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P3 Amplitude and Psychopathic Traits in Youths: Distinct Contributions of the Grandiose-Manipulative and Daring-Impulsivity Traits

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Highlights:

- The daring-impulsive traits were associated with reduced novelty P3.
- The grandiose-manipulative traits were associated with enhanced novelty P3.
- P3 effects were found for the right parietal site only.
- No zero-order correlations were found between psychopathic traits and P3.
- Findings demonstrate the suppressor effects between aspects of psychopathy.

Abstract

Although abnormal P3 amplitude to target or novel stimuli have been found in adults with psychopathic traits, little is known about this relationship in youths and whether this P3 abnormality is differentially associated with dimensions of psychopathy. In this study 250 children and adolescents aged 8-19 years were assessed for P3 amplitudes in an auditory oddball paradigm over the left and right parietal sites. Psychopathic traits were assessed using combined child- and parent-reported scores on the Antisocial Process Screening Device (APSD; (Frick & Hare, 2001)). Although the zero-order correlations showed no significant associations between APSD factors and P3 amplitudes, when the factor scores were analyzed together in a regression analysis, the daring-impulsive traits (APSD impulsivity subscale) were negatively associated with the novelty P3, whereas the grandiose-manipulative traits (APSD narcissism subscale) were positively associated with the novelty P3 at the right parietal site. Results provide further support that varying dimension of psychopathic traits may relate to different neuronal pathway abnormalities, and highlight the importance of examining the suppressor effects between distinct aspects of psychopathy.

Key words: Narcissism; Impulsivity; Callous Unemotional; P300; Psychopathy; Youth

P3 Amplitude and Psychopathic Traits in Youths: Distinct Contributions of the Grandiose-Manipulative and Daring-Impulsivity Traits

Psychopathic personality has been associated with various cognitive impairments, including ~~deficient information processing capacity~~abnormal allocation of attention as reflected by atypical P3 (or P300) responses (Gao & Raine, 2009). The P3 component of the event-related potentials (ERPs – which refer to averaged changes in the electrical activity of the brain in response to specific stimuli) is a positive brainwave deflection that occurs about 300 ms after the onset of the stimulus. In a typical three-stimulus oddball paradigm, participants are asked to detect an infrequent deviant tone (target; e.g., low-pitched tone) amongst a series of standard stimuli (non-target; e.g., high-pitched tone) and novel stimuli (e.g., dog barks, bird chirp). P3 to the targets (target P3 or P3b), maximally recorded at parietal sites, has been associated with the ability to identify the task relevance of a stimulus and actively engaging it for further action. In contrast, P3 to novel distractors (novelty P3 or P3a), maximally recorded at the frontal-central sites, has been implicated in evaluation of qualitatively unique stimuli as well as response inhibition (see (Polich, 2007) for review). It is believed that novelty P3 reflects an involuntary automatic orientation of focused attention to novel stimuli and facilitate the allocation of attentional resources to successive memory storage operations in the hippocampal formation, whereas target P3 reflects this later controlled attentional process in the parietal regions (Polich, 2007). A series of studies have demonstrated P3 abnormalities in psychopathic adults, indicating atypical capability to direct attention to events of importance (e.g., ~~(~~Gao, Raine, & Schug, 2011; Kiehl, Bates, Laurens, Hare, & Liddle, 2006; Kiehl, Smith, Hare, & Liddle, 2000), and this impairment in neural processing of salient environmental stimuli has been postulated to predispose psychopathic individuals to antisocial and criminal behavior (Gao & Raine, 2009).

However, prior work has ~~almost exclusively~~mainly focused on adults and different findings have been reported regarding target P3 responses in psychopathy (see review by Gao & Raine, 2009). For example, whereas reduced target P3 responses have been found ~~in incarcerated psychopaths~~in some studies (Brazil et al., 2012; Kiehl et al., 2006; Kiehl, Hare, Liddle, & McDonald, 1999), ~~whereas other studies have reported~~ enhanced P3 ~~in psychopaths~~ (Raine & Venables, 1987, 1988) or no associations ~~between the two~~ (Jutai, Hare, & Connolly, 1987; Munro et al., 2007; Raine, 1993; Syndulko, Parker, Jens, Maltzman, & Ziskind, 1975) have been reported elsewhere. In addition, much fewer studies have examined novelty P3 responses in relation to psychopathy and the results have also been inconclusive. For example, Kiehl et al. (2006) reported reduced novelty P3, but only in one of the two psychopathic samples tested and no differences were found in the other sample. Gao et al. (2011) reported no differences in novelty P3 between controls, successful (uncaught) and unsuccessful (caught) psychopaths. A later study by Brazil et al. (2012) reported reduced novelty P3 amplitudes in psychopathic and non-psychopathic offenders. Taken together, the findings on psychopathy-based differences in the P3s are inconsistent- and research on youths is lacking~~and rely only on adult samples~~.

One approach to reconcile the inconsistent findings is by evaluating relations of distinguishable dimensions of psychopathy with P3 responses. Most conceptualizations describe psychopathy as a constellation of affective, interpersonal, and behavioral characteristics (Hare, 1991)~~, (e.g., (Drislane et al., 2015),~~ and these separable trait dispositions may be associated with distinctive etiological processes. The interpersonal characteristics include narcissism, manipulativeness, superficial charm, egocentricity and glibness. The affective characteristics are defined by callousness, a lack of empathy and remorse, and short-lived emotions. Finally the behavioral characteristics include impulsivity, irresponsibility, proneness to boredom, novelty

seeking, and antisociality. In children and adolescents, these three dimensions have been described as grandiose-manipulative (GM), callous-unemotional (CU), and daring-impulsive (DI) traits, respectively (Salekin, 2016). In this study, we aim to examine the unique relationships between P3 responses and these three dimensions in children and adolescents. Understanding an earlier manifestation of psychopathic traits and their neurobiological correlates, prior to the influence of harmful sequelae such as time spent in prison and substance abuse, may shed light on more successful early intervention (Frick, Ray, Thornton, & Kahn, 2014).

