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Research report

The effects of trait impulsivity on proactive and reactive interference control

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ABSTRACT

The current study used event-related brain potentials (ERPs) to explore whether self-reported trait impulsivity in healthy individuals might be differentially related to proactive and reactive interference control. Participants with high and low impulsivity (HI and LI, respectively) performed a modified version of the prime-target interference task. Proactive interference control was induced in the mostly incongruent (MI) context and reactive interference control was induced in the mostly congruent (MC) context. Although the behavioral data revealed no difference between HI and LI individuals in terms of the interference effects (incongruent – congruent) under both contexts, the ERP results showed that impulsivity has a different influence on the interference effects under different task contexts. In the MC context, the interference effects on the medial frontal negativity (MFN) and the negative sustained potential (N-SP) were greater, while that on the positive sustained potential (P-SP) were smaller in the HI compared to those in the LI group. This suggests that high levels of impulsivity might be associated with a reduced efficiency of the processes supporting reactive control to resolve interference when interference is not expected. In contrast, the three ERP indices (MFN, P-SP, and N-SP) of interference processing in the MI context were insensitive to variations in impulsivity. This suggests that HI individuals might be as effective as LI individuals in recruiting proactive control for sustained active maintenance of task goals to anticipate and prevent interference throughout the experimental blocks where interference occurs frequently. In conclusion, these results indicate that impulsivity has a more negative influence on reactive interference control than on proactive interference control.

1. Introduction

Impulsivity is considered a personality trait (Aichert et al., 2012; Pietrzak et al., 2008) and is defined as the inability to inhibit inappropriate behavior, as acting without thinking, as acting prematurely and inappropriately to situations with undesirable consequences, or as an aversion to waiting (Benvenuti et al., 2014; Daruna and Barnes, 1993). Barkley (1999) outlined three interrelated processes of behavioral inhibition: (1) inhibition of prepotent response, (2) stopping of ongoing response, and (3) interference control. Interference control is the ability to focus on task goals in the presence of disruptive task-irrelevant information (Burgess and Braver, 2010; Stroux et al., 2015). It is usually assessed in interference tasks such as the Stroop task, Flanker task, and Simon task. Although many studies have found that there were increased interference effects (as indicated by the difference between performance in the incongruent and congruent trials) in attention deficit hyperactivity disorder (ADHD) (King et al., 2007; Mourik et al., 2005), reports on impulsive individuals within the normal population do not consistently indicate a deficit in interference control (Cheung et al., 2004; Kirkeby and Robinson, 2005; Visser et al., 1996). The potential reason for these contradictory findings is that impulsive individuals within the general population might have cognitive impairment in specific aspects of interference control but not generalized interference control impairment. According to the dual mechanisms of control (DMC) theory (Braver, 2012; Braver et al., 2007), cognitive control operates via two distinct operating modes: “proactive control” and “reactive control”. The current study was designed to explore whether there are differential effects of trait impulsivity on proactive and reactive interference control.

Reactive control is considered a transient form of control recruited for situations where one cannot anticipate imminent

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stimuli. It is a fast-acting and "automatic" process that resolves interference via stimulus-driven modulations of that interference after stimulus onset. In contrast, proactive control is a global (sustained) control strategy that involves the prevention and preparatory management of interference via top-down biasing of attention before occurrence of the interference. Although both strategies are equally likely to lead to correct performance on a specific trial, there are some situations wherein one or the other would be more appropriate. For instance, in an interference task, an important factor determining the extent to which proactive or reactive control contributes to task performance is the proportion of incongruent trials. In a mostly incongruent task context (MI), wherein interference is frequent and can be reasonably anticipated, proactive control tends to dominate. In contrast, in a mostly congruent task context (MC), wherein interference is relatively infrequent and unexpected, reactive control is more likely to emerge (Braver, 2012; Grandjean et al., 2012). Previous studies have supported the distinction between proactive and reactive interference control in the Stroop and recent probe tasks (Burgess and Braver, 2010; De Pisapia and Braver, 2006; Grandjean et al., 2012).

Indeed, two qualitatively different control mechanisms proposed by the DMC theory prompted reconsideration of the apparent ubiquity of impaired cognitive control in individuals with high impulsivity. Castromeneses et al. (2015) used the stop signal task to explore whether impulsivity was related to the response inhibition, which can be similarly classified as proactive and reactive control. The results showed that for the high stop probability condition (compared to the low probability condition), more proactive control was evident, and this was correlated with a reduction in the stop-signal reaction times. Moreover, they found that higher scores of dysfunctional impulsivity were related to weaker reactive control, whereas the correlation of scores of dysfunctional impulsivity and proactive control was non-significant.

