1,15	-	-
	**significant at α<0.05				*significant at per test α<0.05				

Figure 10 EAP lateral ANCOVA results

EAP Lateral	Between Groups (n=32)			Low-trait (n=15)			High-Trait (n=17)		
	df	F	Sig	df	F	Sig	df	F	Sig
Block Valence	1,29	0.216	0.646	1,13	0.467	0.506	1,15	0.004	0.95
Stimulus Valence	1,29	0.007	0.935	1,13	4.076	0.065	1,15	2.663	0.124
Hemisphere	1,29	0.179	0.676	1,13	1.724	0.212	1,15	0.217	0.648
Gender	1,29	0.036	0.851	1,13	0.101	0.756	1,15	0.001	0.972
Group	1,29	0.011	0.916	1,13	-	-	1,15	-	-
Block Valence * Gender	1,29	0.294	0.592	1,13	0.389	0.544	1,15	0.052	0.823
Block Valence * Group	1,29	0.059	0.81	1,13	-	-	1,15	-	-
Stimulus Valence * Gender	1,29	4.508	**0.042	1,13	0.085	0.775	1,15	5.565	*0.032
Stimulus Valence * Group	1,29	3.943	0.057	1,13	-	-	1,15	-	-
Hemisphere * Gender	1,29	0.029	0.866	1,13	1.096	0.314	1,15	0.724	0.408
Hemisphere * Group	1,29	0.201	0.658	1,13	-	-	1,15	-	-
Block Valence * Stimulus Valence	1,29	1.721	0.2	1,13	0.099	0.757	1,15	2.789	0.116
Block Valence * Stimulus Valence * Gender	1,29	3.055	0.091	1,13	0.003	0.958	1,15	1.399	0.255
Block Valence * Stimulus Valence * Group	1,29	3.828	0.06	1,13	-	-	1,15	-	-
Block Valence * Hemisphere	1,29	2.067	0.161	1,13	1.259	0.282	1,15	0.904	0.357
Block Valence * Hemisphere * Gender	1,29	0.826	0.371	1,13	0.452	0.513	1,15	0.388	0.543
Block Valence * Hemisphere * Group	1,29	0.48	0.828	1,13	-	-	1,15	-	-
Stimulus Valence * Hemisphere	1,29	9.591	0.004	1,13	1.026	0.33	1,15	10.542	*0.005
Stimulus Valence * Hemisphere * Gender	1,29	0.528	0.473	1,13	0.003	0.958	1,15	0.944	0.347
Stimulus Valence * Hemisphere * Group	1,29	2.906	0.099	1,13	-	-	1,15	-	-
Block Valence * Stimulus Valence * Hemisphere	1,29	0.182	0.673	1,13	0.783	0.392	1,15	0.056	0.816
Block Valence * Stimulus Valence * Hemisphere * Gender	1,29	3.718	0.064	1,13	0.621	0.445	1,15	3.202	0.094
Block Valence * Stimulus Valence * Hemisphere * Group	1,29	0.241	0.627	1,13	-	-	1,15	-	-
	**significant at α<0.05				*significant at per test α<0.05				