To date, only a few studies have examined P3 in relation to dimensions of psychopathy using an oddball paradigm, and all of them are with adult samples. For example, Venables and colleagues recorded P3 in a three-stimulus visual oddball task in incarcerated male offenders and reported that both novelty and target P3 amplitudes were negatively associated with scores on the impulsive-antisocial factor but unrelated to scores on the affective-interpersonal factor of psychopathy (Venables & Patrick, 2014). Using an auditory oddball task, Anderson et al. found target P3 amplitudes to be negatively associated with the interpersonal facet of psychopathy in incarcerated males, and no significant relationship between novelty P3 and facets was found (Anderson, Steele, Maurer, Bernat, & Kiehl, 2015). In a study with non-incarcerated adults, researchers reported a negative association between target P3 and impulsivity only (Carlson, Thái, & McLarnon, 2009). Finally, in female undergraduate students, researchers found that higher psychopathy total scores were associated with target P3 augmentation, although neither factor could, alone, account for the overall effects on P3 (Anderson, Stanford, Wan, & Young, 2011). Clearly, more research is warranted to understand the effects of various dimensions of psychopathy on P3 measures.

Although the CU traits, i.e., a lack of guilt and an inability to show empathy and emotions, has received much attention in research in children and adolescents, the contribution of the remaining psychopathy dimensions, in particular the GM traits, ~~(GM and DI)~~ is less clear (Feilhauer & Cima, 2013; Salekin, 2016). ~~Especially the contribution of the GM traits, which includes narcissistic traits, is not yet clear, as differential analyses regarding the factors have been rare.~~ Narcissistic traits, included in the GM traits, have been shown to be a strong predictor for aggression and delinquency in addition to CU traits (Lau & Marsee, 2013). Furthermore, there are indicators for a positive correlation of CU traits with psychopathy-linked narcissism (Lee-Rowland, Barry, Gillen, & Hansen, 2017). Interestingly, in adolescents who show an increase in CU traits and in conduct problems over the course of one year, narcissistic traits increase as well (Eisenbarth, Demetriou, Kyranides, & Fanti, 2016). Thus, the development and co-development of these traits can be assumed to have an impact on differential effects in underlying neurobiological mechanisms, and determining these correlates in youths is an important step in expanding our understanding of psychopathy.

The main goal of the present study was to assess neural processing of rare novel and target events in relation to different dimensions of psychopathic traits in youths. P3 amplitudes to targets, non-targets, and novel stimuli during an auditory oddball paradigm were recorded over the left and right parietal sites ~~(i.e., P3 and P4 sites according to the international 10-20 system)~~. As part of a more complex study on the effects of neurobiological, psychosocial, and omega-3 supplementation on antisocial behavior among schoolchildren, only two electrodes were utilized in the ERP sub-study due to time constraints. The left and right parietal sites were chosen for three reasons. First, they correspond to the temporal-parietal junction that is critically involved in the generation of P3 to target stimuli (Iwaki, Sutani, Kou, & Tonoike, 2007; Kiehl et al., 2001;

Polich & Criado, 2006). Second, the key areas of the temporal-parietal junction, including the angular gyrus and the posterior superior temporal gyrus, have been implicated in a broad range of social cognition functions that are atypical in psychopathic and antisocial individuals, including representation of the mental states of others (Saxe & Kanwisher, 2003), empathy and moral decision-making (Decety & Lamm, 2007; Moll, de Oliveira-Souza, & Eslinger, 2003), and inhibition (Hedden & Gabrieli, 2010). P3 abnormalities at these sites may therefore reflect dysfunction of the temporal-parietal junction that is particularly relevant to psychopathy. Third, there is some suggestion that psychopathy is associated with reduced P3 asymmetry (Kiehl et al., 1999), therefore we hoped to explore the laterality issue in the current study.

Based on the converging findings that reduced P3 amplitude is a feature common to externalizing and antisocial traits (Yoon, Malone, & Iacono, 2015) and the impulsivity facet of psychopathy in adult samples (Venables & Patrick, 2014), diminished P3s to targets and novel stimuli were expected to be associated with the DI traits. We also expected P3 augmentation to be associated with the GM traits due to some suggestions that interpersonal features of psychopathy are associated with enhanced cognitive function (Bagshaw, Gray, & Snowden, 2014; Sellbom & Verona, 2007); however see (Maes & Brazil, 2013). In addition, narcissism has been found to be associated with a deficit in central serotonergic inhibitory control as seen in a greater autonomic response in the context of threat (Kelsey, Ornduff, McCann, & Reiff, 2001), suggesting an over-attentiveness or hypersensitivity to stimuli signaling potential threat. CU traits were hypothesized to be unrelated to P3 responses. Although the distribution is fronto-central for the novelty P3 (Polich, 2007), an electrophysiological response to task-irrelevant novel stimuli can also be observed in parietal sites, and may be the "left-over" from the early autonomic orienting of focused attention reflected by the "real novelty P3" at fronto-central sites

(Brazil et al., 2012). In this sense, we would investigate if psychopathic traits modulate how well information about the novel stimulus is transferred from fronto-central to parietal sites. Finally, although some evidence has suggested that psychopathic individuals exhibit reduced P3 asymmetry in response to visual stimuli (Kiehl et al., 1999), recent theorizing has not produced substantive lateralization theory of psychopathy. The effect of hemisphere was therefore examined in the current study although no prediction was made.

