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Exogenously triggered response inhibition in developmental stuttering

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ABSTRACT

Purpose: The purpose of the present study was to examine relations between children's exogenously triggered response inhibition and stuttering.
Method: Participants were 18 children who stutter (CWS; mean age = 9;01 years) and 18 children who not stutter (CWNS; mean age = 9;01 years). Participants were matched on age (± 3 months) and gender. Response inhibition was assessed by a stop signal task (Verbruggen, Logan, & Stevens, 2008).
Results: Results suggest that CWS, compared to CWNS, perform comparable to CWNS in a task where response control is externally triggered.
Conclusions: Our findings seem to indicate that previous questionnaire-based findings (Eggers, De Nil, & Van den Bergh, 2010) of a decreased efficiency of response inhibition cannot be generalized to all types of response inhibition.

Introduction

Response inhibition is the ability to suppress a preplanned (Eagle, Bari, & Robbins, 2008), a habitual or a prepotent response (Congdon et al., 2010) or behaviors that are inappropriate or no longer required (Chambers, Garavan, & Bellgrove, 2009). It refers to the suppression of both motor actions as well as higher order responses, such as thoughts and emotions (Verbruggen & Logan, 2009); it is critical to deliberately or unconsciously (Eimer & Schlaghecken, 2003) stopping automatic behaviors in response to goals or environmental contingencies; and, it is also a key component of executive control (Cools, 2008). Although response inhibition is sometimes used as a term for one specific process, namely stopping a motor response, it generally reflects a set of related response control processes such as attending to and interpreting stimuli, decision making based on these stimuli and related internal or external cues, response selection, and successfully executing the appropriate motor response (Eagle et al., 2008; Nigg, 2000).

Several behavioral paradigms have been developed to investigate response inhibition across different age ranges. Currently a variety of measures are being employed of which it is often assumed they all evaluate a common or at least closely related inhibitory mechanism (Baron, 2004; Chambers et al., 2009). Frequently used well-defined paradigms of response inhibition are stop signal tasks (e.g., Logan, 1994), gonogo tasks (e.g., Bokura, Yamaguchi, & Kobayashi, 2001), sustained attention to response tasks (e.g., Robertson, Manly, Andrade, Baddeley, & Yiend, 1997), continuous performance tasks (e.g., Klee & Garfinkel, 1983), and anti-saccadic

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tasks (e.g., Anderson, Husain, & Sumner, 2008). The common feature of these tasks is that they require participants to respond to one set of stimuli (Go trials) and inhibit their response to another set of stimuli (Stop trials). Response inhibition is also thought to be involved in other but related forms of 'effortful' inhibition, such as response interference control and response switching (e.g., Dimoska-Di Marco, McDonald, Kelly, Tate, Johnstone, 2011), which are generally assessed by using paradigms like the Stroop color word tasks (e.g., Milham et al., 2002) or flanker tasks (e.g., Eriksen, 1995). During these tasks participants need to maintain their goal-oriented behavior when confronted with distractors or strongly activated but misleading representations (Friedman & Miyake, 2004). Many of these paradigms have been used in studying response inhibition deficits in different clinical populations such as attention deficit and hyperactivity disorder (Schachar et al., 2007; Trommer, Hoeppner, Lorber, & Armstrong, 1988), autism (Schmitz et al., 2006), Parkinson's disease (Hershey et al., 2010), and Tourette's syndrome (Li et al., 2006). Traditionally these tasks have been used in children 6 or 7 years of age or older (Christ, White, Mandernach, & Keys, 2001; Williams, Ponesse, Schachar, Logan, & Tannock, 1999) but Carver, Livesey, and Charles (2001) showed that modifications to popular tasks, such as the stop signal paradigm (e.g., the use of simple shapes as stimuli, longer stimulus presentation times, fewer trials), make them also appropriate for use in preschool and kindergarten children, and thus making them ideal tools to study aging and developmental effects across a wide age range.

