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Brief Report

Competence with fractions predicts gains in mathematics achievement

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ABSTRACT

Competence with fractions predicts later mathematics achievement, but the codevelopmental pattern between fractions knowledge and mathematics achievement is not well understood. We assessed this codevelopment through examination of the cross-lagged relation between a measure of conceptual knowledge of fractions and mathematics achievement in sixth and seventh grades ($N = 212$). The cross-lagged effects indicated that performance on the sixth grade fractions concepts measure predicted 1-year gains in mathematics achievement ($ß = .14$, $p < .01$), controlling for the central executive component of working memory and intelligence, but sixth grade mathematics achievement did not predict gains on the fractions concepts measure ($ß = .03$, $p > .50$). In a follow-up assessment, we demonstrated that measures of fluency with computational fractions significantly predicted seventh grade mathematics achievement above and beyond the influence of fluency in computational whole number arithmetic, performance on number fluency and number line tasks, central executive span, and intelligence. Results provide empirical support for the hypothesis that competence with fractions underlies, in part, subsequent gains in mathematics achievement.

Introduction

The National Mathematics Advisory Panel (NMAP, 2008) concluded that conceptual understanding of fractions and fluency in using procedures to solve fractions problems are central goals of children's mathematical development (see Siegler, Thompson, & Schneider, 2011). The NMAP also determined

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that these competencies provide the critical foundation for algebra learning. Although this determination follows logically from the mathematical structure of algebra, there is not a strong empirical link between fractions competence and ease of learning algebra or other complex forms of mathematics. The best available evidence is provided by Siegler and colleagues' (2012) analyses of nationally representative data sets from the United States and United Kingdom, which demonstrated that competence with fractions in fifth or sixth grade predicted performance on algebra and mathematics achievement tests 5 or 6 years later, controlling for whole number arithmetic, intelligence, working memory, family background, and other factors. The results support the NMAP's focus on the importance of children gaining competence with fractions before taking high school algebra.

However, it cannot be definitively concluded that fractions competence at the end of elementary school contributed to subsequent gains in mathematics achievement without simultaneously controlling for general mathematics achievement at the end of elementary school and fractions competence in high school; these assessments were not available in the databases analyzed by Siegler and colleagues (2012). It is possible that this is the case, but an alternative (not mutually exclusive) hypothesis for the longitudinal association between fractions knowledge and mathematical achievement is that children with a firm grasp of basic mathematical concepts, as indicated by high initial mathematical achievement, will more easily understand and learn to solve fractions problems. Our first goal was to provide such a cross-lagged assessment of the relations between fractions knowledge and mathematics achievement across sixth and seventh grades. If fractions competence contributes to gains in mathematics achievement, then sixth grade fractions knowledge will predict seventh grade mathematics achievement, controlling for seventh grade fractions knowledge, sixth grade mathematics achievement, working memory, and intelligence (Geary, 2011).

Our second goal was to determine whether measures of conceptual knowledge of fractions and computational fractions skills concurrently predict mathematics achievement, controlling for other factors. As noted, Siegler and colleagues (2012) demonstrated that fractions competence at the end of elementary school predicted later mathematics achievement, controlling for whole number arithmetic, working memory, and intelligence. In another study, Siegler and colleagues (2011) reported significant correlations among a measure of fractions magnitude comparison, the ability to accurately place fractions on a number line, and mathematics achievement in sixth and eighth graders. After controlling for the conceptual fractions measures, the effect of fluency with fractions computations was not significant for either sixth or eighth graders, although both samples were small ($N = 24$) and the authors did not control for working memory or intelligence (see Hecht, 1998; Hecht, Close, & Santisi, 2003).

The current study provided a more comprehensive assessment of the importance of fractions competencies and concurrent mathematics achievement by first controlling for computational skills in whole number arithmetic, more basic number skills, working memory, and intelligence. Second, we examined the extent to which fractions competence also predicted word reading skills. Although Siegler and colleagues (2012) demonstrated that fractions competence predicts mathematical achievement significantly better than it predicts literacy measures, we attempted to replicate this finding and extend it by including a measure of knowledge of fractions concepts. A finding that fractions measures predict word reading would suggest that these measures are proxies for more general cognitive abilities (e.g., working memory) and, thus, weaken the argument that it is competence with fractions in particular that is critical to mathematics achievement.

Method

Participants

The participants were from a longitudinal study of mathematical development (see Geary, Hoard, Byrd-Craven, Nugent, & Numtee, 2007). For the original sample, 288 children completed the first year and 22 children were added to the study during the fifth year; they scored below the 30th percentile on the State of Missouri mathematics assessment and, thus, were considered as at risk for poor long-term mathematics outcomes. These current analyses are based on the 212 children (192 from