Methods

Participants

Participants were 301 Chinese students ages 8 to 19 years (mean age = 11.35, SD = 2.61, 63.5% male) from two local public schools in Hong Kong, including 192 children from the primary school (58.9% male) and 109 from the secondary school (71.6% male), Exclusion criteria include (i) epilepsy, (ii) intellectual disabilities, (iii) autism, (iv) physical impairment, and (v) early psychosis. The study was funded by the University Grants Committee (UGC) of Hong Kong, and ethical approval from the University and the UGC was obtained.

The Psychopathic Measures

We administered both parent and child versions of the Antisocial Process Screening Device (APSD; Frick & Hare, 2001). The scale comprises 20 items answered on a three-point scale: 0 (not at all true), 1 (sometimes true), or 2 (definitely true). Scores from the parent and child forms were combined as recommended by the APSD manual by taking the higher of the two informants' ratings for each item (Frick & Hare, 2001). This method of combining information allows for the incorporation of information about the children's behavior across multiple settings while avoiding underreporting by a specific informant (Frick, Stickle, Dandreaux, Farrell, & Kimonis, 2005). An overall psychopathy score and three factor scores

including narcissism (or GM, 7 items), impulsivity (or DI, 5 items), and callous-unemotional traits (CU, 6 items), were obtained by summing the relevant items. The reliability and construct validity of APSD have been supported in numerous samples (e.g., (Munoz & Frick, 2007; Poythress, Dembo, Wareham, & Greenbaum, 2006; Vitacco, Rogers, & Neumann, 2003), and its reliability and validity in Hong Kong population of schoolchildren are acceptable (Fung, Gao, & Raine, 2010). In the current sample, the reliability of the parent (child) version of the APSD subscales was .69 (.63), .68 (.70), and .44 (.48) for the DI, GM, and CU traits, respectively.

Psychophysiological Measures

Auditory Oddball Task. Psychophysiological data were collected while the participant was seated in a temperature-controlled, light- and sound-attenuated psychophysiological recording laboratory. Each individual was presented with a series of high- and low-pitched tones, at 75 dB and lasting for 150 ms, with an inter-stimulus interval of 1.0 s. The rise and fall times of the tones were 5 ms. They were instructed to press a response button as quickly as possible with their dominant hand in response to the low-pitched tones (‘‘target’’, presented at 500 Hz), but not to the high-pitched tones (‘‘non-target’’, presented at 1000 Hz). In addition to the 35 (10%) targets and 280 (80%) non-target tones, 35 (10%) novel/irrelevant tones (e.g. bell, bird, honk) were also presented. All tones were presented in random order. Before the actual test, participants were given 6 practice trials to ensure that they could distinguish between the high- and low-pitched tones. Participants were asked to keep their eyes fixated on an X on the computer screen in the entire session. One participant had the accuracy rate lower than 40%, and was therefore excluded from analyses. The duration of the oddball task was about 7.5 min. Accuracy data, including number of correct responses to targets and correct rejections to novels or non-targets, as well as reaction time to targets, were used in following analyses.

P3 Recording and Quantification. Electroencephalographic (EEG) activity was recorded from the P3 (left parietal) and P4 (right parietal) recording sites according to the International 10/20 System using Grass gold-plated electrodes and references to linked earlobes. EOG activity was recorded using Biopac EOG100C amplifier from the outer canthus and below the right eye and stored off-line with a band pass settings of 0.05-35Hz. Artifacts created by eye movements were removed in real-time from the cerebral signal with Acknowledge 4.2 EOG artifacts removal function (BIOPAC Systems, Inc.). Data were sampled at 1,000 Hz and amplified by a factor of 10,000 using the Biopac MP150 acquisition unit and EEG100C amplifiers, with band pass settings of 0.01-35Hz and a 60 Hz notch filter. Impedances were kept below 10 KOhms. EEG data analysis was performed using EEGLAB 11.0.3.1b running under MATLAB 7.1 (The Mathworks, Inc.). EEG signals were segmented in each trial to obtain epochs starting from 200ms before the stimulus onset until 800ms after stimulus (baseline-200 to 0 ms), and a 0.1-35 Hz digital filter was performed off-line. Data rejection was performed to remove epochs not fitting in a [-100 μV, 100 μV] window, and none of the trials in each condition were excluded. Responses to novel stimuli, targets, and non-targets were averaged separately, and P3 peak amplitude (microvolts) was identified as the maximum positive peak at each electrode between 250 and 600 ms post stimulus following prior studies (Bernat, Hall, Steffen, & Patrick, 2007; Evans & Maliken, 2011; Gerstle, Mathias, & Stanford, 1998). Due to technical issues, P3 data from 51 participants were not available. Chi-square tests and independent samples t-tests indicated that these participants did not differ from the rest of the sample (n = 250) on gender or APSD measures.

