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A longitudinal study on predictors of early calculation development among young children at risk for learning difficulties

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ABSTRACT

The purpose of this study was to explore domain-general cognitive skills, domain-specific academic skills, and demographic characteristics that are associated with calculation development from first grade to third grade among young children with learning difficulties. Participants were 176 children identified with reading and mathematics difficulties at the beginning of first grade. Data were collected on working memory, language, nonverbal reasoning, processing speed, decoding, numerical competence, incoming calculations, socioeconomic status, and gender at the beginning of first grade and on calculation performance at four time points: the beginning of first grade, the end of first grade, the end of second grade, and the end of third grade. Latent growth modeling analysis showed that numerical competence, incoming calculation, processing speed, and decoding skills significantly explained the variance in calculation performance at the beginning of first grade. Numerical competence and processing speed significantly explained the variance in calculation performance at the end of third grade. However, numerical competence was the only

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significant predictor of calculation development from the beginning of first grade to the end of third grade. Implications of these findings for early calculation instructions among young at-risk children are discussed.

Introduction

Calculation competence is a mathematical skill children learn and develop in the early elementary grades, and yet it represents a major challenge for many young children (National Council of Teachers of Mathematics, 2006). Because of the hierarchical nature of mathematics skills, the development of calculations serves as a foundation for developing increasingly advanced mathematical skills, such as algebra (Ashcraft, 1992; Jensen & Whang, 1994; National Council of Teachers of Mathematics, 2006). Therefore, weak calculation skills pose substantial problems for children's mathematics development in addition to their daily activities. Given the importance of calculations during early childhood, it is critical to understand factors that contribute to the early development of calculation competence. Such knowledge can guide curricular development and instructional interventions aimed at remediating poor calculation performance early on.

Prior studies examining factors that influence calculation competence have shed some light on underlying mechanisms of calculation development (e.g., Berg, 2008; Cowan et al., 2011; Cowan & Powell, 2014; Fuchs et al., 2005; Fuchs et al., 2010a, 2010b). These studies suggest that various domain-general cognitive skills, domain-specific academic skills, and demographic factors contribute to calculation competence. However, a majority of the studies involve typically developing children. Only a few target children with learning difficulties. We identified only two such studies that specifically addressed calculation development among children with learning difficulties (i.e., Alloway, 2009; Namkung & Fuchs, 2016). Specifically, Alloway (2009) investigated whether domain-general cognitive skills, including working memory and IQ, in children with learning difficulties between 7 and 11 years of age predicted comprehensive mathematics skills, which included calculations and mathematics reasoning, two years later. Results indicated that only working memory was a significant predictor. However, Alloway included only two cognitive predictors, and the mathematics skills in her study were indexed by calculations and mathematics reasoning, which were not likely to represent a complete picture of the components involved in early calculation development.

Namkung and Fuchs (2016) extended Alloway's (2009) findings by using a broader set of domain-general cognitive skills and domain-specific academic skills—working memory, processing speed, language, attention, nonverbal reasoning, and incoming calculations (i.e., calculation knowledge acquired prior to the study)—at the beginning of fourth grade to predict calculation performance at the end of fourth grade. They found that processing speed, attentive behavior, and incoming calculations uniquely predicted whole-number calculation competence. Although Namkung and Fuchs included a more comprehensive set of skills, their samples were children with learning difficulties in the intermediate grades, which could not reveal the importance of each skill in early calculation development (i.e., first grade to third grade).

Moreover, all prior studies on calculation development focused on what skills explain calculation performance concurrently (e.g., Berg, 2008; Cowan & Powell, 2014) or focused on how these skills predict calculation performance later in the intermediate grades (e.g., Alloway, 2009; Cowan et al., 2011; Fuchs et al., 2005, 2010a, 2010b; Namkung & Fuchs, 2016). We are unaware of any longitudinal study that has relied on domain-general cognitive skills, domain-specific academic skills, and demographic factors to predict early development (i.e., change rate/slope) of calculations, especially among young children with learning difficulties. In the current study, we used latent growth modeling to explore early childhood cognitive, academic, and demographic factors that predict calculation development from the beginning of first grade to the end of third grade among children identified with learning