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The role of trait impulsivity in response inhibition: Event-related potentials in a stop-signal task

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ABSTRACT

The study examined the relation between self-reported impulsivity and inhibitory control in normal individuals. We compared stopping performance and neural correlates of stopping on stop-signal task between participants who scored in the top (n = 12) and bottom 25% (n = 12) on Impulsivity Scale from a sample of 305 male adults. Participants scoring high on impulsivity did not show impaired inhibitory control. However, it seems that the high impulsive tended to make more errors of commission and omission. Enhanced N1 amplitudes were found in successful than failed inhibition trials. The high impulsive group had smaller P3 amplitude than the low impulsive group. It appears that the high impulsive group may have a less efficient inhibitory control. Impulsivity Scale non-planning impulsiveness score and inattention score of Adult ADHD Self-Report Scale (ASRS) were negatively correlated with P3 amplitudes on successful inhibition trails, suggesting that impulsivity could have the potential influence on inhibitory control.

1. Introduction

Impulsivity is conceived as a personality trait and typically measured by self-report questionnaires, which depend on individuals' perceptions of their own behavior in everyday life. Moeller et al. (2001) stated the definition of impulsivity: "a predisposition toward rapid, unplanned reactions to internal or external stimuli without regard to the negative consequences of these reactions to the impulsive individual or to others". What is more, impulsive behaviors is an important aspect in Diagnostic and Statistics Manual (DSM) diagnostic criteria for several psychiatric disorders, such as attention deficit/hyperactivity disorder (ADHD), conduct disorder, borderline personality disorder, and mania (DSM-IV, American Psychiatric Association, 1994; Moeller et al., 2001). Impulsive behaviors seen in ADHD comprise impatience, distractibility, responding before the task is understood, and failing to correct obviously inappropriate responses (Schachar and Logan, 1990). Poor inhibitory control has been implicated as a core deficit in ADHD and resulted in the observed hyperactivity–impulsivity ADHD symptoms (Barkley, 1997; Schachar and Logan, 1990). Longitudinal data have also indicated that adults with ADHD exhibit a pervasive pattern of disinhibition in several major life activities including money management, excessive drug use, and driving risks (Barkley et al., 2008). Disinhibition means impulsive action and can be defined as the inability to withhold a prepotent response or suppress an inappropriate or unwanted behavior. The stop signal task, developed by Logan and Cowan (1984), makes it possible to quantify inhibition and to disentangle the different processes that operate in response inhibition. Accordingly, impulsivity has been conceptualized and measured as an inability to inhibit a motor response in a laboratory setting (Logan et al., 1997; Moeller et al., 2001).

It is unclear whether a deficient response inhibition underlies the personality trait impulsivity in the non-clinical population; however, some correlational studies in non-clinical populations show that higher scores on Impulsiveness questionnaires correspond with longer stop-signal reaction time (SSRT) (Logan et al., 1997; Marsh et al., 2002) and decrease in inhibition rate (Keilp et al., 2005; Lijffijt et al., 2004; Marsh et al., 2002). On the contrary, other studies have failed to find a reliable relationship between Impulsiveness and SSRT (Cheung et al., 2004; Lijffijt et al., 2004) or inhibition rate (Fallgatter and Herrmann, 2001; Harmon-Jones et al., 1997; Horn et al., 2003). In Lijffijt et al.'s study (2004), the low- and high-impulsive groups did not differ on the speed to stop the response (SSRT). However, the meta-analysis across three studies revealed that high-impulsive group was marginally slower in stopping than low-impulsive group (Lijffijt et al., 2004). The stop-signal task is an effective task to assess sudden forms of response inhibition. In the stop task, subjects perform a speeded choice reaction task (the primary task) and occasionally receive a stop signal that instructs them to suppress their response to the choice reaction stimulus (Logan, 1994; Logan and Cowan, 1984). Successful inhibition is evidence of good impulse control, and failed inhibition is evidence of

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poor impulse control. In non-clinical population, the impulsive individuals have the ability to inhibit their responses but they may be less effective or efficient compared to non-impulsive individuals. Poor stopping behavior is the most robust finding in ADHD, in both children and adults with ADHD where longer stop-signal reaction times were found (Lijffijt et al., 2005). The link between behavioral and laboratory measures of impulsivity has been supported by consistent reports of impaired response inhibition in ADHD characterized by impulsivity. Therefore, the impulsivity in ADHD may be regarded as an extreme form of self-report measure of impulsivity in healthy individuals. The relation between self-reported impulsivity and inhibitory control in healthy individuals deserves further investigation.

1.1. Relationship between impulsivity, inhibition, and the neural correlates of response stopping in non-clinical population