Figure 11 P1 lateral ANCOVA results

P1 Lateral	Between Groups (n=32)			Low-trait (n=15)			High-Trait (n=17)		
	df	F	Sig	df	F	Sig	df	F	Sig
Block Valence	1,29	4.74	0.038	1,13	6.289	*0.026	1,15	0.741	0.403
Stimulus Valence	1,29	0.747	0.394	1,13	3.071	0.103	1,15	0.324	0.578
Hemisphere	1,29	0.347	0.561	1,13	0.009	0.928	1,15	1.138	0.303
Gender	1,29	0.225	0.639	1,13	0.396	0.54	1,15	0.005	0.947
Group	1,29	1.003	0.325	1,13	-	-	1,15	-	-
Block Valence * Gender	1,29	0.661	0.423	1,13	0.788	0.391	1,15	0.143	0.771
Block Valence * Group	1,29	0.414	0.525	1,13	-	-	1,15	-	-
Stimulus Valence * Gender	1,29	0.031	0.861	1,13	0.009	0.928	1,15	0.023	0.88
Stimulus Valence * Group	1,29	4.256	**0.048	1,13	-	-	1,15	-	-
Hemisphere * Gender	1,29	0.139	0.712	1,13	0.632	0.441	1,15	0.226	0.641
Hemisphere * Group	1,29	0.012	0.912	1,13	-	-	1,15	-	-
Block Valence * Stimulus Valence	1,29	0.016	0.9	1,13	0.172	0.685	1,15	0.067	0.799
Block Valence * Stimulus Valence * Gender	1,29	0.058	0.812	1,13	0.373	0.552	1,15	0.602	0.45
Block Valence * Stimulus Valence * Group	1,29	0.012	0.898	1,13	-	-	1,15	-	-
Block Valence * Hemisphere	1,29	2.101	0.158	1,13	4.828	*0.047	1,15	0	0.997
Block Valence * Hemisphere * Gender	1,29	0.115	0.737	1,13	0.699	0.418	1,15	0.043	0.838
Block Valence * Hemisphere * Group	1,29	1.398	0.247	1,13	-	-	1,15	-	-
Stimulus Valence * Hemisphere	1,29	2.382	0.134	1,13	1.244	0.285	1,15	1.387	0.257
Stimulus Valence * Hemisphere * Gender	1,29	0.336	0.567	1,13	0.431	0.523	1,15	0.124	0.73
Stimulus Valence * Hemisphere * Group	1,29	0.813	0.375	1,13	-	-	1,15	-	-
Block Valence * Stimulus Valence * Hemisphere	1,29	0.087	0.77	1,13	4.446	0.055	1,15	0.848	0.372
Block Valence * Stimulus Valence * Hemisphere * Gender	1,29	0.049	0.826	1,13	1.802	0.202	1,15	0.201	0.66
Block Valence * Stimulus Valence * Hemisphere * Group	1,29	2.191	0.15	1,13	-	-	1,15	-	-
	**significant at α<0.05				*significant at per test α<0.05				

Figure 12 AN380 lateral ANCOVA and Correlation results

AN380 Lateral	Low-trait (n=15)			High-Trait (n=17)		
	df	F	Sig	df	F	Sig
Block Valence	1,13	5.769	*0.032	1,15	0.299	0.593
Stimulus Valence	1,13	7.689	*0.016	1,15	0.276	0.607
Hemisphere	1,13	0.924	0.354	1,15	0.139	0.714
Gender	1,13	0.355	0.561	1,15	0.001	0.97
Block Valence * Gender	1,13	1.052	0.324	1,15	0.166	0.69
Stimulus Valence * Gender	1,13	1.767	0.207	1,15	2.998	0.104
Hemisphere * Gender	1,13	4.578	0.052	1,15	0.651	0.432
Block Valence * Stimulus Valence	1,13	0.04	0.844	1,15	2.464	0.137
Block Valence * Stimulus Valence * Gender	1,13	0.523	0.482	1,15	1.569	0.229
Block Valence * Hemisphere	1,13	0.282	0.604	1,15	0.024	0.876
Block Valence * Hemisphere * Gender	1,13	0.109	0.747	1,15	0.025	0.876
Stimulus Valence * Hemisphere	1,13	5.505	*0.035	1,15	0.265	0.614
Stimulus Valence * Hemisphere * Gender	1,13	4.431	0.055	1,15	1.72	0.209
Block Valence * Stimulus Valence * Hemisphere	1,13	1.565	0.233	1,15	0.244	0.629
Block Valence * Stimulus Valence * Hemisphere * Gender	1,13	0.071	0.795	1,15	0.439	0.518
	*significant at per test α<0.05					

Low-trait Within Group Correlations		
(Negative Block Minus Positive Block)		RT Diff
Left ROI Voltage Difference	r=-0.277	p=0.317
Right ROI Voltage Difference	r=-0.234	p=0.400

Tables

Table 1 Demographics: Descriptive statistics

	Male	Female	Right-handed	Left-handed
Low-trait	4	11	14	1
High-trait	8	9	16	1

	Group	N	Mean	Std. Deviation	Std. Error Mean
Age	Low-trait	15	20.4000	3.73784	.96511
	High-trait	17	20.1176	2.54662	.61765
Education	Low-trait	15	14.2667	2.15362	.55606
	High-trait	17	13.8235	1.07444	.26059
PPI-R: SF Total Score	Low-trait	15	94.13	10.035	2.591
	High-trait	17	141.76	5.707	1.384

Table 2 Demographics: Inferential statistics

				95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Lower	Upper
Age	.252	30	.803	-2.00303	2.56773
Education	.750	30	.459	-.76315	1.64943
PPI-R: SF Total Score	-16.760	30	.000	-53.435	-41.827

