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Linking impulsivity and inhibitory control using manual and oculomotor response inhibition tasks

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ABSTRACT

Separate cognitive processes govern the inhibitory control of manual and oculomotor movements. Despite this fundamental distinction, little is known about how these inhibitory control processes relate to more complex domains of behavioral functioning. This study sought to determine how these inhibitory control mechanisms relate to broadly defined domains of impulsive behavior. Thirty adults with attention-deficit/hyperactivity disorder (ADHD) and 28 comparison adults performed behavioral measures of inhibitory control and completed impulsivity inventories. Results suggest that oculomotor inhibitory control, but not manual inhibitory control, is related to specific domains of self-reported impulsivity. This finding was limited to the ADHD group; no significant relations between inhibitory control and impulsivity were found in comparison adults. These results highlight the heterogeneity of inhibitory control processes and their differential relations to different facets of impulsivity.

1. Introduction

Inhibitory control is a complex construct that can be broadly defined as the ability to prevent prepotent actions. It has long been a topic of interest in numerous areas of personality and psychopathology, including childhood behavior disorders (i.e., attention-deficit/hyperactivity disorder [ADHD], conduct disorder), personality disorders, and addiction (Nigg, 2000). Accordingly, investigators from various divisions of psychology have put forward methods of measuring inhibitory control. Personality researchers have measured impulsivity through self-report inventories, whereas researchers in the cognitive sciences have focused on measuring inhibitory control at the behavioral level.[1] Bridging these two methods of assessment is the assumption that the impulsive personality type is driven, at least in part, by behavioral disinhibition. Both methods have proven effective in differentiating between disinhibited and comparison groups (Lawrence, Luty, Bogdan, Sahakian, & Clark, 2009); however, there has generally been poor agreement between these behavioral and self-report measures at the individual difference level. In the current study, we used a series of inhibitory control tasks to examine how these cognitive mechanisms relate to domains of impulsivity. Specifically, we examined how inhibitory control of oculomotor and manual responding related to facets of self-reported impulsivity. In addition, we examined whether these relations differed between a group characterized by disinhibition (i.e., adults with ADHD) and a group of nonimpaired adults.

1.1. Inhibitory control

Inhibitory control represents a loose collection of cognitive processes that are grouped together by virtue of a common function: to facilitate behavioral and cognitive control by suppressing nonproductive behaviors or cognitive processing. It is not a unitary construct; instead, numerous inhibitory control mechanisms have been identified, and there are important differences in the neural circuitry underlying these discrete processes (Alexander, Crutcher, & DeLong, 1991; Aron et al., 2007; Goldstein et al., 2007; Mostofsky et al., 2003). Furthermore, inhibitory mechanisms can be separated by functional characteristics, such as the type of action controlled by the mechanism (e.g., inhibiting a behavior or thought) or the context in which the mechanism is evoked. For example, there is a recognized separation between inhibitory processes activated in delayed reward scenarios and those that govern inhibition when no extended temporal delay is present (Dick et al., 2010). Inhibitory mechanisms also may be

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[1] In the current study, constructs measured by self-report inventories are referred to as impulsivity, and those measured by behavioral tasks are referred to as inhibitory control processes. Delineating between inhibitory control and impulsivity according to measurement method deemphasizes the important overlap between these two constructs (see Nigg, 2000), but is done so here in the interest of clarity.

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classified by the degree to which they are subject to conscious control (i.e., automatic versus intentional; Marzi, 1999). A more basic distinction exists between inhibitory mechanisms that govern overt behaviors (i.e., response inhibition) and those that reduce cognitive load by suppressing task-irrelevant information (i.e., interference control; Nigg, 2000). These and other more nuanced distinctions have prompted the development of numerous behavioral tasks meant to assess the various processes contained under the rubric of inhibitory control. For example, interference control is typically assessed using the Stroop task, whereas a delay-discounting task might be used to measure ability to delay responding for increased reward (Macleod, 1991; Mitchell, 1999).

Of the cognitive processes included in the inhibitory control taxonomy, our understanding of response inhibition is the most advanced with regard to measurement. Prepotent response inhibition is understood as the ability to suppress a prepotent action or inhibit an already initiated response (Dick et al., 2010). Tasks designed to measure response inhibition typically require a participant to execute a behavioral response (e.g., press a button) upon the presentation of a go target and inhibit that response upon the presentation of an infrequently occurring no-go target or stop-signal (Logan, Cowan, & Davis, 1984; Marczinski & Fillmore, 2003). Thus, participants are required to suppress the tendency to execute a prepotent behavioral response. Such tasks (e.g., cued go/no-go task, stop-signal task) have provided a means of measuring individuals' ability to inhibit behavioral responses; these methods have been instrumental in advancing our understanding of this inhibitory control process.

