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The mathematics skills of children with reading difficulties

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ABSTRACT

Although many children with reading difficulty (RD) are reported to struggle with mathematics, little research has empirically investigated whether this is the case for different types of RD. This study examined the mathematics skills of third graders with one of two types of RD: dyslexia ($n = 18$) or specific reading comprehension difficulty ($n = 22$), as contrasted to a comparison group ($n = 247$). Children's performance on arithmetic fact fluency, operations, and applied problems was assessed using standardized measures. The results indicated that children with dyslexia experienced particular difficulty with arithmetic fact fluency and operations: they were 5.60 times and 8.54 times more likely than other children to experience deficits in fact fluency and operations, respectively. Our findings related to arithmetic fact fluency were more consistent with domain-general explanations of the co-morbidity between RD and mathematics difficulty, whereas our findings related to operations were more consistent with domain-specific accounts.

1. Introduction

Research on learning disabilities (LD) has largely focused on reading difficulty (RD) despite documentation that RD is more likely to co-occur with mathematics difficulty (MD) than without (Dirks, Spyer, van Lieshout, & de Sonneville, 2008; Rubinsten, 2009). For example, Badian (1983) found that 56% of students with RD had poor mathematics achievement; other research has found that, as a group, children with RD had lower mathematics achievement than typical achievers (Fuchs, Fuchs, & Prentice, 2004; Miles, Haslum, & Wheeler, 2001). Yet there is a dearth of research that has systematically investigated mathematics ability as it relates to RD. Responding to calls for such research (Gelman & Butterworth, 2005; Rubinsten, 2009; Simmons & Singleton, 2008), the present study examined the performance on arithmetic fact fluency, operations, and problem solving for two types of RD: dyslexia and specific reading comprehension difficulty.

1.1. Types of reading difficulty

Research that has suggested a relationship between RD and MD has focused primarily on dyslexia, which refers to slow, laborious decoding due to underlying deficits in phonological processes (e.g., Swanson & Siegel, 2001; Torgesen, 2000). Phonological processing has also been shown to influence mathematics performance, particularly arithmetic fact fluency (see Simmons & Singleton, 2008). In contrast, those with specific reading comprehension difficulty have intact word reading ability (e.g., Cain & Oakhill, 1999; Cain, Oakhill, & Bryant, 2000) and thus phonological processing is not implicated. This reader's difficulties reflect deficits in higher-order cognitive processes, such as integrating information in text, making inferences, and using metacognitive strategies (Cain & Oakhill, 1999; Cain et al., 2000; Oakhill, 1993). Such skills may also influence mathematics achievement, particularly in word problem solving. Preliminary evidence suggests that children with RD broadly construed may not show uniformly weak achievement across different mathematics domains (e.g., Geary, Hamson, & Hoard, 2000; Hanich, Jordan, Kaplan, & Dick, 2001; Jordan, Hanich, & Kaplan, 2003; Miles et al., 2001; Simmons & Singleton, 2009). Thus, a next step is to examine achievement across different mathematics domains using samples that differentiate dyslexia from specific reading comprehension difficulty.

1.2. The multi-faceted nature of mathematics ability

Like the construct of reading, mathematics is multi-faceted in nature. In elementary school, the target areas for mathematics instruction are arithmetic fact fluency, operations, and word problem solving (e.g., Fuchs et al., 2006; Gersten et al., 2009).

Arithmetic fact fluency refers to the automatic retrieval of simple single-digit addition and subtraction facts and in later elementary years, multiplication facts. There is evidence that children with dyslexia experience difficulty in this area (see Simmons & Singleton, 2008, 2009). Domain-general explanations posit that deficient phonological processing accounts for this relationship (e.g., Simmons & Singleton, 2008, 2009). In contrast, the domain-specific account

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posits that numerical processing underlies the mathematics deficits children with dyslexia experience (Gelman & Butterworth, 2005; Landerl, Bevan, & Butterworth, 2004; Landerl, Fussenegger, Moll, & Willburger, 2009). Little is known about the arithmetic fact fluency skills of children with specific reading comprehension difficulty. Given that these readers do not have phonological processing deficits, in this study, we expected arithmetic fact fluency to be related only to dyslexia.

Operations refers primarily to the ability to perform calculations using algorithms and arithmetic. Some research shows that children with RD perform operations more poorly than typically achieving children (e.g., Jordan et al., 2003) while other research has not found differences between children with RD and typically achieving children (Hanich et al., 2001; Jordan & Hanich, 2000). These studies did not, however, differentiate dyslexia from specific reading comprehension difficulty, making it difficult to discern how children with specific types of RD perform on operations. Neuropsychological evidence suggests that operations and arithmetic fact fluency are processed in different brain regions and that unlike arithmetic fact fluency, operations do not make heavy demands on the language system (e.g., Dehaene, Piazza, Pinel, & Cohen, 2003). Given the primarily language-based nature of both dyslexia and specific reading comprehension difficulty, we expected minimal impairment on operations. However, because arithmetic fact fluency is foundational for operations (e.g., Fuchs et al., 2006), we expected the dyslexia group would show some impairment on operations.

