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# Executive function in school-aged children with cerebral palsy: Relationship with speech and language

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ABSTRACT

*Background and Aims:* Although children with cerebral palsy (CP) are at an increased risk for developing speech, language, and executive function (EF) impairments, little is known regarding the relationship among these risk factors. The current study examined how different profiles of speech and language impairment might be associated with impairments in EF skills in school-aged children with CP.

*Methods and Procedures:* Forty-seven school-aged children with CP were included. Each child contributed between one and four data points for a total of 87 data points. Children were classified into speech and language profile groups at each data point. EF skills were examined using the Behavior Rating Inventory of Executive Function questionnaire. Outcomes and Results. Compared to a mean of 50 from a normative population of children, mean scores on all measures of EF were significantly elevated for all groups ($p < .05$). The proportion of children with CP with elevated EF scores was significantly higher for all groups compared to the expected proportion in a normal population of children ($p < .05$).

*Conclusions and Implications:* Children with CP who do not have impairments in speech or language may be at risk for EF difficulties which may negatively affect social communication, academic performance, and functional independence.

## 1. Introduction

Cerebral palsy (CP) is a complex and heterogeneous disorder that can have a profound impact on all aspects of life (Kennes et al., 2002; Liptak et al., 2001). Due to brain insult experienced early in life, children with CP are at an increased risk for co-occurring problems, including impairments with sensation, perception, cognition, communication, and behavior (Rosenbaum et al., 2007).

CP is associated with a range of underlying neuropathologies including basal ganglia damage, focal infarct, cortical/subcortical damage, and malformations (Bax, Tydeman, & Flodmark, 2006). The predominant type of injury to the brain associated with CP results from damage to white matter (otherwise referred to as periventricular leukomalacia (PVL)), found in 42.5% of children with CP (Bax et al., 2006). Functional neuroimaging studies have shown that the prefrontal cortex and white matter tracts connecting the prefrontal and posterior regions of the brain (Christ, White, Brunstrom, & Abrams, 2003) are especially important for the development of executive functioning (EF) skills (Krasenegor, Lyon, & Coldman-Rakic, 1997).

Broadly defined, EF skills are a set of higher order cognitive abilities that are responsible for guiding and managing an individual's functions and behaviors (Welsh, Pennington, & Groisser, 1991). Owing to underlying neuropathologies mentioned above, children

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with CP are at risk for difficulties with EF skills (Odding, Roebroeck, & Stam, 2006). Only recently have researchers begun to examine EF skills in children with CP. Studies have found that compared to typically developing peers, adolescents and school-aged children with CP show deficits in inhibitory control, working memory, visual and auditory attention, flexibility, planning, and information processing (Anderson et al., 2010; Bodimeade, Whittingham, Lloyd, & Boyd, 2013; Christ et al., 2003; Edgin et al., 2008; Pirila, van der Meere, Rantanen, Jokiluoma, & Eriksson, 2011; Schatz, Craft, White, Park, & Figiel, 2001; White & Christ, 2005). These studies have primarily focused on examining EF skills with regard to a specific type of CP (mainly spastic) or in relation to the type of anatomical involvement (i.e., left unilateral vs. right unilateral (Bodimeade et al., 2013); bilateral vs. unilateral (Pirila et al., 2011)), or time of injury (congenital vs. peri-natal vs infancy vs. different points during childhood (Anderson et al., 2010)). Several studies have also examined the association between certain EF skills and skills from other domains, such as mathematical ability (Jenks, De Moor, & Van Lieshout, 2009; Jenks, van Lieshout, & de Moor, 2012).

Although recent work has contributed to our understanding of EF abilities in children with CP, the relationship between EF skills and speech and language problems - another common area of impairment for children with CP - is unknown (Cheney & Palmer, 1997; Krigger, 2006; Rosenbaum et al., 2007). Approximately 60% of children with CP experience some type of communication difficultly (Bax et al., 2006). These impairments may include dysarthria, a motor speech disorder affecting about half of all persons with CP (Nordberg, Miniscalco, & Lohmander, 2014), impaired language abilities, also affecting about half of all persons with CP, or a combination of impaired speech and language skills (Himmelmann, Lindh, & Hidecker, 2013; Hustad, Gorton, & Lee, 2010; Sigurdardottir & Vik, 2011). In 2010, Hustad and colleagues proposed and validated a four-group classification model based on the speech and language abilities of children with CP (Hustad et al., 2010). Children with CP who had no clinical evidence of a speech or language impairment were classified as NSMI (no speech motor involvement); those children with a clinical diagnosis of dysarthria and typical receptive language skills were classified as SMI-LCT (speech motor involvement-language comprehension typical); those with a clinical diagnosis of dysarthria and impaired receptive language skills were classified as SMI-LCI; and those children who were able to produce 5 or fewer spoken words were classified as ANAR (anarthric or the inability to produce functional speech). This model has provided a useful framework for studying different patterns of developmental change in speech and language abilities and as a tool for predicting longer term outcomes (Hustad et al., 2017).

Past research has highlighted the important role that language plays in the development of cognitive skills (Barkley, 1997; Cohen et al., 2000; Liss et al., 2001; Russell, 1997) and research from other populations of individuals with neurodevelopmental disabilities has shown that children with language impairment often present with co-occurring deficits in EF skills (Henry, Messer, & Nash, 2012; Wittke, Spaulding, & Schechtman, 2013). Less is known about the relationship between speech development and EF skills; however, due to the cognitive underpinnings of spoken language one might expect an important linkage (Barkley, 1997).

The current study utilized the four-group classification system described above (Hustad et al., 2010) in order to examine EF skills in groups of children with similar speech and language abilities, with a particular focus on the three groups of children who were able to produce speech (NSMI, SMI-LCT, and SMI-LCI). A better understanding of the relationship between speech, language, and EF abilities would help to further define the profiles of associated impairments in children with CP. Furthermore, due to the negative impacts that speech, language and EF deficits may have on functional independence in school and in the community, a more comprehensive understanding of this relationship is crucial to the development of better interventions tailored to meet needs of individual children.

The current study addressed the following questions:

1) Are there differences in mean scores on standardized measures of EF among three profile groups of children with CP (NSMI, SMI-LCT, and SMI-LCI)?
2) Are mean scores on standardized measures of EF within each of three profile groups of children with CP different from an expected typically developing mean score of 50?
3) Are there differences in the proportion of clinically elevated scores on standardized measures of EF between the three groups of children with CP?
4) Is the proportion of children with clinically elevated scores on standardized measures of EF within each of the three profile groups of children with CP greater than the expected proportion in typically developing children?

## 2. Methods

### 2.1. Participants

Participants were selected from a larger cohort of children (n = 139) participating in a longitudinal study on communication development in children with CP. Between 2005 and 2012, children were recruited though local and regional neurology and physiatry clinics in the Upper Midwestern region of the US. Children were between 2;0 and 5;0 years old upon initial enrollment. Children were seen twice a year, roughly 6 months apart, until their 8$^{th}$ birthday, after which children were seen yearly. Criteria for inclusion into the larger study required that children have a medical diagnosis of CP and have hearing within normal limits as documented by either formal audiological evaluation or distortion product otoacoustic emission screening. Inclusion criteria for the current study were: 1) have at least one completed data collection session between the ages of 5;0 and 15;0; and 2) have at least one valid Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000) completed by a parent. A total of 47 children with CP (27 males) met criteria and were included in the current study. Table 1 presents demographic characteristics of these children. All children were born between 2001 and 2009. Because the larger study was longitudinal, each child