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Reduced frontal activity during response inhibition in individuals with psychopathic traits: An sLORETA study

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ABSTRACT

This study investigated the response inhibition in individuals with psychopathic traits. We examined the cortical source localization of the NoGo stimuli in a Go/NoGo task by employing a standardized low-resolution electromagnetic tomography (sLORETA) using EEG. Fifteen psychopathic trait subjects and 15 control subjects performed the Go/NoGo task. The statistical analysis of P3 elicited by the NoGo stimuli indicated that the psychopathic trait group showed significantly reduced NoGo-P3 amplitudes than the control group at the frontocental area. In the Wisconsin Card Sorting Test, the psychopathic trait group showed significantly higher perseverative responses than the control group. Compared to the control group, cortical sources reduction elicited by NoGo-P3 in the psychopathic trait group was found at the left superior frontal gyrus, bilateral anterior cingulate, right precentral gyrus, and the right inferior parietal lobule. These results suggest that individuals with psychopathic traits have difficulties in inhibiting a response with reduced frontal function.

1. Introduction

Psychopathy is a syndrome characterized by a constellation of affective, interpersonal, and behavioral/lifestyle features, including impulsivity, lack of empathy or remorse, shallow emotions, sensation-seeking, poor behavioral controls, and a persistent violation of social norms and expectations (Cleckley, 1976; Hare, 2003). Psychopathy has been associated with reduced executive functioning (Blair et al., 2006; Morgan & Lilienfeld, 2000). In previous studies of the performance on the Wisconsin Card Sorting Test (WCST), a widely used test for measuring executive functioning, psychopaths made more errors than normal controls (Gorenstein, 1982; Morgan & Lilienfeld, 2000; Sutker, Moan, & Allain, 1983). However, several researchers did not find significant differences between pasychopathic and nonpsychopathic subjects in the WCST (Devonshire, Howard, & Sellars, 1988; Mol, Van Den Bos, Derks, & Egger, 2009). Ishikawa, Raine, Lencz, Bihrle, and Lacasse (2001) reported that successful psychopaths showed better WCST performance than unsuccessful psychopaths and controls. Blair et al. (2006) reported that individuals with psychopathy showed executive dysfunction on the measure sensitive to orbitofrontal cortex functioning. However, individuals with psychopathy did not show impairment on measures of executive function linked to the dorsolateral prefrontal cortex or anterior cingulate cortex. Individuals with psychopathic traits had difficulty in inhibiting dominant response sets and also showed a deficient capability in learning to avoid the stimuli that predict punishment (Newman & Kosson, 1986; Turgay, 2004). Newman (1998) proposed that the impulsive and disinhibitory behavior of psychopaths is the result of poor response modulation. Kiehl, Smith, Hare, and Liddle (2000) suggested that the neural processes involved in response inhibition are abnormal in psychopathy.

A growing number of studies have reported that psychopathy is associated with a range of neurobiological abnormalities (Oliveira-Souza et al., 2008; Patrick, 2006). The results of a meta-analysis on 43 structural and functional imaging studies showed significantly reduced prefrontal structure and function in antisocial and psychopathic individuals (Yang & Raine, 2009). The Frontal Lobe Dysfunction Theory has been suggested that antisocial behavior in humans might be a consequence of inherited or acquired deficits in the frontal brain areas, particularly in the orbitofrontal cortex (Gorenstein & Newman, 1980). The volume of the prefrontal cortex was reduced in high psychopathy males who had committed crimes (Raine, Lencz, Bihrle, LaCasse, & Colletti, 2000; Yang et al., 2005). A considerable number of studies demonstrated that amygdala dysfunction is associated with callous-unemotional traits and represents a reduced electrodermal response to aversive stimuli in psychopaths (Birbaumer et al., 2005; Marsh et al.,

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2008). It has been argued that the orbitofrontal cortex and amygdala dysfunction in individuals with psychopathic traits disrupts emotion-based decision-making, including moral judgment (Blair, 2007; Kiehl, 2006). Using DT-MRI (Diffusion Tensor Magnetic Resonance Imaging), Sundram et al. (2012) suggested that the abnormal uncinate fasciculus in antisocial individuals indicated fronto-limbic disconnectivity. Marsh et al. (2011) reported that youths with psychopathic traits showed reduced amygdala–orbitofrontal connectivity during moral judgments.