Table 3 LPP midline ROI voltage by condition

Group	Block Valence	Stimulus Valence	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Low-trait	Positive	Emotional	2.281	1.343	-.466	5.028
		Neutral	1.083	1.456	-1.894	4.060
	Negative	Emotional	2.356	1.537	-.788	5.500
		Neutral	-.462	1.758	-4.058	3.134
High-trait	Positive	Emotional	1.663	1.260	-.913	4.240
		Neutral	1.566	1.365	-1.226	4.359
	Negative	Emotional	1.744	1.442	-1.205	4.693
		Neutral	.874	1.649	-2.500	4.247

Table 4 LPP lateral ROI voltage by condition

Group	Block Valence	Stimulus Valence	Hemisphere	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Low-trait	Positive	Emotional	Right	1.830	1.174	-.571	4.231
			Left	1.561	1.118	-.726	3.847
		Neutral	Right	.994	1.201	-1.462	3.451
			Left	.413	1.153	-1.945	2.771
	Negative	Emotional	Right	2.033	1.301	-.627	4.693
			Left	1.687	1.444	-1.267	4.640
		Neutral	Right	-.879	1.351	-3.642	1.885
			Left	-1.100	1.447	-4.059	1.859
High-trait	Positive	Emotional	Right	1.619	1.101	-.633	3.872
			Left	.707	1.049	-1.438	2.851
		Neutral	Right	1.281	1.126	-1.023	3.585
			Left	.619	1.081	-1.593	2.831
	Negative	Emotional	Right	1.959	1.220	-.536	4.454
			Left	.982	1.355	-1.788	3.753
		Neutral	Right	.690	1.267	-1.902	3.282
			Left	-.387	1.357	-3.163	2.388

Table 5 EAP midline ROI voltage by condition

Group	Block Valence	Stimulus Valence	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Low-trait	Positive	Emotional	-8.502	1.257	-11.073	-5.931
		Neutral	-9.082	1.383	-11.910	-6.254
	Negative	Emotional	-8.020	1.207	-10.488	-5.552
		Neutral	-9.938	1.256	-12.507	-7.369
High-trait	Positive	Emotional	-8.749	1.179	-11.161	-6.338
		Neutral	-9.454	1.297	-12.107	-6.801
	Negative	Emotional	-8.892	1.132	-11.207	-6.577
		Neutral	-9.118	1.178	-11.527	-6.708

Table 6 EAP lateral ROI voltage by condition

Group	Block Valence	Stimulus Valence	Hemisphere	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Low-trait	Positive	Emotional	Right	-6.012	1.196	-8.459	-3.566
			Left	-6.660	1.091	-8.892	-4.429
		Neutral	Right	-6.829	1.287	-9.461	-4.196
			Left	-6.837	1.197	-9.286	-4.388
	Negative	Emotional	Right	-5.651	1.051	-7.801	-3.501
			Left	-6.172	1.090	-8.402	-3.942
		Neutral	Right	-7.228	1.008	-9.290	-5.165
			Left	-7.855	1.272	-10.456	-5.254
High-trait	Positive	Emotional	Right	-6.297	1.122	-8.592	-4.002
			Left	-6.732	1.023	-8.826	-4.639
		Neutral	Right	-7.450	1.207	-9.919	-4.981
			Left	-6.812	1.123	-9.109	-4.515
	Negative	Emotional	Right	-6.944	.986	-8.961	-4.928
			Left	-7.525	1.023	-9.617	-5.433
		Neutral	Right	-6.369	.946	-8.304	-4.435
			Left	-6.330	1.193	-8.770	-3.890

Table 7 P1 lateral ROI voltage by condition

Group	Block Valence	Stimulus Valence	Hemisphere	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Low-trait	Positive	Emotional	Right	3.379	1.027	1.279	5.479
			Left	4.189	1.062	2.016	6.362
		Neutral	Right	2.623	1.034	.509	4.737
			Left	3.369	1.028	1.265	5.472
	Negative	Emotional	Right	3.103	1.030	.996	5.211
			Left	3.201	1.092	.967	5.435
		Neutral	Right	2.130	1.038	.006	4.254
			Left	2.774	1.036	.655	4.892
High-trait	Positive	Emotional	Right	1.856	.963	-.114	3.825
			Left	1.956	.997	-.082	3.994
		Neutral	Right	1.567	.970	-.416	3.550
			Left	2.441	.965	.468	4.414
	Negative	Emotional	Right	1.359	.967	-.618	3.336
			Left	1.642	1.024	-.454	3.737
		Neutral	Right	1.499	.974	-.494	3.491
			Left	2.085	.972	.098	4.073

