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Relations between preschoolers' mathematical language understanding and specific numeracy skills

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ABSTRACT

Understanding of mathematical language is critical for numeracy skill development. However, prior research has focused exclusively on relations between mathematical language and numeracy skills, broadly measured. Thus, the aim of the current study was to explore more targeted relations between preschoolers' mathematical language and specific numeracy skills (e.g., cardinality, numeral comparison). The participants were 124 preschoolers aged 3.52 to 6.03 years (M = 4.78 years, SD = 0.53). Children were assessed on a battery of early numeracy skills and mathematical language as well as expressive vocabulary. Mixed-effects regression models were conducted, with school as a random effect and age, gender, and parental education as fixed effects covariates. Results indicated that mathematical language was significantly related to most numeracy skills, including verbal counting, one-to-one correspondence, numeral identification, cardinality, comparisons of sets and/or numerals, ordering numerals, and story problems. As hypothesized, mathematical language was not significantly related to either subitizing or formal addition because these skills are independent of general language ability. Importantly, mathematical language was generally more proximal to each of these numeracy skills than was general language. These results provide direction for future research, in particular for the development of more precise measures to identify children at risk for

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mathematics difficulties as well as the incorporation of focused mathematical language instruction within early mathematics interventions.

Introduction

Children's early mathematical skills are important for later academic achievement (Duncan et al., 2007; Jordan, Kaplan, Ramineni, & Locuniak, 2009; Watts, Duncan, Siegler, & Davis-Kean, 2014). It is evident from prior literature that understanding of mathematical language is critical for numeracy skill development (Purpura & Logan, 2015; Purpura & Reid, 2016; Toll & Van Luit, 2014a, 2014b). However, prior research has focused on relations between mathematical language and broad measures of numeracy skills even though measures of numeracy skills are composed of more targeted skills (e.g., comparing quantities, cardinality). To date, no study has examined the relations between understanding of mathematical language and specific numeracy skills (e.g., numeral identification, connecting numerals to quantities). Just as cognitive skills such as working memory capacity and response inhibition may be differentially related to various early mathematics skills (Lan, Legare, Ponitz, Li, & Morrison, 2011; Purpura, Schmitt, & Ganley, 2017), children's understanding of mathematical language may be differentially related to specific early numeracy skills. It is important to understand the skill-specific relations that exist in order to develop more precise measures to identify children at risk for mathematics difficulties as well as design interventions that take these relations into account in order to improve numeracy skills in young children. Thus, the aim of the current study was to assess targeted relations between mathematical language and specific numeracy skills above and beyond general language.

Defining early numeracy skills and mathematical language

Children's early numeracy skills are categorized in a few interconnected domains: numbering, relations, and arithmetic operations (National Research Council, 2009). Numbering skills include knowledge of the rules of the counting sequence and the ability to flexibly obtain quantity (Purpura & Lonigan, 2013). This includes skills such as subitizing (enumerating small sets of objects without counting), verbal counting (learning to recite the verbal number word sequence), structured counting (counting with one-to-one correspondence), and cardinality (understanding that the last word counted of the set indicates the total quantity) (Clements & Sarama, 2007; Gelman & Gallistel, 1978; Jordan, Kaplan, Oláh, & Locuniak, 2006). Relations skills involve knowing how two or more items (sets/numbers) are related and understanding the association between numbers on the mental number line. Many relations tasks require knowledge of Arabic numerals (e.g., numeral identification, connecting numerals to quantity, numeral comparison, ordering numerals), whereas others require distinguishing quantities of objects (e.g., set comparison; Clements & Sarama, 2007; Starkey, Klein, & Wakeley, 2004). Arithmetic operations skills include knowledge of composition and decomposition of numbers as well as an early understanding of addition and subtraction (Clements & Sarama, 2007; Fuson, 1988) through both story problems (Hiebert, Carpenter, & Moser, 1982; Levine, Jordan, & Huttenlocher, 1992) and formal addition problems with Arabic numerals (Jordan et al., 2006).

Distinct from these early numeracy skills is children's understanding of mathematical language. Mathematical language is children's understanding of key words in mathematics, including quantitative words such as "more" and "less" (Barner, Chow, & Yang, 2009) and spatial words such as "before" and "after" (Pruden, Levine, & Huttenlocher, 2011). Understanding of these specific mathematics terms is thought to facilitate understanding of more complex numerical concepts (Barner et al., 2009). Importantly, the understanding of these content-specific words such as "most" and "fewest" is separate from conceptual knowledge of exact quantities and numeracy skills (Lansdell, 1999). Thus,