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Influences of problem format and SES on preschoolers' understanding of approximate addition

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ABSTRACT

Recent studies suggest that 5-year-olds can add and compare large numerical quantities through approximate representations of number. However, the nature of this understanding and its susceptibility to environmental influences remain unclear. We examined whether children's early competence depends on the canonical problem format (i.e., arithmetic operations presented on the left side). Sixty children from middle-to-high-SES backgrounds (Experiment 1) and 47 children from low-SES backgrounds (Experiment 2) viewed events that required them to add and compare large numbers. Events were shown in a canonical or noncanonical format. Children from both SES backgrounds performed above chance on the approximate addition tasks, but children from middle-to-high-SES backgrounds performed significantly better. Moreover, children from middle-to-high SES backgrounds performed better when problems were presented in the canonical format, whereas children from low-SES backgrounds did not. These results suggest that children's understanding of approximate number is affected by some of the same environmental factors that affect performance on exact arithmetic tasks.

1. Introduction

Children's mathematical competence is highly sensitive to environmental influences (Blevins-Knabe & Musun-Miller, 1996; Klibanoff, Levine, Vasilyeva, & Hedges, 2006; Levine, Jordan, & Huttenlocher, 1992; McNeil & Alibali, 2005a). Some environments facilitate understanding and

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Fig. 1. Example of how children's internationalization of the "operations on left side" format affects performance on exact addition problems. This problem was presented to a child (age 9 years, 0 months) with average math skills. It appeared on a worksheet titled "Write the number of apples on Jada's bag" with the following instructions under the title: "Jada wants to have the same number of apples as Joe. How many apples should she put in her empty bag?" These instructions were read aloud to the child.

performance, whereas others hinder it. For example, environments with high levels of mathematically-relevant speech and activities support children's early mathematics achievement better than do those with lower ones (Blevins-Knabe & Musun-Miller, 1996; Klibanoff et al., 2006; Saxe, Guberman, & Gearhart, 1987). These environmental influences operate not only with respect to variations in the global contexts in which children develop, such as those associated with socioeconomic status or childcare quality (Ginsburg & Russell, 1981; NICHD, 2003), but also with respect to variations in the local mathematics context itself, such as the specific format in which problems are presented or the way number is represented in the problems (McNeil & Alibali, 2004; Levine et al., 1992).

In the present study, we examine effects of both local and global context on young children's arithmetic reasoning. Our primary interest is the effect of a particular local arithmetic context – the format in which problems are presented. Research has shown that children's understanding and performance solving exact arithmetic problems depends heavily on the canonical problem format, in which arithmetic operations appear on the left side (e.g., 3 + 4 = 7, Baroody & Ginsburg, 1983; Behr, Erlwanger, & Nichols, 1980; Seo & Ginsburg, 2003). Children's behavior on a variety of mathematics tasks suggests that children have internalized this canonical "operations on left side" format (McNeil & Alibali, 2004, 2005b). For example, when children are asked to check the "correctness" of arithmetic problems written by a child who "attends another school," most mark sentences such as 10 = 6 + 4 as "incorrect" and change them to 6 + 4 = 10, 4 + 6 = 10, or even 10 + 6 = 4 (Cobb, 1987; Behr, Erlwanger, & Nichols, 1980; Baroody & Ginsburg, 1983; Rittle-Johnson & Alibali, 1999). Similarly, when children are asked to reconstruct a problem such as "3 + 5 = 6 + __" after viewing it briefly, many write "3 + 5 + 6 = __" (McNeil & Alibali, 2004). Children's misinterpretation of non-canonical problem formats such as "__ = 6 + 4" and "8 + 4 = __ + 5" appears as early as first grade (Falkner, Levi, & Carpenter, 1999), and possibly even earlier (Baroody & Ginsburg, 1983). Moreover, misinterpretation is not restricted to problems written in equation form; indeed, our pilot data suggests that poor performance on non-canonical exact symbolic arithmetic problems persists, even when the equal sign is not present (see Fig. 1).

In addition to variations in problem format, we also consider the effects of variations in a global context that contributes to individual differences in mathematics achievement – socioeconomic status (SES). On average, children from low-SES backgrounds have poorer mathematical competence than their peers from higher-SES backgrounds (Griffin, Case, & Siegler, 1994; Jordan, Kaplan, Olah, & Locuniak, 2006; Jordan, Huttenlocher, & Levine, 1992; Kirk, Hunt, & Volkmar, 1975; Saxe et al., 1987; Siegler & Ramani, 2008). These differences are present from the start of formal schooling and are especially pronounced when young children are asked to perform exact arithmetic calculations (Ginsburg & Russell, 1981; Griffin et al., 1994; Jordan et al., 2006). For example, Griffin et al. (1994) asked kindergarteners from high- and low-SES backgrounds to solve this problem: "If you had 4 chocolates and someone gave you 3 more, how many chocolates would you have all together?" Seventy-two percent of children from high-SES backgrounds solved the problem correctly, compared to 14% of children from low-SES backgrounds. Similarly, Jordan et al. (1992) asked kindergarteners from middle- and