Impulsive behavior is potentially harmful to self or to others, as it is one of the core symptoms in psychopathy and has also been linked to response inhibition (Chamberlain & Sahakian, 2007; Kiehl et al., 2000). Response inhibition is the ability to suppress a prepotent response, which can be examined in Go/NoGo tasks (Pandey et al., 2012). The stimuli in Go/NoGo tasks elicit two event-related potential (ERP) components, the N2 and P3 (Kopp, Mattler, Goertz, & Rist, 1996). The N2 is seen as a negative deflection with a maximum over the frontal scalp locations in the NoGo (no button press) compared to the Go trials (button press). It can be observed between 250 and 350 ms after stimulus onset. The P3 is a larger positive deflection at about 300–600 ms post-stimulus with a frontocentral maximum in the NoGo compared to the Go trials (Bokura, Yamaguchi, & Kobayashi, 2001; Eimer, 1993; Gajewski & Falkenstein, 2013). The NoGo-N2 was suggested to be related to conflict detection or a top-down inhibition mechanism suppressing an inappropriate response tendency at a processing stage prior to motor execution (Kim, Kim, Yoo, & Kwon, 2007; Nieuwenhuis, Yeung, van den Wildenberg, & Ridderinkhof, 2003). The NoGo-P3 was assumed to reflect response inhibition in the frontal cortex (Kopp et al., 1996; Ruchsow et al., 2008; Tian & Yao, 2008).

Dimoska and Johnstone (2007) reported that reduced response inhibition has been linked to increased levels of impulsivity in healthy volunteers. There were several ERP studies using Go/NoGo tasks in subjects with a psychiatric disorder of impulsivity. Ruchsow et al. (2008) found reduced NoGo-P3 amplitudes in individuals with a borderline personality disorder. Also, a reduction of the NoGo-N2 has been found in subjects with an attention deficit hyperactivity disorder (Pliszka, Liotti, & Woldorff, 2000). Kiehl et al. (2000) reported alterations of N2 and P3 in subjects with schizophrenia and psychopathy. Using a visual Go/NoGo task, Varlamov, Khalifa, Liddle, Duggan, and Howard (2011) found that psychopathic subjects showed significantly reduced amplitude of an early frontal negative ERP component. However, Munro et al. (2007) found the enhanced frontal N2 and P3 effect in response to the NoGo relative to the Go conditions in psychopaths. Gao and Raine (2009) conducted a meta-analysis of 38 ERP studies in psychopathic individuals and found that compared to the non-psychopathic offenders, psychopathic offenders showed reduced P3 amplitudes in oddball tasks, but not in other tasks. Collectively, the results of the previous ERP studies in psychopaths using Go/NoGo tasks are controversial.

Several ERP studies in undergraduates with psychopathic traits were published. Campanella, Vanhoolandt, and Philippot (2005) reported that subjects with psychopathic tendencies presented decreased N300 components in a visual oddball task. Carlson, Thái, and McLarnon (2009) found frontal P3 amplitude reduction, which was inversely related to the Self-Centered Impulsivity factor of the Psychopathic Personality Inventory in a rotated heads task. In contrast, Carlson and Thái (2010) suggested that the Fearless Dominance factor of the Psychopathic Personality Inventory was associated with P3 augmentation in an expectancy AX-continuous performance task. These results support that subjects with psychopathic traits have specific ERP pattern characteristics.

