



Delayed N2 response in Go condition in a visual Go/Nogo ERP study in children who stutter



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ABSTRACT

Purpose of the study: The main aim of the study was to investigate the attentional and inhibitory abilities and their underlying processes of children who stutter by using behavioural measurement and event-related potentials (ERP) in a visual Go/Nogo paradigm. **Methods:** Participants were 11 children who stutter (CWS; mean age 8.1, age range 6.3–9.5 years) and 19 typically developed children (TDC; mean age 8.1, age range 5.8–9.6 years). They performed a visual Go/Nogo task with simultaneous EEG recording to obtain ERP responses.

Results: Results showed that CWS had longer N2 and P3 latencies in the Go condition compared to the TDC. In contrast, the groups did not differ significantly in the Nogo condition or behavioural measures.

Conclusions: Our findings did not confirm less efficient inhibitory control in CWS but suggest atypical attentional processing such as stimulus evaluation and response selection.

Educational Objectives: The reader will be able to (a) describe recent findings on attention and inhibitory control in children who stutter, (b) describe the measurement of attentional processing, including inhibitory control, and (c) describe the findings on attentional processing in children who stutter as indexed by the event-related potentials in a visual Go/Nogo paradigm.

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1. Introduction

Developmental stuttering is a speech fluency disorder that is characterized by repetitions, prolongations and interruptions during speech. Some recent conceptualizations suggest that dysfluencies in stuttering may stem from neurobiological and neurophysiological factors such as differences in brain areas related to speech motor and language production as well as auditory processing (Giraud et al., 2008; Jansson-Verkasalo et al., 2014; Watkins, Smith, Davis, & Howell, 2008; for an overview, see review by Alm, 2004). These theories suggest malfunctioning basal ganglia and cortico-striato-thalamo-cortical networks as a possible pathology behind stuttering. In support of this, there is increasing evidence of structural and functional brain abnormalities linked with persistent developmental stuttering both in adults (Beal, Gracco, Lafaille, & de Nil,

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2007; Salmelin, Schnitzler, Schmitz, & Freund, 2000; Sommer, Koch, Paulus, Weiller, & Büchel, 2002; Watkins et al., 2008) and children (Beal, Gracco, Brettschneider, Kroll, & De Nil, 2013; Chang & Zhu, 2013; Chang, Erickson, Ambrose, Hasegawa-Johnson, & Ludlow, 2008). Some of these brain areas have also been connected to cognitive control, including inhibitory processes (Bunge, Dudukovic, Thomason, Vaidya, & Gabrieli, 2002; Chambers, Garavan, & Bellgrove, 2009).

The Communication-Emotional model of stuttering proposed by Conture et al. (2006) holds that stuttering is caused by distal and proximal factors. Distal factors, genetics and environment may have an effect on proximal contributors, such as speech and language planning and production. Temperamental factors, such as emotional reactivity and self-regulation, are related to the way that children react and cope with speech disruptions (Bloodstein & Bernstein Ratner, 2008; Conture et al., 2006). Reactivity refers here to somatic, autonomic, cognitive and neuro-endocrine responses to internal and external stimuli. Self-regulation, in turn, refers to the processes that modulate reactivity, such as inhibitory control and effortful control of attention as well as approach and withdrawal (Rothbart, 1989). Inhibitory control is important for the performance of everyday tasks. It is defined as the ability to suppress, interrupt or delay an inappropriate response under instruction or in novel or uncertain situations (Rothbart, 1989), or the ability to ignore irrelevant information (Rothbart & Posner, 1985). Temperamental factors, such as strong reaction to stuttering, may increase the level of disruption and these in turn trigger more reactivity. In accordance with these theories, Eggers, De Nil, and Van den Bergh (2012) found less-efficient attentional orienting in CWS. Earlier the same authors showed significant differences in the inhibitory control and attention-related scales of CWS in a psychological questionnaire (Eggers, De Nil, & Van den Bergh, 2010). This suggests poorer competence in these aspects of cognitive control in CWS, although contrary findings also exist (Anderson & Wagovich, 2010).

The Go/Nogo paradigm is an inhibition-related task in which a stimulus requires either a response (Go) or no response (Nogo), often with equiprobable or, in order to increase the inhibitory control demands, infrequent Nogo stimuli (for an overview, see Huster, Enriquez-Geppert, Lavalée, Falkenstein, & Herrmann, 2013). In a recent fMRI study, during a visual Go/Nogo-task (Steele et al., 2013) inhibition-correlated activity was detected quite widely in the brain, among others in the prefrontal areas, the anterior cingulate (ACC), supplementary motor areas, fronto-striatal regions and some parts of the basal ganglia. Considering the overlap in the brain differences found in children who stutter (Beal et al., 2013; Chang et al., 2008; Chang & Zhu, 2013), one would expect CWS to differ from controls in this task. Indeed, in the Go/Nogo task of the Amsterdam Neuropsychological Tasks (ANT) CWS showed more false alarms and premature responses and difficulties adapting their response style after errors compared to TDC (Eggers, De Nil, & Van den Bergh, 2013).