Statistical Analyses

Outliers, including 28 data points that were beyond 3 SDs above the corresponding

means and two data points beyond 3 SDs below the means (mainly base on ERP measures), were removed on a case-by-case basis prior to further analyses (see Table 1 for the numbers of available cases for each variable). First, the Pearson coefficient of APSD measures, behavioral responses (accuracy and response time), and P3 variables were computed. Independent samples t-tests were conducted to examine potential gender differences on behavioral measures and APSD scores. For ERP analyses, repeated measures analysis of variance (ANOVA) with stimulus type (novel, targets, non-targets) and hemisphere (left, right) as within-subject factors and gender as between-subjects factor were conducted. Effect sizes were reported as Cohen's *d* and partial η^2. To examine the possibility that the APSD factors were reciprocal suppressors, that is, certain psychopathic traits may act as suppressors of other psychopathic traits in predicting P3s (Hicks & Patrick, 2006), standard multiple regressions was performed with each of the P3 measures as the criterion variable and three APSD factor scores entered at once as the predictor variables. A suppressor effect would be present if the beta coefficient for each APSD factor increased after the inclusion of the other APSD factor(s) in the model. In cases where effects for APSD factor scores on P3 measures emerged as significant, depictions of high versus low quartile groups were presented to illustrate the nature of the effects. Finally, given that some evidence has suggested that significant changes occur from childhood to adolescence in the morphology and amplitude of the P3 (van Dinteren, Arns, Jongsma, & Kessels, 2014), age was entered as a covariate in all of the analyses.

Results

Descriptive Statistics

Means, standard deviations, and zero-order correlations among variables are listed in Table 1. GM and DI traits were significantly correlated ($r = .59$, $p < .001$), and neither of them

was associated with CU traits ($p > .166$). GM traits and APSD total score were each positively associated with P3 amplitude to non-targets in the left hemisphere ($r = .14$ for GM and .13 for APSD total score, respectively, both $p < .05$). No other significant associations were found between APSD scores and any of the P3 measures.

Compared to girls, boys had higher scores on APSD total scores ($t = 2.05$, $p = .042$; for boys $M = 13.53$, $SD = 4.51$; for girls $M = 12.45$, $SD = 4.19$, $d = 0.25$) ~~and marginally higher scores on CU traits ($t = 1.88$, $p = .061$; for boys $M = 4.32$, $SD = 1.68$; for girls $M = 3.94$, $SD = 1.75$, $d = 0.22$)~~. No other significant sex differences were found, $p > .06$~~18~~. Means and standard deviations for each gender group, along with t-tests statistics are reported in Table 2.

[Insert Tables 1 and 2]

Behavioral Measures

~~In general,~~On average, participants had no difficulty correctly responding to the 35 targets ($M = 27.92$, $SD = 8.06$) ~~or~~ or rejecting (not responding to) the 315 non-targets and novels ($M = 304.58$, $SD = 11.55$). Shorter response time to the targets was associated with larger target P3 amplitudes in both left ($r = -.14$, $p < .05$) and right hemispheres ($r = -.33$, $p < .01$), as well as larger novelty P3 amplitudes in the right hemisphere ($r = -.18$, $p < .01$). ~~Higher number of~~More accurate responses to targets ~~was~~ were associated with larger target P3 amplitude bilaterally ($p < .05$; see Table 1). None of the APSD measures were associated with accuracy measures or reaction time. Finally, boys and girls did not differ on behavioral measures ($p > .10$; see Table 2).

P3 Measures

A three-way ANCOVA was conducted with stimulus type (novels, targets, non-targets) and hemisphere (left, right) as within-subject factors, gender as between-subjects factor, and age as a covariate. The main effect of stimulus type was ~~marginally~~ not significant, F (2, 227) = 2.43,

p = .091, partial η^2 = 021, although post-hoc comparisons indicated that. P3 amplitudes to both novel stimuli (M = 4.44, SE = .25) and targets (M = 3.81, SE = .24) were significantly larger than those to non-targets (M = 1.13, SE = .07), p < .001. P3 amplitudes to novels were higher than those to targets, p = .019. The main effect of hemisphere was also significant, F (1, 228) = 4.80, p = .030, partial η^2 = 021. P3 amplitudes in the left hemisphere (M = 2.84, SE = 0.18) were lower than those in the right hemisphere (M = 3.42, SE = 0.16, d = .22). Finally, the stimulus type × hemisphere interaction was significant, F (2, 227) = 4.17, p = .009, partial η^2 = 041. P3 amplitudes to novels and to targets were significantly higher than those to non-targets in both hemispheres (p < .001). However, P3 amplitudes to novels were only significantly higher than those to targets in the left (p = .032) but not right hemisphere (p = .107). No main effect or interaction effect involving gender was found (p > .082). The grand-average P3 waves at the left and right hemispheres for all participants are displayed in Figure 1.

[Insert Figure 1]

P3 and Psychopathic Traits. To examine the potential suppressor effects, the three dimensions of psychopathic traits (GM, DI, and CU traits) were entered in the regression models by using forced entry with novelty or target P3 amplitude as the criterion variable. All variables were mean centralized before analyses. Collinearity diagnostic tests were conducted and results showed that our regression models were not affected by multicollinearity problems (tolerance > 0.65 and variance inflation factor < 1.53; (Tabchnick & Fidell, 2006). Results of the regression models to predict P3 amplitudes are listed in Table 3.

