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Numerical and Arithmetical Cognition: A Longitudinal Study of Process and Concept Deficits in Children with Learning Disability

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Based on the stability and level of performance on standard achievement tests in first and second grade (mean age in first grade = 82 months), children with IQ scores in the low-average to high-average range were classified as learning disabled (LD) in mathematics (MD), reading (RD), or both (MD/RD). These children (n = 42), a group of children who showed variable achievement test performance across grades (n = 16), and a control group of academically normal peers (n = 35) were administered a series of experimental and psychometric tasks. The tasks assessed number comprehension and production skills, counting knowledge, arithmetic skills, working memory, the ease of activation of phonetic representations of words and numbers, and spatial abilities. The children with variable achievement test performance did not differ from the academically normal children in any cognitive domain, whereas the children in the LD groups showed specific patterns of cognitive deficit, above and beyond the influence of IQ. Discussion focuses on the similarities and differences across the groups of LD children.

Key Words: learning disabilities; mathematical disabilities; reading disabilities; number; counting; arithmetic.

Research on learning disabilities in mathematics (MD) has progressed more slowly than reading disabilities (RD) research. One impediment to research on MD is the complexity of the domain of mathematics and the resulting wide array of cognitive deficits that could contribute to this form of LD. One way to circumvent this impediment is to apply the theoretical models and experimental measures used to study mathematical development in academically normal children to the study of children with poor achievement in mathematics (Geary,

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1990; Jordan & Montani, 1997; Siegler, 1988). The current study followed this approach and included a longitudinal component. In a previous longitudinal study, children with low mathematics achievement scores across consecutive grades were found to differ on several cognitive measures from normal children and children with low mathematics achievement scores in one grade but average or better scores in the next (Geary, 1990; Geary, Brown, & Samaranayake, 1991). The latter group did not differ from normal children on measures of numerical working memory or arithmetical cognition. In comparison to these two groups, the children with MD (i.e., consistently low mathematics achievement scores) showed shorter digit spans and an array of deficits and delays in arithmetical competencies.

In the current study, children were classified respectively as MD, RD, or MD and RD (MD/RD) if they showed low achievement scores in mathematics, reading, or both in first grade and in second grade and had low-average or higher IQ scores. These groups were contrasted with groups of children who showed variable achievement levels from one grade to the next or showed average or better achievement levels in both grades. The groups were contrasted on experimental measures derived from models of children's normal development in the number, counting, and arithmetic domains. The groups were also contrasted on measures that assess the basic cognitive systems—such as numerical memory span—that appear to support these early mathematical competencies (Geary, 1994; Siegler, 1996). The use of this approach enabled the study of MD within a well-developed theoretical framework and, at the same time, reduced the frequency of early false positives, that is, children with low mathematics achievement but no real cognitive deficit (Geary, 1990). The first section below provides a brief summary of relevant models in the number, counting, and arithmetic literatures, while the second focuses on several supporting cognitive systems (see Geary, Hoard, & Hamson, 1999, for further discussion).

NUMERICAL AND ARITHMETICAL COGNITION

Number Production and Comprehension

The comprehension and production of numbers requires the ability to process verbal (e.g., "forty-two") and Arabic number representations (e.g., "42"), as well as an understanding of the meaning of the processed numbers (e.g., that the 4 in 42 represents 4 sets of 10). Number processing is also dependent on the ability to transcode, or translate, numbers from one representation to another (e.g., "forty-two" to "42"; Seron & Fayol, 1994). The few studies that have been conducted suggest—but are not definitive—that the cognitive systems that support number production and comprehension are intact in children with MD, at least for the processing of simple numbers (Badian, 1983; Gross-Tsur, Manor, & Shalev, 1996). The current study is the first longitudinal assessment of these competencies in children with MD/RD or MD, and should help to clarify if these children show number processing deficits.