The Go/Nogo paradigm combined with event-related potential (ERP) measurements with visual or auditory stimuli has been used to assess inhibitory control both in the study of normal development of cognitive control (Johnstone, Pleffer, Barry, Clarke, & Smith, 2005; Jonkman, Lansbergen, & Stauder, 2003; Jonkman, 2006) as well as of different clinical entities, such as ADHD (Johnstone, Barry, Markovska, Dimoska, & Clarke, 2009; Spronk, Jonkman, & Kemner, 2008). The ERP components have been found to be modified by the task parameters. Similarly, the age and maturation of attentional abilities and inhibition processes exert an influence on ERPs (Brydges, Anderson, Reid, & Fox, 2013; Johnstone et al., 2005; also see review Huster et al., 2013).

The ERP waveform consists of a sequence of positive (P) and negative (N) deflections, or peaks, that are named according to their polarity and latency (i.e. timing relative to the stimulus onset), as well as their serial order or cognitive meaning (Näätänen, 1992). The N1, P2, N2 and P3 responses are commonly measured in studies investigating attentional processes (Luck, 2005). The N1 and P2 peaks represent early-evoked responses to a stimulus and can usually be defined in the time windows of 90–200 ms and 180–270 ms in visual Go/Nogo paradigms, respectively (Johnstone et al., 2007; Jonkman et al., 2003; Jonkman, 2006). The N2 and P3 responses are the main ERP components modified by the Go/Nogo paradigm, visible respectively at 200–360 ms and 250–650 ms post-stimulus in visual paradigms (Johnstone et al., 2007; Jonkman et al., 2003; Jonkman, 2006). Compared to the Go condition, the N2 and P3 usually show enhancement in Nogo condition (the Nogo effect) (Donkers & van Boxtel, 2004; Falkenstein, Hoormann, & Hohnsbein, 1999; Jonkman et al., 2003; Jonkman, 2006).

The N2 peak has a maximum fronto-centrally and its generators have consistently been located to the anterior cingulate cortex (ACC) during inhibitory tasks (Bekker, Kenemans, & Verbaten, 2005; Jonkman, Sniedt, & Kemner, 2007; Nieuwenhuis, Yeung, & Cohen, 2004; Van Veen & Carter, 2002). ACC is an area linked to self-regulation processes such as conflict monitoring, response selection and outcome evaluation (Botvinick, Cohen, & Carter, 2004, for an overview, see Van Veen & Carter, 2002). According to many authors, the N2 reflects monitoring of conflict, more specifically the conflict between the prepotent Go response and the inhibition-requiring Nogo response (Donkers & van Boxtel, 2004; Randall & Smith, 2011; Smith, 2011; see also the review by Van Veen & Carter, 2002), although some have also suggested inhibitory processes (Falkenstein et al., 1999; Pliszka, Liotti, & Woldorff, 2000). It likely contains components enhanced by novel stimulus, as well (Albert, López-Martín, Hinojosa, & Carretié, 2013; for an overview, see Folstein & Van Petten, 2008).

The P3 can be divided into two subcomponents which are modulated independently and have different topography in Go and Nogo tasks, probably due to separate neural generators (Bokura, Yamaguchi, & Kobayashi, 2001; Gajewski & Falkenstein, 2011; Tekok-Kilic, Shucard, & Shucard, 2001). In an equiprobable Go/Nogo paradigm the Go P3 probably represents the same processes as the P3b in the oddball paradigm as suggested by Barry and Rushby (2006) (also see review by Polich, 2007). These processes include stimulus evaluation and classification (see review by Linden, 2005; Picton, 1992) or a monitoring process spanning from stimulus discrimination to the response (Verleger, Jaśkowski, & Wascher, 2005). The Go P3 is maximal in centroparietal regions in adults (Barry & De Blasio, 2013; Bokura et al., 2001; Tekok-Kilic et al., 2001) and children (Barry, De Blasio, & Borchard, 2014). In contrast, the Nogo P3 is maximal fronto-centrally (Bokura et al., 2001; Johnstone et al., 2007; Jonkman, 2006; Smith, 2011; Tekok-Kilic et al., 2001). An increasing number of studies have suggested that the Nogo P3

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