[Insert Table 3]

For novelty P3 in the right hemisphere the regression model approached significance, F (4, 244) = 2.091, p = .083. Specifically, higher GM scores were associated with larger novelty P3

(*B* = .0374, *t* = 2.673, *p* = .008), whereas higher DI scores were related to smaller novelty P3 (*B* = -0.360, *t* = -2.068, *p* = .040). CU traits were not related to novelty P3 (*B* = 0.089, *t* = 0.538, *p* = .591). Thus, both GM and DI traits were significant predictors of novelty P3 in the right hemisphere, but their relationships to the P3 responses were opposite in direction. Together, 3.4% (1.8% adjusted) of the variance in novelty P3 responses was predicted by these three psychopathic dimensions. As can be seen in Figure 2, participants scoring high as compared to low on the GM traits (i.e., upper- versus lower-quartile) exhibited enhanced novelty P3, and that participants with high DI traits showed reduced novelty P3. In an exploratory analysis, we also examined the interaction effects of the three dimensions on novelty P3, but no significant two-way or three-way interaction effects were detected. No other regression models, including those predicting target P3s and non-target P3s, were significant.

[Insert Figure 2]

Discussion

To our knowledge, this is the first study examining unique contributions of ~~various~~ the interpersonal (GM), affective (CU), and behavioral (DI) dimensions of psychopathic traits to P3 responses in youths. We found that novelty P3 responses in the right parietal site were negatively associated with DI traits and positively with GM traits, and that P3 responses were not related to CU traits, likely in part due to its low reliability. Most notably, our finding that the magnitude of the associations for GM and DI traits increased when the two were entered together in prediction models demonstrated the existence of suppression effects, after controlling for age. Suppression effects suggest that when the multifaceted constructs embedded within a single instrument have opposing relations to a criterion variable, to increase their predictive power, they should be assessed separately from one another (Hicks & Patrick, 2006). In this respect, the current work is

in line with prior work in adults that when distinct dimensions of psychopathy are considered in isolation from one another, they exhibit greater predictive power for P3 responses (Anderson et al., 2015; Carlson et al., 2009; Venables & Patrick, 2014). These findings also suggest that contrasting relations for differing dimensions of psychopathy may, at least in part, contribute to the mixed results from prior studies of P3 responses in psychopathy (Gao & Raine, 2009).

It is important to note that the novelty P3s observed in our study may not reflect the "real novelty P3" at fronto-central sites (Brazil et al., 2012). Nevertheless, our finding that novelty P3 reductions in the parietal sites, likely indicating inefficient transfer of information from the fronto-central sites, are selectively related to the DI traits is consistent with the two process-model of psychopathy (Fowles & Dindo, 2009; Patrick & Bernat, 2009), which posits that deficits in neural indicators of cognitive function should be related to the features of psychopathy that overlap most with externalizing tendencies. Our finding is also in line with Venables and Patrick (2014)'s results that novelty P3 amplitudes in offenders were reduced as a function of scores on the impulsive-antisocial factor of the PCL-R, and further extends these findings to youths. Related to findings on stability of P3 amplitudes across a 12-year span, from 17 to 29 years of age (Yoon et al., 2015) as well as its predictive validity for externalizing symptoms (Gao, Raine, Venables, & Mednick, 2013) and its role as a marker for genetic vulnerability for externalizing (Hicks et al., 2007), our findings suggest that the relationship between P3 reduction and DI traits seems to be present at an earlier age, and that reduced P3 amplitudes may serve as a neurodevelopmental marker for externalizing/impulsive behavior. Future studies recording ERPs from the fronto-central sites, the optimal site for detection of the novelty P3, are needed to directly test this hypothesis.

Consistent with our hypothesis, the GM traits are positively associated with novelty P3

amplitudes, suggesting that youths with high GM traits might have been overallocating attentional resources to process the novel stimuli. Interestingly, this matches the findings that high expressions of Fearless Dominance traits are related to higher selective attention for positive words in the Stroop task (Sadeh et al., 2013), a relationship that was moderated by activity in the brain regions relevant for attentional control. But more importantly, one study using a continuous performance task (Carlson & Thái, 2010) has revealed that scores on the Fearless Dominance factor were associated with P3 augmentation in response to cues, indicating an enhanced attention allocation. This is also in line with the finding that psychopathic inmates show larger ERP amplitudes implicated in early attentional processing (P140; a positive ERP occurring around 140 ms after stimulus presentation), suggesting superior allocation of attention in early stage of cognitive processing (Baskin-Sommers, Curtin, Li, & Newman, 2012). Taken together, findings suggest that GM traits, contrary to DI traits, are characterized by a heightened involuntary attention for signals in the environment that are relevant to the self (Krusemark, Lee, & Newman, 2015).

Our finding that significant relationships were only found in the right hemisphere is not completely surprising. Kiehl et al. (2000) found that psychopathic participants, compared to the nonpsychopathic controls, showed less of an increase in P3 amplitudes at right hemisphere sites. Brain imaging studies have also associated antisocial behavior and psychopathy with structural and functional reductions in the right orbitofrontal cortex and right anterior cingulate cortex (Yang & Raine, 2009), regions that are critical in emotion processing and decision-making (Angrilli, Palomba, Cantagallo, Maietti, & Stegagno, 1999; Tranel, Bechara, & Denburg, 2002). The right hemisphere has also been found to be more involved in empathy than the left hemisphere (Rueckert & Naybar, 2008). For example, researchers found that imagining another's

perspective, compared to their own perspective, resulted in activation in frontopolar cortex and right inferior parietal lobe (Ruby & Decety, 2004), and that greater empathy deficits have been associated with more lesions involving the right hemisphere (Perry et al., 2001). Future studies should test the hypothesis that ~~Together with our finding of atypical P3 in the right hemisphere, evidence suggests that~~ a right-sided neural pathology might~~ay~~ be associated with cognitive, emotional, and empathy deficits~~, which in turn may in particular~~ that contribute to impaired decision-making and antisocial behavior in psychopathic individuals.