It must be said that response inhibition tasks such as the stop signal task do not require interference control processes to operate at the stimulus discrimination or response selection stages; rather, they only require participants to withhold, modify, or stop an already selected response (Bari and Robbins, 2013; Harnishfeger, 1995; Stahl et al., 2013). Thus, Castro-Meneses et al.'s study (2015) provides preliminary support for the idea that high impulsivity individuals showed impairment in response inhibition only for reactive control, instead of proactive control. It is, therefore, worth exploring whether high impulsivity individuals show the same impairments pattern in interference control.

Three ERP components were identified as related to the interference processing: frontal negativity (MFN), positive sustained potential (P-SP), and negative sustained potential (N-SP (Chen et al., 2011). The MFN is a transient component of higher negativity over frontal-central scalp locations for incongruent trials relative to congruent trials between 300 and 500 ms after stimulus onset (Liotti et al., 2000; West and Alain, 2000). The MFN seems to be more strongly related to conflict detection than to response selection or conflict resolution (West, 2003; West and Bailey, 2012). The SP reflects greater positivity for incongruent trials than for congruent trials over the parietal region (labeled the P-SP) and greater negativity for incongruent trials than for congruent trials over the lateral frontal regions (labeled as the N-SP) (Lansbergen et al., 2007). The conflict P-SP appears approximately 500–800 ms after stimulus onset and its amplitude is positively correlated with response time and accuracy for incongruent trials; this suggests that it is associated with processes underlying conflict resolution or response selection within the current trial (Bailey et al., 2010; West, 2003). Conversely, the conflict NSP appears to begin around the end of the PSP (around 800 ms) and lasts for several hundred milliseconds (800–1200 ms) after a response (Chen et al., 2011). This persistence of the frontal slow wave beyond the response for the current trial suggests that the N-SP is associated with a reactive and compensatory recruitment of additional control resources to avoid interference in subsequent trials (Appelbaum et al., 2014; Bailey et al., 2010; Chen et al., 2011).

To our knowledge, few studies have explored the association between trait impulsivity and proactive and reactive interference control. Lansbergen et al. (2007) conducted an ERP study with the Stroop task to test whether impulsivity within the normal population was associated with weaker interference control. They found that high impulsivity (HI) individuals did not show differences in the N/P450 from low impulsivity (LI) individuals, but did find that the SP seemed to originate from a more posterior and right-sided cortical network in the HI individuals relative to the LI individuals. Lansbergen et al. (2007) varied the proportion of incongruent trials to induce high conflict situations and hypothesized that the HI individuals would show greater interference only when the amount of inhibitory control needed to overcome interference was relatively high, as might be expected when incongruent color word stimuli are infrequently presented. Contrary to their expectations, no increased Stroop interference effects were found in the HI individuals relative to the LI individuals, not even in the high-conflict version of the Stroop task. However, the control process in Lansbergen et al. (2007) might have been contaminated by bottom-up associative learning such as frequency confounds (Atalay and Misirlisoy, 2012; Schmidt and Besner, 2008). For example, certain congruent items in MC contexts might repeat more frequently than incongruent ones, whereas in MI contexts, certain incongruent items might repeat more frequently than congruent ones (Jacoby et al., 2003). The frequency confounds might have influenced the lack of difference between the HI and LI individuals in Lansbergen et al. (2007) study. Thus, in the present study, we sought to reduce the frequency confounds in the cognitive control measures as much as possible. For this purpose, a prime-target interference task was used in which a specific prime target digit pair was set to repeat with equal frequency rather than different frequencies in both the MC and MI contexts (Xiang et al., 2016).

To examine the relationship between non-clinical trait impulsivity, as measured by the Barratt Impulsiveness Scale (BIS-11; Patton et al., 1995; Stanford et al., 2009), and specific components of cognitive control, the subjects were asked to perform a prime-target interference task wherein the proportion of congruent and incongruent trials was manipulated to induce the use of reactive or proactive interference control. According to the DMC theory, individuals are more likely to utilize proactive control in the MI block and reactive control in the MC block.

In the current study, we did not adhere to the simpler hypothesis that the HI group would exhibit global impairments in cognitive control; instead, we suggest that impulsivity might have more negative effects on reactive interference control (MC context) than proactive interference control (MI context). First, HI participants, compared to LI participants, were expected to have greater difficulty in suppressing irrelevant response tendencies in MC context, when advance preparation is not feasible and reactive control would likely be recruited after interference was detected. The less efficient reactive interference control ability in the HI group would be evidenced by increased behavioral interference effects in the MC context. In the ERP index, this would be reflected as one or more of the following impairments in the HI group compared to the LI group: (1) a greater interference effect on MFN due to experiencing greater interference from irrelevant information when interference was not expected; (2) a reduced interference effect on P-SP due to worse conflict resolution ability within the current trial; (3) an enhanced interference effects on N-SP due to the need for additional control resources to avoid interference on subsequent trials. Second, we expected that in the MI context, when interference is relatively frequent, HI participants, like LI partici-