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Executive function in Chilean preschool children: Do short-term memory, working memory, and response inhibition contribute differentially to early academic skills?☆

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ABSTRACT

A large body of literature demonstrates that different cognitive components related to executive function (EF), such as short-term memory, working memory, and response inhibition, are linked to early academic skills in preschool children. Nevertheless, few studies have focused on the unique contributions of these components to distinctive early numeracy and literacy skills in preschool children. Moreover, most studies have not considered the covariance between these early academic skills in preschool-aged children. The present study examined whether there are differential contributions of visual–spatial and verbal short-term memory, working memory, and response inhibition to specific early numeracy and literacy skills in preschool-aged children, taking into account the covariance among these outcomes. Several seemingly unrelated regression (SUR) analyses were conducted with 419 Chilean preschool-aged children ($M = 53.9$ months; $SD = 4.22$). The results show that both response inhibition and verbal short-term memory uniquely predicted all academic outcomes; working memory predicted all early academic skills (with the exception of verbal counting); and visual–spatial short-term memory predicted all numeracy skills and receptive vocabulary. When comparing the marginal effects of the EFs on the outcomes, response inhibition more strongly predicted applied problems than did working memory. Both visual–spatial short-term memory and response inhibition had a greater effect on explaining applied problems, compared to early decoding skills. Implications for teachers and interventions are discussed.

1. Introduction

The main goal of this study is to examine whether there are differential contributions of verbal and visual–spatial short-term memory, working memory, and response inhibition to distinct components of early numeracy and literacy skills, taking into account the shared variance among these early academic skills. In recent years, there has been an increasing focus on understanding young children's executive function (EF). EF is an important developmental and cognitive construct that is associated with other developmental outcomes and academic achievement in young children. Research shows that better executive function skills in preschool provide children with the building blocks for numeracy and early literacy skills, resulting in more advanced academic skills early in development (Blair & Razza, 2007; Bull, Espy, & Wiebe, 2008). This academic advantage is maintained not only throughout the first years of formal schooling (Bull et al., 2008), but also until adolescence (Watts, Duncan, Siegler, & Davis-Kean, 2014).

Despite the value of these findings, most studies conducted with preschool-aged children consider only one aspect of executive function (Fei-Yin, Tamis-LeMonda, Yoshikawa, & Sze, 2015; Fuhs & McNeil, 2013) or use a composite score without distinguishing among the specific contributions of each (Blair, Ursache, Greenberg, Vernon-Feagans, & Family, 2015; Weiland, Barata, & Yoshikawa,

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2014). Also, the research that links EFs and early academic abilities, such as numeracy or literacy skills, generally considers only a single measure of academic abilities (Fei-Yin et al., 2015). Because of this need for studies targeting different executive functions and academic skills, no generalizable conclusions can be made about the specific contributions of EFs to early academic skills. Some studies have found that WM and RI have differential contributions to numeracy and early literacy skills in preschool-aged children (Davidse, De Jong, & Bus, 2015; Lan, Legare, Ponitz, Li, & Morrison, 2011; McClelland et al., 2014; Purpura, Schmitt, & Ganley, 2017). These findings highlight the idea that the more cognitively complex aspects of EFs are related to the more sophisticated aspects of early numeracy and literacy skills in young children. However, these studies have been conducted with small preschool samples (Davidse et al., 2015; Purpura et al., 2017), with older children (St Clair-Thompson & Gathercole, 2007), or have only included measures of literacy skills (Lonigan, Lerner, Goodrich, Farrington, & Allan, 2016) without incorporating numeracy assessments.

Similarly, studies conducted with preschool-aged children typically do not consider the relation that exists between early numeracy and literacy skills. Research shows that early numeracy and literacy skills share variance that could be related to cognitive abilities (Davidse, De Jong, & Bus, 2014; Singer & Strasser, 2017). Ignoring this covariance could be problematic when trying to identify which EFs are more associated with early academic skills in both academic domains, given that these outcomes are highly correlated.

Examining the differential relations between EFs and academic outcomes has potential implications for the design and evaluation of interventions related to numeracy or literacy in the early years. Recent evidence suggests that for preschool children it may be more beneficial if teachers target EF and numeracy skills simultaneously (Schmitt, Purpura, Duncan, & McClelland, 2017). If teachers know the EFs that are more beneficial for children, they could develop better instructional strategies to target those skills in preschool classrooms.