Contrary to findings from prior studies of adults, we did not find abnormal P3 responses to task-relevant target stimuli. This null finding may indicate that youths with high and low psychopathic traits processed targets similarly. Alternatively, it is important to know that properties of the P3 may change with varying circumstances such as task complexity and memory load (Polich, 2007) and that the relationship between P3 and psychopathy could vary due to changes in task demands, stimulus properties, and population differences (Gao & Raine, 2009). The only prior study using an auditory three-stimulus oddball paradigm that is very similar to ours was Anderson et al. (2015)'s. Anderson and colleagues employed Principal Component Analyses with the EEG data and derived 6 components from all 64 channels of recording in a group of male offenders. They reported that reduced target P3 was associated with the facet 1 (interpersonal) of the PCL-R. Interestingly, when only right-handed participants were included, a significant relationship with Factor 2 (impulsive-antisocial) emerges as well. However, it is unknown if reduced target P3 found in their psychopathic offenders is stronger in anterior, central, or posterior areas of the brain. Finally, P3 reductions may not be driven by the same variation in the daring-impulsive traits recognized in non-incarcerated groups as opposed to among inmates who more uniformly exhibit antisocial behavior (Gao & Raine, 2009).

One limitation of the study was that only two electrode sites at the parietal lobe, P3 and P4, were included. As mentioned above, the novelty P3 observed in our study may not reflect the real novelty P3 that is maximal in the fronto-central sites. Future studies recording novelty P3 in the fronto-central sites are needed to examine if similar suppressor effects of the psychopathic traits can be found. In addition, it should be noted that although the use of partial correlations may be a powerful and informative technique to identify associations between different variables and their suppression effects, we are cautious that our conclusions drawn from partial analysis may only apply to the residual but not the original variables, which may have~~it also has~~ several drawbacks including difficulties in the interpretation of results (Lynam, Hoyle, & Newman, 2006). ~~Therefore, we are cautious that our conclusions drawn from partial analyses may apply to the residual but not the original variables.~~

In conclusion, our findings indicate that electrophysiological responses to novel stimuli in the right parietal site were positively and negatively associated with the GM and DI traits of psychopathic personality, respectively, in a group of schoolchildren. Specifically, reduced P3, reflecting impaired cognitive function or attention, may be specific for the daring-impulsive dimension. In contrast, the grandiose-manipulative dimension may be characterized by enhanced involuntary attention allocation to the unexpected novel stimuli. These exploratory findings suggest that P3 abnormality may be present in youths with higher psychopathic traits, and highlight the importance of examining the suppressor effects between distinct aspects of psychopathy on predicting cognitive processing.

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Table 1. Descriptive Statistics and Zero – Order Correlations Among the Measures

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	GM	DI	CU	Total psychopathy	Novelty P3 Left	Novelty P3 Right	Target P3 Left	Target P3 Right	Non-Target P3 Left	Non-Target P3 Right	Reaction Time (ms)	Accuracy[1]	Accuracy[2]	Age
1	1													
2	.59**	1												
3	.08	.04	1											
4	.84**	.79**	.46**	1										
5	.01	.00	.01	.02	1									
6	.12	-.03	.04	.06	.38**	1								
7	.02	.03	.03	.05	.23**	.15*	1							
8	-.01	-.07	-.04	-.05	.10	.33**	.18**	1						
9	.14*	.12	-.02	.13*	.06	-.03	.16*	.16*	1					
10	.07	.06	.00	.07	.03	.08	.15*	.05	.00	1				
11	-.09	.04	-.05	-.07	-.12	-.18**	-.14*	-.33**	-.05	-.06	1			
12	-.03	-.03	-.06	-.04	.08	.08	.14*	.20**	.14*	.01	-.19**	1		
13	-.07	-.10	-.04	-.10	-.07	-.08	.07	.06	.05	.09	.05	.32**	1	
14	-.01	-.11	.13*	.01	.14*	.04	.05	-.01	-.08	.09	-.39**	.16*	.22**	1
Mean	4.69	4.21	4.18	13.13	3.88	4.54	3.70	4.18	1.19	1.16	522.93	27.92	304.58	11.35
SD	2.46	2.05	1.72	4.42	4.92	4.44	5.02	4.05	1.70	1.41	104.93	8.06	11.55	2.61
n^{+}	300	301	299	298	244	247	245	246	243	245	247	247	247	301

Note: GM = grandiose-manipulative; DI = daring-impulsive, CU = callous-unemotional; n^{+}: Available cases after outliers removed; Accuracy[1]: Number of correct responses to targets; Accuracy[2]: Number of correct rejections to non-targets and novels.
* $p < .05$, ** $p < .01$