Table 8 AN380 lateral ROI voltage by condition

Group	Block Valence	Stimulus Valence	Hemisphere	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Low-trait	Positive	Emotional	Right	-4.249	1.712	-7.750	-.749
			Left	-4.589	1.436	-7.527	-1.652
		Neutral	Right	-5.713	1.711	-9.211	-2.214
			Left	-5.501	1.490	-8.548	-2.454
	Negative	Emotional	Right	-4.908	1.638	-8.257	-1.558
			Left	-4.628	1.391	-7.473	-1.784
		Neutral	Right	-7.144	1.692	-10.605	-3.683
			Left	-6.798	1.552	-9.973	-3.624
High-trait	Positive	Emotional	Right	-3.345	1.606	-6.629	-.061
			Left	-4.558	1.347	-7.313	-1.802
		Neutral	Right	-4.693	1.605	-7.974	-1.411
			Left	-5.572	1.398	-8.430	-2.714
	Negative	Emotional	Right	-4.500	1.536	-7.642	-1.358
			Left	-5.794	1.305	-8.463	-3.126
		Neutral	Right	-4.172	1.587	-7.419	-.926
			Left	-5.075	1.456	-8.053	-2.098

References

American Psychiatric Association. (2000). *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; text revision). Arlington, VA: American Psychiatric Association.

Benning, S. D., Patrick, C. J., Hicks, B. M., Daniel, M. B., & Kruegar, R. F. (2003). Factor structure of the Psychopathic Personality Inventory: Validity and implications for clinical assessment. *Psychological Assessment, 15,* 340-350. doi:10.1037/1040-3590.15.3.340

Carlson S. R., Thai, S., McLarnon, M. E. (2009). Visual P3 amplitude and self-report psychopathic personality traits: frontal reduction is associated with Self-Centred Impulsivity. *Psychophysiology, 46,* 100-113. doi:10.1111/j.1469-8986.2008.00756.x

Carlson S. R., Thai, S. (2010). ERPs on a continuous performance task and self-report psychopathic traits: P3 and CNV augmentation are associated with Fearless Dominance. *Biological Psychology, 85,* 318-330. doi:10.1016/j.biopsycho.2010.08.002

Carolan, P. L., Wilson, C., Sramko, V., Liotti, M., & Douglas, K. S. *Confirmatory factor analysis of gender and ethnicity for the Psychopathic Personality Inventory-Revised: Short Form*. Manuscript in preparation.

Cleckley, H. (1976). *The mask of sanity* (5th ed.). St. Louis, MO: Mosby.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112,* 155-159. doi: 10.1037/0033-2909.112.1.155

Comechero, M. D., & Polich. J. (1999). P3a and P3b from typical auditory and visual stimuli. *Clinical Neurophysiology, 110,* 24-30. doi:10.0168-5597(98)00033-1

Conroy, M. A. & Polich, J. (2007). Normative variation of P3a and P3b from a large sample. *Journal of psychophysiology, 21,* 22-32. doi:10.1027/0269-8803.21.1.22

Criminal Code of Canada, 46 R.S.C. § 752-753 (1985).

Falkenbach, D., Poythress, N., Falki, M., & Manchak, S. (2007). Reliability and Validity of Two Self-Report Measures of Psychopathy. *Assessment, 14,* 341-350. doi:10.1177/1073191107305612

Fowles, D. C., & Dindo, L. (2006). A dual deficit model of psychopathy. In C. J. Patrick (Ed.), *Handbook of Psychopathy, (*pp. 14-34). New York: Guilford

Hajcak, G., & MacNamara, A. (2010). Event-related potentials, emotion, and emotional regulation: An integrative review. *Developmental Neuropsychology, 35,* 129-155. doi:10.1080/87565640903526504

Hajcak, G., Nieuwenhuis, S. (2006). Reappraisal modulates the electrocortical response to unpleasant pictures. *Cognitive, Affective & Behavioural Neuroscience, 6,* 291-297. doi:10.3758/cabn.6.4.291

Hare, R. D. (1991). *Manual for the hare psychopathy checklist-revised.* Toronto: Multi-Health Systems.

Hare, R. D. (1993). *Without Conscience: The disturbing world of the psychopaths among us.* New York: Simon and Shuster Inc.

