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Number-specific and general cognitive markers of preschoolers' math ability profiles

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ABSTRACT

Different number-specific and general cognitive markers have been claimed to underlie preschoolers' math ability. It is unclear, however, whether similar/different cognitive markers, or combinations of them, are associated with different patterns of emerging math abilities (i.e., different patterns of strength and weakness). To examine this question, 103 preschoolers (40–60 months of age) completed six math tasks (count sequence, object counting, give a number, naming numbers, ordinal relations, and arithmetic), three number-specific markers of math ability (dot enumeration, magnitude comparison, and spontaneous focusing on numerosity), and four general markers (working memory, response inhibition, attention, and vocabulary). A three-step latent profile modeling procedure identified five math ability profiles that differed in their patterns of math strengths and weaknesses; specifically, the profiles were characterized by (a) excellent math ability on all math tasks, (b) good arithmetic ability, (c) good math ability but relatively poor count sequence recitation ability, (d) average ability on all math tasks, and (e) poor ability on all math tasks. After controlling for age, only dot enumeration and spontaneous focusing on numerosity were associated with the math ability profiles, whereas vocabulary was also marginally significant, and these markers were differentially associated with different profiles; that is, different cognitive markers were associated with different patterns of strengths and weaknesses in math abilities. Findings are discussed in terms of their implications for the development of math cognition.

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Introduction

Research with school children suggests that math competence is not unitary but rather comprises different component skills (Cowan et al., 2011; Jordan, Mulhern, & Wylie, 2009). Although children are often labeled globally as good or poor at math, it appears that weaknesses in one math skill can occur somewhat independently of weaknesses in other skills (Dowker, 2005; Holmes & Dowker, 2013). Similar findings have been observed in preschoolers; for example, Dowker (2008) showed that some preschoolers lack basic procedural counting skills but understand how counting can be used to determine cardinality, whereas others are proficient counters but lack cardinal knowledge. Evidence that preschoolers may perform poorly on foundation skills (e.g., counting) and yet succeed on seemingly more complex tasks (e.g., arithmetic) suggests that there might not be a single developmental sequence for emerging math skills and that no skill is a necessary prerequisite for another skill (Dowker, 2008; Holmes & Dowker, 2013). It has been argued that different math skills develop simultaneously, although they influence and reinforce one another across development (Baroody & Ginsburg, 1986; Rittle-Johnson, Siegler, & Alibali, 2001; Sarnecka & Carey, 2008).

Currently, little is known about the significance of different patterns of emerging math skills in preschoolers. Different number-specific markers (e.g., magnitude comparison, dot enumeration) and general cognitive markers (e.g., working memory, inhibition) have been proposed to underlie early math ability. We currently do not know whether similar or different cognitive markers, or combinations of them, are associated with different patterns of strength and weakness in emerging math competence. Clarifying these issues could help to explain the significance of the often observed heterogeneity in early math abilities.

Significance of early math ability patterns

Several researchers have suggested that we need to better understand the significance of individual differences in patterns of early cognition generally and in early math in particular (Ansari, 2010; Aunola, Leskinen, Lerkkanen, & Nurmi, 2004; Dowker, 2005; Kaufmann et al., 2013). Research examining math development in both typical and atypical learners shows that children possess diverse ability profiles and learning growth trajectories (Aunola et al., 2004; Geary et al., 2009; Jordan et al., 2009; Salaschek, Zeuch, & Souvignier, 2014; Siegler, 1988). Moreover, different cognitive markers have been shown to be associated with different math ability profiles, suggesting that there may be no single cognitive marker, or set of markers, that underlies math development (Ansari, 2010; Aunola et al., 2004; Geary et al., 2009). Currently, however, research is limited to school-aged children. Characterizing distinct math ability profiles in preschoolers, and their associate cognitive correlates, is important for at least two reasons. First, identifying these patterns may help to decide whether particular patterns of emergent math abilities signal early math development difficulties. Indeed, differences in early math profiles may, of course, reflect different pathways to a common competence (Miller, 2002); however, they may also reveal early math difficulties that are precursors to later difficulties (Aunola et al., 2004). Second, by examining the cognitive correlates of different early math patterns, it would help to clarify whether similar or different cognitive markers underlie different patterns of emerging math abilities.

Number-specific markers

Some researchers propose that domain-specific cognitive processes support early math development. Specifically, the abilities to rapidly and precisely enumerate small sets and compare the magnitude of non-symbolic quantities are claimed to be core numerical competencies that support math abilities (Feigenson, Dehaene, & Spelke, 2004; Hyde, 2011; Reeve & Gray, 2015; Reeve, Reynolds, Humberstone, & Butterworth, 2012). Dot enumeration (DE) and magnitude comparison (MC) tasks assess these two competences. The ability to spontaneously focus on numerosity (SFON) in the environment is also claimed to be critical for early math ability (Hannula & Lehtinen, 2005).