Due to its high temporal resolution and convenience, ERP has been widely used for studies of psychopathy. However, ERP offers a rather limited spatial resolution. This limited spatial resolution can be elevated by the use of high-density electrode arrays. Several current density estimation techniques have been developed to determine the electrophysiological source locations in the subjects. Low-resolution electromagnetic tomography (LORETA) assumes that the voltage will change gradually and selects the distribution of the source magnitudes that is maximally smooth (Pascual-Marqui, Michel, & Lehmann, 1994). Standardized LORETA (sLORETA) (Pascual-Marqui, 2002) uses the normalization by noise power, and recommends to use the pseudo-statistic values as estimates of brain activity, and to apply in statistical non-parametric mapping for the analysis of experimental designs. To our knowledge, there is no study using the cortical source localization for a Go/NoGo task in individuals with psychopathic traits. In healthy subjects, the cortical source localizations of the P3 component in a Go/NoGo task showed activations in the orbitofrontal cortex and medial frontal gyrus (Bokura et al., 2001; Jonkman, Sniedt, & Kemner, 2007; Tian & Yao, 2008).

In this study, we aimed to explore the cortical generators of NoGo-P3 in individuals with psychopathic traits. Undergraduate students were divided into a psychopathic trait and control group according to the scores of the Psychopathic Personality Inventory-Revised (PPI-R, Lilienfeld & Widows, 2005). We used sLORETA with a high-density 64-channel EEG acquisition system. We used a template 3-dimensional MRI as a realistic head model of the boundary element method (Fuchs, Drenckhahn, Wischmann, & Wagner, 1998) for all subjects. This is the first study to determine the cortical correlates of NoGo-P3 in individuals with psychopathic traits using high-density EEG, within the general framework of the voxel-based statistical parametric mapping of current density images. We examined the ERPs produced by the NoGo and Go stimuli in a Go/NoGo task. The sLORETA analysis was conducted using the ERP results for NoGo and Go conditions. Further, statistical analyses were performed to compare the current density images of each condition from sLORETA analysis within and between groups in order to understand the neural correlates of response inhibition. To examine the executive function, we also used a Wisconsin Card Sorting Test. On the basis of the previous studies, we expected reduced NoGo-P3 amplitudes and reduced frontal activation in individuals with psychopathic traits reflecting the impaired response inhibition processes. As the N2 component is also discussed as an important component of Go/NoGo tasks (Bruin & Wijers, 2002; Falkenstein, Hoormann, & Hohnsbein, 1999), we further added analyses on N2.

2. Materials and methods

2.1. Subjects

Fifteen right-handed participants (males 5, females 10) with psychopathic traits (psychopathic trait group) were recruited from 743 undergraduate students from Kyonggi University on the basis of the Psychopathic Personality Inventory-Revised (PPI-R, Lee & Park, 2008; Lilienfeld & Widows, 2005). PPI-R is a useful self-report measure to assess psychopathic personality traits in forensic and clinical samples as well as in nonclinical samples (e.g., student, community). PPI-R contains 154 items which are answered using a 4-point Likert scale. The *T*-score cut-off scores of 65 are used in clinical practice as markers of scores that are significantly elevated (Lilienfeld & Widows, 2005). In this study, the psychopathic trait group consisted of participants with a PPI-R *T*-score of 65 or above. Fifteen controls (control group) with a PPI-R *T*-score of 55 or below were matched by age, educational level, gender, and handedness. Participants had normal or adequately corrected vision. Those subjects, regardless of group, with a history of head injury, medical and neurological disorder, or alcohol and drug abuse were excluded from this study.

In order to confirm that the two groups only differ in psychopathic traits, the participants were rated with the Beck Depression Inventory (BDI, Beck & Steer, 1987), Beck Anxiety Inventory (BAI, Beck, Epstein, Brown, & Steer, 1988), Personality Assessment Inventory (PAI, Morey, 1997), Personality diagnostic questionnaire (PDQ, Hyler, 1998), Buss-Perry Aggression Scale (BPA, Buss & Perry, 1992), Barratt Impulsiveness Scale (BIS, Patton, Stanford, & Barratt, 1995), and Narcissistic Personality Inventory (NPI, Raskin & Hall, 1979).

To examine the executive function, the Wisconsin Card Sorting Test (WCST, Heaton, Chelune, Talley, Kay, & Curtiss, 1993) was performed. The subject sorted