Hare, R. D., Harpur, T. J., Hakstian, A. R., Forth, A. E., Hart, S. D., & Newman, J. P. (1990). The revised Psychopathy Checklist: Reliability and factor structure. *Psychological Assessment, 2,* 338-341.

Kiehl, K. A., Bates, A. T., Laurens, K. R., Hare, R. D., & Liddle, P. F. (2006). Brain potentials implicate temporal lobe abnormalities in criminal psychopaths. *Journal of Abnormal Psychology, 115,* 443-453. doi:10.1037/0021-843X.115.3.443

Kiehl, K. A., Hare, R. D., McDonald, J. J., & Brink, J. (1999). Semantic and affective processing in psychopaths: An-event related potential (ERP) study. *Psychophysiology, 36,* 765-774. doi:10.1017/S0048577299971081

Kiehl, K. A., Hare, R. D., McDonald, J. J., & Liddle, P. F. (1999). Reduced P3 response in criminal psychopaths during a visual oddball task. *Biological Psychiatry, 48,* 210-221. doi:10.1016/S0006-3223(98)00193-0

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2005). *International affective picture system (IAPS): Affective ratings of pictures and instruction manual*. Technical Report A-8.
Gainesville: University of Florida.

Lilienfeld, S. O., & Andrews, B. P. (1996). Development and preliminary validation of a self-report measure of psychopathic personality traits in non-criminal populations. *Journal of Personality Assessment, 66,* 488-524. doi:10.1207/s15327752jpa6603_3

Lilienfeld, S. O., & Widows, M. (2005). *Professional Manual for the Psychopathic Personality Inventory-Revised (PPI-R).* Lutz, Florida: Psychological Assessment Resources.

Luck, S. J. (2005). *An introduction to the event-related potential technique.* Cambridge, MA: MIT Press.

Moser, J. S., Hajcak, G., Bukay, E., & Simons, R. F. (2006). Intentional modulation of emotional responding to unpleasant pictures: An ERP study. *Psychophysiology, 43,* 292-296. doi:10.1111/j.1469-8986.2006.00402.x

Munro, G. E. S., Dywan, J., Harris, G. T., McKee, S., Unsal, A., Segalowitz, S. J. (2007). ERN varies with degree of psychopathy in an emotion discrimination task. *Biological Psychology, 76,* 31-42. doi:10.1016/j.biopsycho.2007.05.004

Olvet, D. M., & Hajcak, G. (2007). The error-related negativity (ERN) and psychopathology: Toward and endophenotype. *Clinical Psychology Review, 28,* 1343-1354. doi:10.10161/j.cpr.2008.07.003

Pauil, P., Amrhein, C., Muhlberger, A., Dengler, W., & Wiedemann, G. (2005). Electrocortical evidence for an early abnormal processing of panic-related words in panic disorder patients. *International Journal of Psychophysiology, 57,* 33-41. doi:10.1016/j.ijpsycho.2005.01.009

Phaf, R. H., Kan, K. J. (2007). The automaticity of emotional Stroop: A meta-analysis. *Journal of Behavioural Therapy and Experimental Psychiatry, 38,* 184-199. doi:10.1016/j.jbtep.2006.10.008

Poythress, N. G., Edens, J. F., & Lilienfeld, S. O. (1998). Criterion-related validity of the Psychopathic Personality Inventory (PPI): Findings from a large incarcerated sample. *Psychological Assessment*, *10*, 426-430. doi:10.1037/1040-3590.10.4.426

Poythress, G. N., Edens, J. F., Skeem, J. L., Lilienfeld, S. O., Douglas, K. S., Frick, P. J., Patrick, C. J., Epstein, M., & Wang, T. (2010). Identifying subtypes among offenders with Antisocial Personality Disorder: A cluster-analytic study. *Journal of Abnormal Psychology, 119,* 389-400. doi:10.1037/a0018611

Pratto, F., & John, O. (1991). Automatic vigilance: The attention-grabbing power of negative social information. *Journal of Personality and Social Psychology, 61,* 380–391. doi: 10.1037/0022-3514.61.3.380

Raine, A. (1988). Evoked potentials and psychopathy. *International Journal of Psychophysiology, 8,* 1-16. doi:10.0167-8760/89/$03.50

Rice, M. E., Harris, G., & Cormier, C. (1992). An evaluation of a maximum security therapeutic community for psychopaths and other mentally disordered offenders. *Law and Human Behavior, 16*, 399-412. doi:10.1007/bf02352266

