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Clarifying inhibitory control: Diversity and development of attentional inhibition

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ABSTRACT

Attentional inhibition is the ability to suppress task-irrelevant cognitive processing and ignore salient yet irrelevant features of the situation. However, it remains unclear whether inhibition is a singular function. Prominent are four proposals: a one-factor model of inhibition, an attentional model of inhibition, a response- versus cognitive-inhibition taxonomy, and an effortful- versus automatic-inhibition taxonomy. To evaluate these models, we administered nine inhibition and three attention tasks to 113 adults (Study 1) and 109 children (Study 2). Inhibition models were evaluated using confirmatory factor analysis after statistically controlling for attentional activation. Subsequent age analyses investigated whether inhibition tasks and factors related differentially to age, yielding distinct developmental trajectories. Results provide converging evidence for the automatic-effortful taxonomy – a distinction masked when the contribution of attention is ignored. These results highlight problems of isolated task-based characterizations of inhibition without a theoretical foundation based on evidence from multiple methodologies and populations.

1. Introduction

Inhibition is important in both normal and atypical development across the lifespan. In childhood, proficient inhibitory control is associated with an early literacy and numeracy advantage (Bull, Espy,

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& Wiebe, 2008; Clark, Pritchard, & Woodward, 2010; Espy et al., 2004), which is maintained through the early school years (Bull et al., 2008). In fact, inhibitory proficiency is implicated in children's learning more generally (Bull et al., 2008), as well as emerging cognitive, behavioral, social, and emotional competencies (Garon, Bryson, & Smith, 2008; Riggs, Blair, & Greenberg, 2004; Riggs, Jahromi, Razza, Dillworth-Bart, & Mueller, 2006). Conversely, in older adults, inefficient inhibition interferes with memory retrieval, resisting distraction, and speed of processing (Hasher, Stoltzfus, Zacks, & Rypma, 1991; Hasher & Zacks, 1988). Further, deficient inhibitory control often is found in attention-deficit/hyperactivity disorder (Lijffijt, Kenemans, Verbaten, & van Engeland, 2005), schizophrenia (Bullen & Hemsley, 1987), autism (Ozonoff & Strayer, 1997), and obsessive–compulsive disorders (Enright & Beech, 1993).

However, there remains debate regarding development and construal (i.e., quantity, composition, and interpretation) of inhibitory function(s). Conceptual distinctions, suggesting fractionation of inhibitory processes, include automatic inhibition (Johnson, Im-Bolter, & Pascual-Leone, 2003; Pritchard & Neumann, 2009), behavioral inhibition (Harnishfeger, 1995; Nigg, 2000); cognitive inhibition (Harnishfeger, 1995; Nigg, 2000), effortful inhibition (Johnson et al., 2003; Pritchard & Neumann, 2009), inhibition of return (Posner & Cohen, 1984), pre-potent inhibition (Ozonoff, Strayer, McMahon, & Filloux, 1994), resistance to proactive interference (Friedman & Miyake, 2004), and response inhibition (Verbruggen & Logan, 2008). There is similar diversity in proposed inhibitory functions, with inhibition suggested to apply in situations demanding: resistance to interference from distracting or competing stimuli; suppression of pre-potent responding/processing that impedes successful performance; interruption of processes no longer task-relevant; or automatic deactivation of processes when controlled attention is applied elsewhere (Andres, Guerrini, Phillips, & Perfect, 2008; Collette, Germain, Hogge, & van der Linden, 2009; Friedman & Miyake, 2004; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000; Nigg, 2000). Few studies have attempted to reconcile these conceptual distinctions, and fewer still present developmental data. As a result, currently there is no integrated model of inhibitory function.

1.1. Investigating the factor structure of inhibition

Prominent models of inhibition include one-factor (Cohen, Dunbar, & McClelland, 1990; Dempster, 1992; Diamond, 2006; Morton & Munakata, 2002) and two-factor accounts (Andres et al., 2008; Bjorklund & Harnishfeger, 1995; Collette et al., 2009; D'Amico & Passolunghi, 2009; Englehardt, Nigg, Ferreira, & Carr, 2008; Johnson et al., 2003; Pascual-Leone, 1984; Pritchard & Neumann, 2009). One-factor models propose a single inhibitory resource for interrupting task-irrelevant cognitive processes. Such models assume a single developmental trajectory of inhibitory control. In contrast, multi-factor accounts (described below) propose that multiple resources contribute to inhibitory function, resulting in diverging developmental trajectories and distinct relationships with other cognitive processes.

1.1.1. The TCO model of mental attention and attentional interruption

The Theory of Constructive Operators' (TCO) model of mental attention distinguishes between *effortful* and *automatic* inhibition (Johnson et al., 2003; Pascual-Leone, 1984; for additional researchers drawing a similar distinction, see Andres et al., 2008; Collette et al., 2009; D'Amico & Passolunghi, 2009; Munakata et al., 2011; Pritchard & Neumann, 2009). According to the TCO, the most highly activated cluster of compatible schemes applies to determine performance. It is not always the case, however, that the most highly activated schemes are ideal. In *misleading situations*, such as those typical of inhibition tasks, schemes that are highly activated (e.g., due to salience or over-learning) are often incompatible with correct performance. Correct performance in these situations requires that task-relevant schemes be hyper-activated by way of effortful mental attention, while task-irrelevant schemes are concurrently inhibited (Pascual-Leone, 1984). *Effortful inhibition* thus entails the intentional suppression of task-incompatible mental operations. Pascual-Leone (1984) maintains that as a by-product of this process, an automatic form of inhibition applies on schemes outside the focus of effortful mental attention (Arsalidou, Pascual-Leone, Johnson, Morris, & Taylor, 2013; Pascual-Leone, 1984). That is, *automatic inhibition* spontaneously and effortlessly deactivates mental operations outside the focus of controlled effortful attention, which occurs as a by-product of effortful focus on