Previous studies in children who stutter (CWS) have yielded results pointing in the direction of reduced response inhibition. Using the Children's Behavior Questionnaire (CBQ; Rothbart, Ahadi, Hershey, & Fisher, 2001), a parent-report temperament questionnaire, Eggers, De Nil, and Van den Bergh (2009), Eggers, De Nil, and Van den Bergh (2010) found a lowered score for 3-to-8-year-old CWS on the 'Inhibitory Control' scale, a finding in line with an earlier questionnaire-based study by Embrechts, Ebben, Franke, and van de Poel (2000). Since response inhibition can be directly linked to the broader concept of self-control (Aron, Behrens, Smith, Frank, & Poldrack; Aron, Durston, et al., 2007), the lowered scores for CWS on the CBQ-superfactor of Effortful Control (Eggers et al., 2010) and on the Behavioral Style Questionnaire (McDevitt & Carey, 1978) scales of emotional and attentional self-regulation (Karrass et al., 2006) corroborate these findings. Also, studies employing computerized paradigms, such as gonogo- and stopsignal-tasks, have revealed lowered response inhibition in both CWS (Eggers et al., 2013) and adults who stutter (Markett et al., 2016). However, not all findings have been unequivocal. Anderson and Wagovich (2010) used the CBQ and did not find any differences in inhibitory control between CWS and CWNS, although it needs to be added their participant group was considerably smaller compared to those of Eggers et al. (2010) and Embrechts et al. (2000). Finally, a recent study using both behavioral measurements and event-related potentials in a gonogo-paradigm did not find inhibition differences (Piispala et al., 2017; Piispala, Kallio, Bloigu, Jansson-Verkasalo, 2016). Taken together, response inhibition may be an important dimension to study in stuttering but since prior studies have reported inconsistent findings, more specific studies are warranted.

The right prefrontal cortex and the fronto-basal ganglia circuit play a crucial role in response inhibition (e.g., Aron, Behrens, et al., 2007; Aron, Durston, et al., 2007; Boehler, Appelbaum, Krebs, Hopf, & Woldorff, 2010; Chambers et al., 2009; Congdon et al., 2010; Jahanshahi, Obeso, Rothwell, & Obeso, 2015). Interestingly, several authors have hypothesized about a possible role of the basal ganglia or the cortical and/or subcortical structures of the fronto-basal ganglia circuit in the pathophysiology of developmental stuttering (e.g., Alm, 2004; Caruso, 1991; Smits-Bandstra & De Nil, 2007; Toyomura & Omori, 2004). Alm (2004) suggests that a dysfunction of this circuit may have various causes, such as focal lesions or aberrant neurotransmitter release, but implies that the core dysfunction lies in the "*impaired ability of the basal ganglia to produce timing cues*" (pp. 359). Also more recently, several authors have linked stuttering to a generalized deficit in the internal timing network, comprised of the basal ganglia and the supplementary motor area (Etchell, Johnson, & Sowman, 2014; Etchell, Ryan, Martin, Johnson, & Sowman, 2016). In a same line of reasoning, Smits-Bandstra and De Nil (2007) proposed that dysfunctions in this circuit might result in deficits in motor sequence skill learning and reduced automaticity development.

Many authors have adhered to the idea that a single mechanism underlies the ability to inhibit responses by generalizing the results obtained from different paradigms previously mentioned and several data point in the direction of at least partly overlapping circuits, especially with respect to the involvement of the pre-supplementary motor area (pre-SMA) and inferior frontal cortex (IFC) (e.g., Aron, Behrens, et al., 2007; Aron, Durston, et al., 2007; Boehler et al., 2010; Chambers et al., 2009; Jahanshahi et al., 2015). Others have argued that these tasks assess slightly different but related response inhibition processes or even that it is not clear that all of these tasks isolate response inhibition processes rather than related control processes such as response selection, conflict resolution, sustained attention, and working memory (Nigg, 2000). At the least, there seems a reasonable amount of support for the existence of different, partly overlapping forms of response inhibition. Three categorizations are commonly made (Jahanshahi et al., 2015), namely the difference between a) volitional/intentional (i.e. self-generated, in the absence of external stimuli) versus automatic inhibition, b) reactive (triggered by external stimuli) versus proactive inhibition (preparedness to respond with restraint when faced with temptations), and c) global (stopping all actions) versus selective inhibition (stopping only certain actions). Friedman and Miyake (2004) distinguish three components of response inhibition: a) inhibition of prepotent responses, b) resistance to interference from distracting stimuli, and c) protection from proactive interference. Inhibition is also influenced by maturation since at a young age primarily reactive inhibition is present whereas older children and adults show more proactive mechanisms of inhibition (Chatham, Frank, & Munakata, 2009).

In the current study, we will focus on externally/exogenously triggered response inhibition, in other words the process that cancels the action is the result of an external signal (e.g., an auditory signal indicating the response has to be inhibited). This type of inhibition differs from endogenously triggered or internally generated inhibition since different brain regions seem to be involved (Filevich, Kühn, & Haggard, 2012; Schel et al., 2014). Endogenously triggered inhibition refers to tasks with no external stop signals. Examples are the marble task (Kühn, Haggard, & Brass, 2009) in which the person has to intentionally/voluntarily stop externally triggered responses or sustained attention tasks (e.g., Robertson et al., 1997) in which the person needs to self-sustain conscious