Rosenktants, B., & Polich, J. (2008). Affective ERP processing in a visual oddball task: Arousal, valence, and gender. *Clinical Neurophysiology, 119,* 2260-2265. doi:10.1016/j.clinph.2008.07.213

Seto, M., & Barbaree, H. (1999). Psychopathy, treatment behaviour, and sex offender recidivism. *Journal of Interpersonal Violence, 14,* 1235-1248. doi:10.1177/088626099014012001

Taake, I., Jaspers-Fayer, F., & Liotti, M. (2009). Early frontal responses elicited by physical threat words in an emotional Stroop task: Modulation by anxiety sensitivity. *Biological Psychology, 81,* 48-57.

Uzieblo, K., Verschuere, B., Van den Bussche, E., & Crombez, G. (2010). The Validity of the Psychopathic Personality Inventory–Revised in a Community Sample. *Assessment, 17,* 334-346. doi:10.1177/1073191109356544

Vogel, E. K., and Luck, S. J. (2000). The visual N1 component as an index of a discrimination process. *Psychophysiology, 37,* 190-203. doi:10.1017/S0048577200981265

Webster, C. D., Douglas, K., Eaves, D., & Hart, S. (1997). *HCR-20: Assessing risk for violence, Version 2.* Burnaby, British Columbia, Canada: Simon Fraser University.

Weinburg, A., & Hajcak, G. (2010). Beyond good and evil: The time-course of neural activity elicited by specific picture content. *Emotion, 10,* 767-782. doi:10.1037/a0020242

Williamson, S., Harpur, T. J., Hare, R. D. (1991). Abnormal processing of affective words in psychopaths. *Psychophysiology, 28,* 260-273. doi: 10.1111/j.1469-8986.1991.tb02192.x

Appendices

Appendix 1: Psychopathic Personality Inventory-Revised: Short Form (PPI-R: SF)

INSTRUCTIONS

This test measures different personality characteristics – that is, the ways in which people's personality styles make them different from each other. Starting on the next page, read each statement carefully and decide how false or true it is as a description of you. Then mark the best choice on the Response Form. Use the answer choices provided below.

1) False 2) Mostly False 3) Mostly True 4) True

Even if you feel that a statement is neither false nor true about you, or if you are not sure which answer to choose, select the answer that is the closest to describing you.

Here's an example: **I like going to movies.**

If it is true that you like going to movies, fill in the 4 on the answer sheet, as shown below.

1 2 3 4

If it is mostly false that you like going to movies, fill in the 2 on the answer sheet, as shown below.

1 2 3 4

Try to be as honest as you can. Please be sure to give your own opinion about whether each statement is false or true about you.