1.2. Manual and oculomotor inhibitory control are independent processes

Most measures of response inhibition have assessed inhibitory control of manual responding (e.g., button press). The inhibitory control processes that govern response inhibition of other behavior, such as eye movements, are not as well studied. There is evidence, however, that oculomotor inhibitory control operates separately from manual inhibitory control, both anatomically (Aron, Robbins, & Poldrack, 2004) and functionally (Nigg, 2000). For example, the frontal eye field area is involved in the inhibition of saccadic eye movements (Hanes, Patterson, & Schall, 1998; Schall, Stuphorn, & Brown, 2002) but not manual actions (Chevrier, Noseworthy, & Schachar, 2007). Children with ADHD show larger impairments of oculomotor inhibitory control relative to manual inhibitory control (Adams, Milich, & Fillmore, 2010). Logan and Irwin (2000) provided behavioral evidence for the independence of these systems: manual inhibitory control differed from oculomotor inhibitory control in simple activation time, and these inhibitory processes were differentially affected by task manipulations. Furthermore, unlike manual inhibitory control, oculomotor inhibitory control processes are closely associated with the allocation of attention (Godijn & Theeuwes, 2003). The ability to effectively inhibit saccades towards to-be-ignored stimuli is likely important in the effective execution of goal-directed actions. Consistent with this notion, dysfunctional inhibitory control of eye movements is thought to contribute to symptoms of inattention and distractibility associated with ADHD (Adams, Roberts, Fillmore, & Milich, 2011), and has been observed in other types of psychopathology (e.g., obsessive–compulsive disorder; Rosenberg et al., 1997).

Recognizing that oculomotor inhibitory control likely constitutes a separate inhibitory system from manual inhibitory control, researchers have developed tasks used to measure inhibitory control of eye movements (Logan & Irwin, 2000). These tasks are similar in principle to their manual counterparts—participants are required to inhibit a prepotent behavioral tendency. The difference here is in the behavior to be inhibited: instead of stopping a hand movement, participants must countermand a saccadic eye movement. In these tasks (e.g., countermanding task, delayed ocular response task [DORT]), participants are presented with a stimulus that would under normal circumstances capture attention and elicit a saccadic eye movement towards the location of that stimulus (Everling & Fischer, 1998; Hanes & Carpenter, 1999). Instead, participants are instructed to consciously inhibit this reflexive saccade and maintain focus on a fixation point in accordance with this internal goal.

Oculomotor inhibitory control tasks have been instrumental in furthering our understanding of attentional processes, and more recently these tasks have been applied to the study of psychopathology. Dysfunction of oculomotor inhibitory control may disrupt other cognitive processes (e.g., selective attention; Houghton & Tipper, 1994) and may play a role in the symptom profiles of numerous psychological and neurological disorders (Ross, Harris, Olincy, & Radant, 2000). These findings provide preliminary empirical evidence that disruption of the basic cognitive processes captured by these tasks may result in maladaptive behavior. Considering the independence of oculomotor and manual inhibitory control, it is likely that impairments of each process would manifest as separate constellations of behavioral tendencies. Consistent with this notion, Weafer, Fillmore, and Milich (2011) demonstrated that manual and oculomotor inhibitory control differed in their relations with alcohol-use behaviors. These researchers reported that oculomotor inhibitory control uniquely predicted alcohol-use behavior in adults with ADHD, whereas the relation between manual inhibitory control and alcohol use did not differ across groups. This highlights the importance of recognizing a distinction between manual and oculomotor inhibitory control processes. Furthermore, considering that these relations differed between ADHD and comparison adults, there may be a benefit in examining how inhibitory control deficits manifest in special populations. Although encouraging, this research is preliminary and examined a relatively narrow domain of behavior (i.e., alcohol-use behavior). Many questions remain as to how separate inhibitory control processes differentially relate to more broadly defined areas of behavioral functioning, such as impulsivity (Dick et al., 2010).

1.3. Inhibitory control and impulsivity

In the personality literature, impulsivity refers to several different personality processes that lead to rash or unplanned acts (Dick et al., 2010). A shift towards a heterogeneous view of impulsivity has occurred in recent years. Whiteside and Lynam (2001) identified four personality traits associated with impulsive behaviors, including urgency (i.e., tendency to experience strong impulses under negative affect), (lack of) premeditation (i.e., tendency to act on the spur of the moment without regard to the consequences), (lack of) perseverance (i.e., difficulty with focusing on a task that may be boring or difficult), and sensation seeking (i.e., tendency to enjoy activities that are exciting or novel). Such multi-trait models of impulsivity recognize that a single impulsive behavior might be realized through multiple personality pathways. For example, a person may impulsively use drugs to alleviate negative affect (i.e., urgency) or because he or she is unable to foresee negative consequences associated with this behavior (i.e., [lack of] premeditation).

There is reason to expect agreement between behavioral measures of inhibitory control and trait impulsivity. For example, models of child temperament identify poor inhibitory control (i.e., effortful control; Rothbart & Ahadi, 1994) as a pathway to impulsive personality (Nigg, 2000). Studies examining the relations between impulsivity inventories and behavioral measures of manual inhibitory control have typically reported poor agreement among measures, however (e.g., Lawrence et al., 2009; Lane, Cherek, Rhoades, Pietras, & Tcheremissine, 2003; but see Logan, Schachar, & Tannock, 1997). These inconsistent findings likely reflect methodological issues relating to the measurement of impulsivity. It is common practice to measure impulsivity using an omnibus self-report measure that does not differentiate between the facets of impulsivity, and instead provides a single score