The main goal of this study is to examine whether there are specific contributions of distinct executive functions to specific early numeracy and literacy skills, distinguishing those EFs that have a greater effect on these academic outcomes. We used a singular measure of each EF construct, as well as different measures of early numeracy and literacy skills, to isolate the differential contributions of each construct to the outcomes and account for issues of task impurity (Miyake et al. 2000). Task impurity refers to the idea that a specific measure of children's cognitive skills taps into other components. Thus, we expanded upon previous work by using one measure for each cognitive construct of EF in an attempt to provide a better understanding of the relations between EFs and academic outcomes. Acknowledging the issues of task impurity inherent in measures of cognitive skills at this age, we included measures of working memory (WM) and response inhibition (RI), as well as verbal and visual–spatial short-term memory (STM) skills, because of their reported contributions to the understanding of numeracy and early literacy skills in young children (Bull et al., 2008; Lan et al., 2011; LeFevre et al., 2010; Purpura et al., 2017). We also used an analytical approach that allowed us to examine the specific contributions of EFs to academic outcomes in early years and compare their marginal effects, considering the shared variance between academic outcomes.

We studied whether there are distinct links between EFs and school readiness outcomes in a large and diverse sample of Chilean preschoolers, extending the literature, which has mainly focused this research on samples from Western, educated, industrialized, rich, and democratic (WEIRD) societies. Thus, the inclusion of a Latin-American sample will provide a better understanding of how EFs are related to academic outcomes across different cultural contexts.

1.1. Executive functions

Executive functions appear to be particularly important for the cognitive development of children. They refer to the "online" processes that allow for the self-regulation of complex cognitive activities as well as overt goal-directed behavior (for a review Diamond, 2013). In general, there is consensus that EFs represent a unifying latent construct, and most researchers agree that effective executive functioning entails the coordination of several component skills (Garon, Bryson, & Smith, 2008). Indeed, studies using factor analysis and that include children and adult samples have identified some subcomponents of EF: working memory, response inhibition, and attentional set shifting (Espy et al., 2004). With samples of preschool children, particularly, current research indicates that EFs are best represented at this age by distinct working memory and response inhibition factors (Lerner & Lonigan, 2014; Lonigan et al., 2016).

Working memory is defined as the ability to simultaneously store and manipulate information (Baddeley, 1992; Baddeley & Hitch, 1974). WM is critical for making sense of anything that unfolds over time, and by definition it requires holding in mind what happened earlier and relating that to what comes later (Baddeley & Hitch, 1974). Thus, it is a skill necessary for grasping written or spoken language, whether a sentence, a paragraph, or longer. Similarly, doing any math requires WM because it helps to solve problems, such as translating instructions into action plans, or incorporating new information into thinking actions (Baddeley, 1992, 2010; Baddeley & Hitch, 1974). There are some studies that have also looked at specific aspects of working memory involved in early academic skills, such as verbal and visual–spatial short-term memory (Bull et al., 2008). The first is in charge of storage and processing of verbal information (Baddeley & Hitch, 1974), whereas the second stores and processes visual and spatial structures (Baddeley, 2010). This basic modular structure of working memory has proven to be stable and assessable in children as young as four years of age (Alloway, Gathercole, Kirkwood, & Elliot, 2008; Alloway, Gathercole, Willis, & Adams, 2004).

Response inhibition refers to the ability to override a dominant or proponent response in favor of a more adaptive one, which makes it possible to change and choose how to react to a stimuli (Friedman & Miyake, 2004; Garavan, Ross, & Stein, 1999). It allows an individual to not blurt out what first comes to mind or to not jump to a conclusion before getting all the facts.

All these abilities have been shown to predict early numeracy skills (Purpura et al., 2017), because when children are asked to solve a problem, count, or perform mental calculations, they are required to use these abilities to give a correct answer. Also, RI plays an important role in identifying word meaning (Lonigan et al., 2016), revealing children's ability to give a correct answer instead of the first that comes to mind, in case the first is not correct, as described more in detail below.

1.2. Relations between EFs and numeracy skills

Solving mathematical problems is an important activity for children before formal schooling. From an early age onwards, learning to count, acquiring number skills, and performing mathematical operations become part of children's daily activities. When preschool children need to solve a problem, they recruit skills such as verbal and visual–spatial STM, WM, and RI. These skills allow children to maintain information in their memories (Bull et al., 2008), follow a sequence of steps (Schmitt, Pratt, & McClelland, 2014), suppress a mental representation (Bull & Scerif, 2001), inhibit knowledge or automatic associations, and process information that is necessary to complete a task (Schmitt et al., 2014).

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