1) False	2) Mostly False	3) Mostly True	4) True

____ 1. Dangerous activities like skydiving scare me more than they do most people.

____ 2. I have always seen myself as something of a rebel.

____ 3. I am easily flustered in pressured situations.

____ 4. I would find the job of a movie stunt person exciting.

____ 5. I might like to hang out with people who "drift" from city to city with no permanent home.

____ 6. A lot of people have tried to “stab me in the back.”

____ 7. I get mad if I don’t receive special favors I deserve.

____ 8. I am hardly ever the center of attention.

____ 9. It might be exciting to be on a plane that was about to crash but somehow landed safely.

____10. A lot of times, I worry when a friend is having personal problems.

____ 11. I tend to get crabby and irritable when I have too many things to do.

____ 12. I get mad when I hear about the injustices in the world.

____ 13. I don’t let everyday hassles get on my nerves.

____ 14. I could be a good "con artist."

____ 15. I have a talent for getting people to talk to me.

____ 16. I might like to travel around the country with some motorcyclists and cause trouble.

____ 17. In conversations, I’m the one who does most of the talking.

____ 18. I feel sure of myself when I'm around other people.

____ 19. Parachute jumping would really scare me.

____ 20. When people lend me something, I try to get it back to them quickly.

____ 21. I like to stand out in a crowd.

1) False	2) Mostly False	3) Mostly True	4) True

____ 22. It would be fun to fly a small airplane by myself.

____ 23. In school or at work, I try to "stretch" the rules just to see what I can get away with.

____ 24. I’ve often been betrayed by people I trusted.

____ 25. It would break my heart to see a poor or homeless person walking the streets at night.

____ 26. Some people say that I am a “worry wart.”

____ 27. It bothers me a lot when I see someone crying.

____ 28. I get stressed out when I’m “juggling” too many tasks.

____ 29. It’s easy for me to go up to a stranger and introduce myself.

____ 30. I don’t care about following the “rules”; I make up my own rules as I go along.

____ 31. I’ve been the victim of a lot of bad luck.

____ 32. I'm hardly ever the "life of the party."

____ 33. I’ve thought a lot about my long-term career goals.

____ 34. Some people have gone out of their way to make my life difficult.

____ 35. I sometimes lie just to see if I can get someone to believe me.

____ 36. I like my life to be unpredictable and surprising.

____ 37. I get very upset when I see photographs of starving people.

____ 38. I might like flying across the ocean in a hot-air balloon.

____ 39. I worry about things even when there’s no reason to.

____ 40. When I am doing something important, like taking a test or doing my taxes, I check it over first.

____ 41. People I thought were my “friends” have gotten me into trouble.

1) False	2) Mostly False	3) Mostly True	4) True

____ 42. I think long and hard before I make big decisions.

____ 43. I tell people only the part of the truth they want to hear.

____ 44. I get blamed for many things that aren't my fault.

____ 45. I feel bad about myself after I tell a lie.

____ 46. I quickly get annoyed with people who do not give me what I want.

____ 47. I would like to have a "wild" hairstyle.

____ 48. I'm the kind of person who gets "stressed out" pretty easily.

____ 49. I usually think about what I'm going to say before I say it.

____ 50. Some people have made up stories about me to get me in trouble.

____ 51. I watch my finances closely.

____ 52. I am a daredevil.

____ 53. I would like to hitchhike across the country with no plans.

____ 54. I try to use my best manners when I'm around other people.

____ 55. I often place my friends' needs above my own.

____ 56. If I can't change the rules, I try to get others to bend them for me.

Appendix 2: Medical Questionnaire

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Participant ID: __________
Date: __________

Demographics

□ What is your date of birth? _______________________(DD/MM/YY)
□ What is your gender? ____________
□ What is your major (if known)? ___________
□ Years of post-secondary education? __________
□ Were you born in Canada? Yes / No
□ Is English your first language? Yes / No
□ If 'No', for how many years have you spoken English fluently? ___________
□ What is your dominant hand (the hand that your write with)? Left / Right
□ Are you wearing glasses or contacts? Yes / No
□ Is your vision normal or corrected to normal if wearing glasses/contacts? Yes / No
□ Are you color-blind? Yes / No
□ Have you seen a psychiatrist or have you been treated for any of the following:
□ Depression Yes No
□ Anxiety Yes No
□ Attention-Deficit Disorder Yes No
□ Thought Disorder Yes No
□ Other (specify):
____
□ Have you ever seen a neurologist or been to an emergency room for:
□ Loss of motor or sensory function Yes No
□ Loss of consciousness Yes No
□ Head concussion Yes No
□ Sleep disorder Yes No
□ Migraines Yes No
□ CT scan, MRI scan or Electroencephalogram Yes No
□ Have you been told you have a learning disorder or disability, such as dyslexia (i.e. a reading disorder)? Yes / No
□ If Yes, please
explain:____
□ Do you have a serious medical condition? Yes / No

1

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Participant ID: __________
Date: __________

Demographics

□ If Yes, please explain:____
□ Are you currently taking any prescription medication? Yes / No
□ If Yes, please explain:____
□ Do you use non-prescription drugs (optional) Yes/No
□ If Yes, please explain (optional):____
□ Which/how many alcoholic beverages do you typically have in a week: ______________________
□ How many hours do you typically sleep? ___________
□ How many hours did you sleep last night? __________

2

Appendix 3: IAPS Stimuli

3.1 Positive images

Animals (n=5)

Image	Number	Valence	Arousal
Jaguar	1650	6.65	6.23
Puppies	1710	8.34	5.41
Kittens	1463	7.45	4.79
Seal	1440	8.19	4.61
Lion	1720	6.79	5.32

Solo/Faces (n=5)

Image	Number	Valence	Arousal
Gymnast	8470	7.74	6.14
AttractiveFem	2300	7.04	5.55
WaterSkier	8200	7.54	6.35
Bungee	8179	6.48	6.99
HangGlider	8161	6.71	6.09

2 People (n=4)

Image	Number	Valence	Arousal
Father	2160	7.58	5.16
Romance	4619	6.46	5.09
Kiss	2352	6.94	4.99
Couple	2550	7.77	4.68