Table 2. Descriptive Statistics and T-Tests Comparing Girls and Boys

	Girls		**Boys**			
	Mean	***SD***	***Mean***	***SD***	***t***	***p***
GM	4.51	2.30	4.80	2.54	-0.98	.327
DI	4.00	1.75	4.33	2.20	-1.34	.182
CU	3.94	1.75	4.32	1.68	-1.88	.061
Total Psychopathy	12.45	4.19	13.53	4.51	-2.05	.042
Novelty P3 Left	4.37	4.35	3.59	5.21	1.19	.236
Novelty P3 Right	4.71	5.14	4.45	4.02	0.43	.667
Target P3 Left	3.40	4.44	3.86	5.32	-0.69	.488
Target P3 Right	4.41	4.77	4.06	3.61	0.66	.513
None-Target P3 Left	1.41	1.96	1.06	1.53	1.56	.120
None-Target P3 Right	1.05	1.58	1.22	1.31	-0.88	.380
Reaction Time (ms)	539.44	116.44	513.63	97.02	1.87	.063
Accuracy (total)	331.09	17.94	333.29	14.90	-1.03	.302
Number of correct responses to targets	26.82	8.96	28.54	7.46	-1.61	.108
Number of correct rejections to non-targets and novels	304.27	12.68	304.75	10.90	-.315	.753
Age	10.81	2.41	11.65	2.68	-2.73	.007

Note: GM = grandiose-manipulative, DI = daring-impulsive, CU = callous-unemotional.

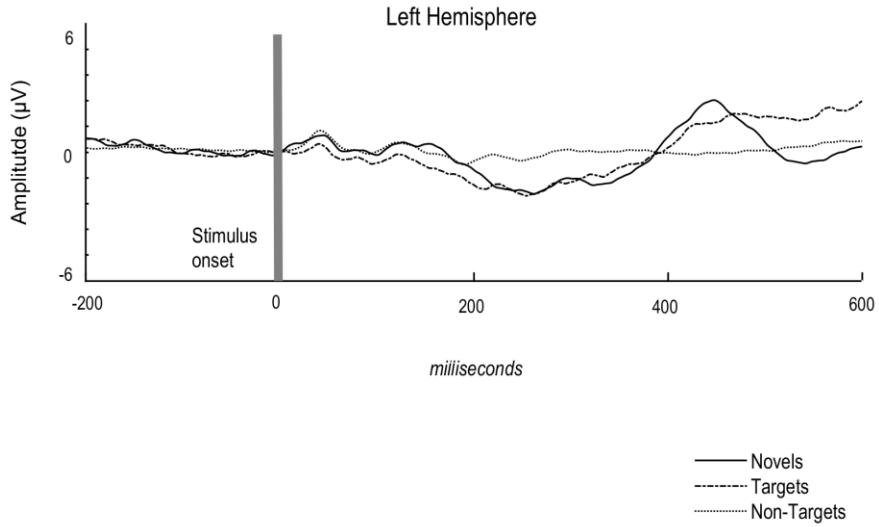
Table 3. Predictive Effects of APSD Measures on the P3 Amplitude to Novels and Targets at Left and Right Hemispheres

Novelty P3	Left Hemisphere						Right Hemisphere				
	$R^{2\ change}$	*p*	Adjusted R^2				$R^{2\ change}$	*p*	Adjusted R^2		
	.020	.029	.016				.002	.529	-.002		
	B	*SE*	*beta*	*t*	*p*		*B*	*SE*	*beta*	*t*	*p*
Age	.286	.132	.141	2.169	.031	Age	.059	.118	.032	.499	.618
	$R^{2\ change}$	*p*	Adjusted R^2				$R^{2\ change}$	*P*	Adjusted R^2		
	.001	.981	.004				.032	.049	.018		
	B	*SE*	*beta*	*t*	*p*		*B*	*SE*	*beta*	*T*	*p*
GM	.060	.155	.031	.384	.701	**GM**	**.374**	**.140**	**.209**	**2673**	**.008**
DI	-.021	.195	-.009	-.107	.915	**DI**	**-.360**	**.174**	**-.162**	**-2.068**	**.040**
CU	.014	.184	.005	.074	.941	CU	.089	.164	.034	.538	.591
Target P3	Left Hemisphere						Right Hemisphere				
	$R^{2\ change}$	*p*	Adjusted R^2				$R^{2\ change}$	*p*	Adjusted R^2		
Age	.002	.509	-.002			Age	.000	.894	-.004		
	B	*SE*	*beta*	*t*	*p*		*B*	*SE*	*beta*	*t*	*p*
	.093	.136	.045	.683	.495		-.015	.109	-.009	-.136	.892
	$R^{2\ change}$	*p*	Adjusted R^2				$R^{2\ change}$	*P*	Adjusted R^2		
	.003	.864	-.012				.007	.644	-.020		
	B	*SE*	*beta*	*t*	*p*		*B*	*SE*	*beta*	*t*	*p*
GM	.034	.161	.016	.208	.835	GM	.072	.129	.045	.558	.577
DI	.096	.196	.039	.487	.627	DI	-.174	.161	-.086	-1.083	.280
CU	.058	.188	.020	.307	.759	CU	-.101	.152	-.043	-.661	.509

Note: GM = grandiose-manipulative, DI = daring-impulsive, CU = callous-unemotional.