A number of studies have used event-related potentials (ERPs) of the brain to provide more direct information about the neural mechanisms underlying response inhibition. Two paradigms frequently used to investigate response inhibition in the laboratory are the Go/Nogo and stop-signal tasks. Subjects perform a Go/Nogo task requiring the ability to inhibit prepotent responses, whereas they need to inhibit an ongoing response in a stop-signal task. Although different aspects of brain activation show in both tasks, it appears that the Go/Nogo and stop-signal tasks share the same goal, that is, response inhibition. In a Go/Nogo task, subjects have to refrain from an action (like key pressing) after certain stimuli in Nogo-trials. ERPs consistently reveal differences between Go-trials (button press) and Nogo-trials (no response to button press). These differences consist of a frontal negative displacement in a time range of about 200 to 300 ms after the stimulus (N2), and a fronto-central positive displacement in a time range of about 300 to 500 ms after the stimulus (P3) in Nogo-trials as compared to Go-trials (Eimer, 1993; Falkenstein et al., 1995, 1999; Fox et al., 2000; Kok, 1986; Pfefferbaum et al., 1985; Schröger, 1993). Jodo and Kayama (1992) argued that the amplitude of N2 increased when effort was required to withhold the Go response, reflecting response inhibition. However, Donkers and van Boxtel (2004) assumed that the fronto-central N2 in a Go/Nogo task is mainly associated with conflict monitoring processes. The P3 has been related to inhibition by several researchers in a Go/Nogo task (Karlin et al., 1970; Roberts et al., 1994; Schupp et al., 1994). With regard to the stop-signal task, N2 and P3 components have been separately associated with response inhibition. The N2 is maximal in fronto-central site (Bruin and Wijers, 2002), occurs at a latency of 200–350 ms after stimulus onset, and has been interpreted as reflecting the inhibition process (Dimoska et al., 2006; Falkenstein et al., 1999; Pliszka et al., 2000). Van Boxtel et al. (2001) showed that N2 had a similar pattern both on No-go and on stop-signal trials suggesting that the same mechanism may initiate inhibitory control in both situations. However, Botvinick et al. (2001) portrayed cognitive control as serving to prevent the occurrence of conflicts in information processing. They argued that there exists a system that monitors for the occurrence of conflicts in information processing, a function they refer to as conflict monitoring. If task performance deviates from what is expected or required by the task demands, the cognitive control system is activated. Therefore, an alternate explanation for the frontal-central N2 was an index for conflict detection (Chen et al., 2008; Enriquez-Geppert et al., 2010; Huster et al., 2010; Liotti et al., 2000; Nieuwenhuis et al., 2003; Ridderinkhof et al., 2004; Yeung et al., 2004). Moreover, it is generally accepted that the P3 is related to the success of inhibition, as it typically shows enhanced amplitude for successful compared to failed stop trials (De Jong et al., 1990; Dimoska et al., 2003; Kok et al., 2004). Topographical distributions and dipole analysis of high density EEG recordings indicated that different cortical generators were involved in P3 elicited on successful and unsuccessful stop-signal trials. Kok et al. (2004) suggest that P3 on successful stop-signal trials not only reflects stop-signal processing per se, but also efficiency of inhibitory control. In sum, two ERP components related to inhibition are the N2 and P3 in the Go/Nogo and stop-signal tasks. The N2 has been related to inhibition or conflict detection. The P3 is typically maximal in the central or fronto-central region (Falkenstein et al., 2002; Pfefferbaum et al., 1985) and has been associated with the success of response inhibition (De Jong et al., 1990; Dimoska et al., 2003; Kok et al., 2004).

Correlation studies in non-clinical populations had reported that higher scores on Impulsiveness questionnaires correspond with longer stop-signal reaction time (SSRT) (Lijffijt et al., 2004; Logan et al., 1997; Marsh et al., 2002). However, other studies showed a lack of relationship between SSRT and impulsiveness (Cheung et al., 2004; Lijffijt et al., 2004). Previous studies indicated that high and low impulsive groups did not differ with respect to stopping performance (Dimoska and Johnstone, 2007; Lansbergen et al., 2007). Dimoska and Johnstone (2007) identified that high relative to low impulsive subjects showed a larger N1 and central P3 to successful inhibition. Lansbergen et al. (2007) observed that N1 and P3 were larger for successful than failed inhibition, and reported that subjects scoring high relative to low on impulsivity had larger P3, but similar N1 effect. N1 has been interpreted as reflecting the amount of attention that is oriented towards a stop-signal, which is partly determinative of the subsequent success of inhibition in stopping the Go response (Bekker et al., 2005). Enhanced N1 amplitude suggests that the more amount of attention is shifted to the stop signal (Bekker et al., 2005; Lansbergen et al., 2007). These studies mentioned above argued that subjects scoring high relative to low on impulsivity needed more effortful inhibitory control to yield equal stopping performance (Dimoska and Johnstone, 2007; Lansbergen et al., 2007).

1.2. Reduced or enhanced P3 amplitudes in samples with higher levels of impulsiveness?

Contrary to Lansbergen et al. (2007) and Dimoska and Johnstone (2007), several studies employed a visual Go/Nogo task and reported reduced P3 amplitudes in high relative to low impulsive subjects, reflecting a low-level response inhibition (Justus et al., 2001). Ruchsow et al. (2008a) found reduced P3 amplitudes in patients with borderline personality disorder and a negative correlation between the Barratt Impulsiveness Scale and P3 amplitudes, a finding that provides further evidence for impaired response control in participants with higher levels of impulsiveness. In healthy subjects, Ruchsow et al. (2008b) also found that high impulsive subjects had reduced P3 amplitudes compared to low impulsive subjects. In addition, Bekker et al. (2005) revealed smaller stop P3 in adults with ADHD relative to controls. They argued that although individuals with ADHD can generate an inhibitory response to stop signals, stopping was less efficient or the activation of the inhibition system was weaker in individuals with ADHD, as was also indicated by the increase in SSRT (Bekker et al., 2005). It is still an open question to whether reduced or enhanced P3 amplitudes in samples with higher levels of impulsiveness.

1.3. Purpose of this study

The aim the study was to explore the stopping performance and the neural correlates of inhibition in healthy male individuals that varied on self-reported impulsivity. The relation between inhibition and the values of Impulsiveness Scale and the amount of ADHD symptoms assessed on the World Health Organization Adult ADHD Self-Report Scale (ASRS) (Kessler et al., 2005) were also investigated. We predicted that there would be significant differences in P3 amplitude between participants with higher levels and lower lever of trait impulsivity. In addition, we predicted there would be a correlation between self-reported impulsivity score and stop-signal reaction time (SSRT) or the amplitude of the ERP components (N2/P3).