3+ People (n=6)

Image	Number	Valence	Arousal
SkyDivers	5621	7.57	6.99
Children	2345	7.41	5.42
HappyTeens	8461	7.22	4.69
Children	2347	7.83	5.56
Athletes	8540	7.48	5.16
Crowd	7660	6.61	5.59

Objects/scenes (n=5)

Image	Number	Valence	Arousal
Rollercoaster	8492	7.21	7.31
Money	8501	7.91	6.44
Rollercoaster	8499	7.63	6.07
Beach	5833	8.22	5.71
Liftoff	5450	7.01	5.84

Grand Average		7.3512	5.6872

3.2 Negative images

Animals (n=5)

Image	Number	Valence	Arousal	*Valence Transformed
Snake	1050	3.46	6.87	6.54
HurtDog	9183	1.69	6.58	8.31
AttackDog	1304	3.37	6.37	6.63
Dog	9570	1.68	6.14	8.32
DeadCows	9181	2.26	5.39	7.74

Solo/Faces (n=5)

Image	Number	Valence	Arousal	*Valence Transformed
Attack	6510	2.46	6.96	7.54
StarvingChild	9075	1.66	6.04	8.34
DeadMan	9412	1.83	6.72	8.17
BlackEye	2345	2.26	5.5	7.74
Soldier	9421	2.21	5.04	7.79

2 People (n=4)

Image	Number	Valence	Arousal	*Valence Transformed
Attack	6550	2.73	7.09	7.27
Abduction	6312	2.48	6.37	7.52
CarTheft	6571	2.85	5.59	7.15
Boys	9530	2.93	5.2	7.07

3+ People (n=6)

Image	Number	Valence	Arousal	*Valence Transformed
Hanging	9413	1.76	6.81	8.24
KKKrally	9810	2.09	6.62	7.91
WarVictim	9250	2.57	6.6	7.43
Soldiers	9163	2.1	6.53	7.9
Gang	6821	2.38	6.29	7.62
Assault	9429	2.68	5.63	7.32

Objects/scenes (n=5)

Image	Number	Valence	Arousal	*Valence Transformed
AimedGun	6260	2.44	6.93	7.56
Cemetery	9000	2.55	4.06	7.45
Fire	8485	2.73	6.46	7.27
Cemetery	9220	2.06	4	7.94
AimedGun2	6230	2.37	7.35	7.63
Grand Average		2.384	6.1256	7.616

*Valence score subtracted from 10

3.3 Neutral images

Animals (n=5)

Image	Number	Valence	Arousal
Wolf	1645	4.99	5.14
Pig	1350	5.25	4.37
Lizard	1122	5.15	4.32
Buffalo	1675	5.24	4.37
HermitCrab	1935	4.88	4.29

Solo/Faces (n=7)

Image	Number	Valence	Arousal
Man	2211	5.19	4.05
Man	2002	4.95	3.35
NeuWoman	2038	5.09	2.94
NeuMan	2102	5.16	3.03
Farmer	2191	5.3	3.61
Man	7493	5.35	3.39
Cowboy	2635	5.22	4.42

2 People (n=4)

Image	Number	Valence	Arousal
Biking/train	8475	4.85	6.52
Twins	2890	4.95	2.95
Women	2595	4.88	3.71
GirlMakeup	2308	5.22	3.82

3+ People (n=3)

Image	Number	Valence	Arousal
Airplane	7632	5.22	4.78
Tourist	2850	5.22	3
Casino	7506	5.34	4.25

Objects/scenes (n=6)

Image	Number	Valence	Arousal
Dice	7058	5.29	3.98
Volcano	5920	5.16	6.23
Stove	7077	5.12	4.61
Crowd	7497	5.19	4.97
Crochet	7513	5.45	3.47
Chess	7512	5.38	3.72

Grand Average		5.1616	4.1316

Appendix 4: IAPS Independent t-tests

4.1 Positive versus negative images

	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Arousal	-1.895	48	.064	-.43840	.23132
Valence	-1.808	48	.077	-.26480	.14646

4.2 Positive versus neutral images

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Arousal	6.538	48	.000	1.55560	.23794
Valence	19.043	48	.000	2.18960	.11498

4.3 Negative versus neutral images

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Arousal	7.827	48	.000	1.99400	.25476
Valence	24.090	48	.000	2.45440	.10189