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Mathematical Problem Solving and Working Memory in Children with Learning Disabilities: Both Executive and Phonological Processes Are Important

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The purpose of this investigation was to explore the relationship between working memory (WM) and mathematical problem solving in children with learning disabilities (LD). Children with LD (age 11.5 years) were compared to chronologically age-matched (CA-M) and younger comprehension/computation achievement-matched children (age 8.9 years) on measures of verbal and visual-spatial WM, phonological processing, components of problem solving, and word-problem solving accuracy. The results showed that (1) children with LD were inferior on measures of word solution accuracy, components of problem solving, phonological processing, domain-general WM, and verbal WM when compared to children who were CA-M, (2) children with LD were comparable to younger children on all processing measures, except measures of domain-general WM, visual-spatial WM, phonemic deletion, and identifying problem goals, (3) measures of verbal and visual-spatial WM contributed significant variance to solution accuracy independent of phonological processing, and (4) the influence of WM on solution accuracy was mediated by long-term memory (LTM) processes related to the knowledge of algorithms. The results support the notion that information activated from LTM, rather than phonological processing, mediates the relationship between executive processing and solution accuracy in children with LD.

Key Words: word problem solving; working memory; phonological processing; executive processing; long-term memory; learning disabilities.

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Mathematical solving of word problems is said to depend on working memory (WM; Anderson, Reder, & Lebiere, 1996; LeBlanc & Weber-Russell, 1996; Logie, Gilhooly, & Wynn, 1994; Swanson, Cooney, & Brock, 1993), which is a limited capacity system involved in the preservation of information while processing the same or other information (Baddeley & Logie, 1999; Cantor & Engle, 1993; Miyake, Just, & Carpenter, 1994). Baddeley (1986, 1996) provides a popular model of WM for understanding individual differences in problem solving. The model characterizes WM as comprising a central executive controlling system that interacts with a set of two subsidiary storage systems: the speech-based phonological loop and the visuo-spatial sketchpad. The phonological loop is responsible for the temporary storage of verbal information; items are held within a phonological store of limited duration, and the items are maintained within the store via the process of articulation. The visuo-spatial sketchpad is responsible for the storage of visual-spatial information over brief periods and plays a key role in the generation and manipulation of mental images. The central executive system is considered primarily responsible for coordinating the activities of the phonological and visual-spatial systems, but it also draws resources from long-term memory (LTM) when the capacities of these subsidiary systems are exceeded (Baddeley & Logie, 1999).

Children with learning disabilities (LD) experience considerable difficulty on both WM (e.g., De Jong, 1998; Siegel & Ryan, 1989; Swanson, Ashbaker, & Sachse-Lee, 1996) and mathematical word-problem solving tasks (e.g., Case, Harris, & Graham, 1992; Swanson, 1993). Deficits on these tasks can be linked to the phonological system. This is because mathematical word problems are a form of text and the decoding and comprehension of text draws upon the phonological system (see Gathercole & Baddeley, 1993, for a review).

Thus, this study assumes that understanding mathematical word problems involves a complex interaction of text comprehension and mathematical processes that are related to WM. We focus on the text comprehension aspects of mathematical word problems, however, because there has been progress in understanding the computational aspects of arithmetic problems of children with LD (Geary, 1993). Traditionally, solution difficulty for mathematical word problems has been explained in terms of logicomathematical competencies (e.g., deficient numerical structures; Riley, Greeno, & Heller, 1983). However, a growing body of empirical and theoretical work has shown that children's difficulties in mathematical word problems are strongly related to deficient language and comprehension strategies (e.g., Delclos & Harrington, 1991; Swanson et al., 1993). By focusing on comprehension, we do not diminish the crucial role of computational procedures. Rather, our motivation for studying the comprehension of word problems in children with LD emerges from growing evidence that such children have particular difficulty mentally constructing an adequate problem representation (for review, see Swanson, 1988, 1993).

Considerable evidence exists showing that children with LD have deficits in the use, operation of their phonological loop on both reading (see Hulme &