Figure 1. Grand-average P3 at the (A) left and (B) right hemispheres for all participants

(A)



(B)

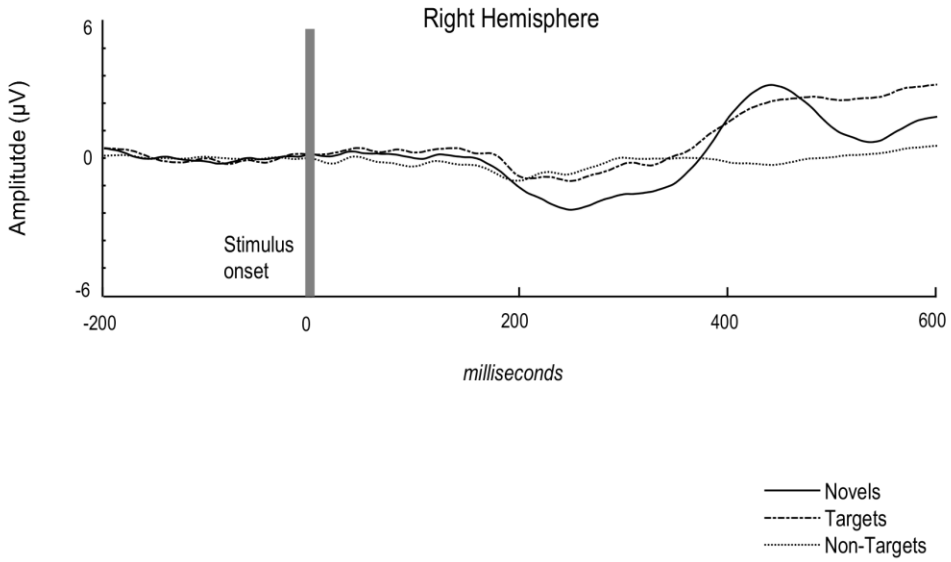
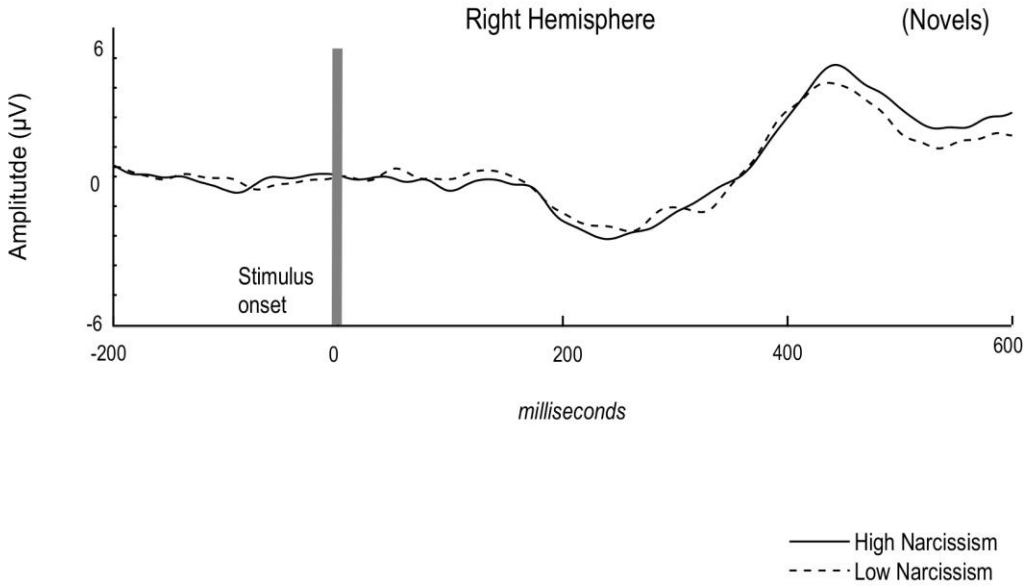
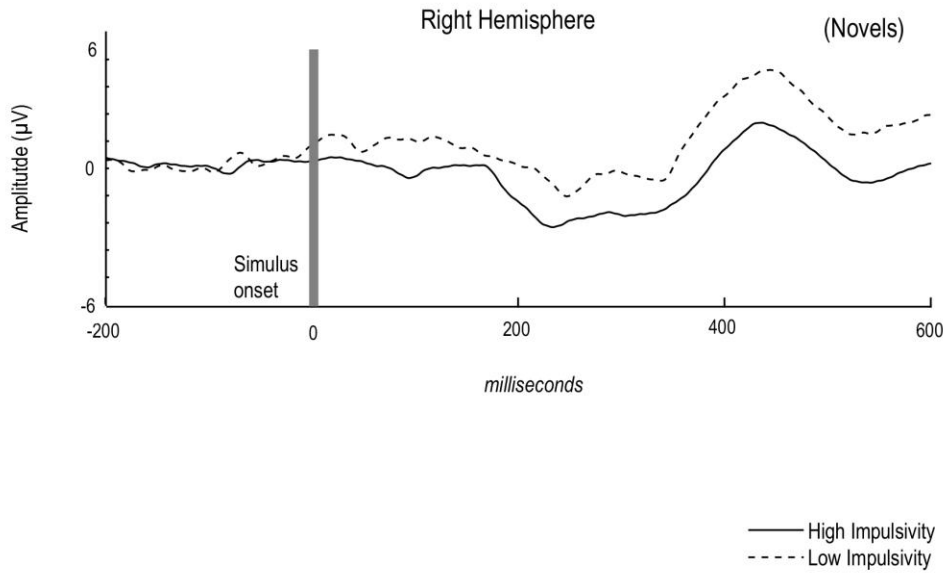

Right Hemisphere
Amplitutde (μV)
6
0
-6
Stimulus
onset
-200
0
200
400
600
milliseconds
Novels
Targets
Non-Targets

Figure 2. Grand-average novelty P3 at the right hemisphere for (A) high and low grandiose-manipulative (narcissism) individuals and (B) high and low daring-impulsive (impulsivity) individuals

(A)



(B)


Right Hemisphere
(Novels)
Amplitude (μV)
6
0
-6
Simulus
onset
-200
0
200
400
600
milliseconds
High Impulsivity
Low Impulsivity

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