Word problem solving refers to linguistically presented problems involving mathematical relations and properties. Evidence suggests that children with RD perform similarly to typical achievers on word problems (e.g., Hanich et al., 2001; Jordan et al., 2003). These results are somewhat surprising given the language-based nature of RD. To account for these findings, researchers have speculated that children with RD use their relative strengths in mathematics to compensate for their low reading abilities. However, the children with RD in these studies were selected to demonstrate at least average mathematical ability. More research is needed with RD samples that are not selected on the basis of their mathematics ability. Given that arithmetic fact fluency is foundational for word problems (e.g., Fuchs et al., 2006), we expected that children with dyslexia would perform lower than children with specific reading comprehension difficulty and that both groups would perform lower than a comparison group.

1.3. Present study

Previous research has not systematically investigated the mathematics profiles of children with different types of RD. This lack of knowledge limits a comprehensive understanding of the etiology and typology of dyslexia and specific reading comprehension difficulty, which has implications for both research and practice. We sought to advance the research base by examining the mathematics skills of third graders with dyslexia or specific reading comprehension difficulty, contrasted to a comparison sample. We chose third grade to ensure variation in reading and mathematics achievement (Fuchs et al., 2006). This study was guided by a single research question: What are the differences among third graders with dyslexia, specific reading comprehension difficulty, and comparison children on measures of operations, arithmetic fact fluency, and word problem solving?

2. Method

2.1. Participants

The participants were 287 third graders (mean age = 8.60 years, sd = .31, range = 8.00- to 9.75-years) attending five elementary schools in western Canada. The schools were located primarily in working class neighbourhoods characterized by high mobility rates (43%–67%). Demographic characteristics of the sample are presented in Table 1; there were no differences by demographic group on the study measures.

Table 1
Student demographic characteristics by reader group.

Variable	Comparison (n = 247)		Specific reading comprehension difficulty (n = 22)		Dyslexia (n = 18)	
	n	%	*n*	%	*n*	%
Sex						
Female	117	47.4	8	36.4	9	50
Family background						
Majority culture	134	54.3	9	40.9	9	50.0
First nations	32	13.0	3	13.6	6	33.3
Middle Eastern	36	14.6	2	9.1	2	11.1
Asian	21	8.5	1	4.5	0	0
Other	24	9.7	7	31.8	1	5.6

Note. There were no differences in gender distribution by reader group, X^2 (2, N = 287) = 1.07, p > .05. The distribution of family background by reader group were not subjected to chi-square analyses because 6 cells (40%) had frequencies less than 5 and in one instance had a frequency of 0.

2.1.1. Classification scheme

Children were classified into one of three groups: dyslexia, specific reading comprehension difficulty, or comparison. Consistent with the RD literature, dyslexia was defined as performance below the 15th percentile on the *Woodcock Johnson-III* (*WJ-III*) Letter-Word Identification (LWID) test; and specific reading comprehension difficulty was defined as performance below the 15th percentile on the *Stanford Diagnostic Reading Test* (*SDRT*) Reading Comprehension subtest *and* performance above the 50th percentile on LWID. The dyslexia group included 18 children (6.3%), 22 children (7.7%) were classified with specific reading comprehension difficulty, and the remaining 247 children (86.1%) were placed into the comparison group.

One-way analyses of variance (ANOVA) confirmed three distinct reader groups: word reading, $F(2, 284) = 59.13$, $p < .001$; and reading comprehension, $F(2, 284) = 56.14$, $p < .001$. The comparison and the specific comprehension difficulty group had significantly higher word reading scores than the dyslexia group; both RD groups had significantly lower reading comprehension scores than comparison children.

2.2. Materials

Raw scores for tests were converted to standard scores based on normative data. Standard scores were utilised in the tables and analyses.[1]

2.2.1. Word reading

The LWID test of the *WJ-III: Research Edition* (Woodcock, McGrew, & Mather, 1999) was used; in this task children identify and pronounce isolated letters and words of increasing difficulty (e.g., cat, palm). The publisher reports reliability between .96 and .97.

2.2.2. Reading comprehension

The Reading Comprehension test of the *SDRT* (Karlsen & Gardner, 1994) was used; children have 45 min to read short passages and provide responses to multiple-choice questions. The publisher reports .91 reliability for third graders.

[1] Standard scores for reading comprehension represent approximately equal-interval units that are particularly suitable for analyses (Karlsen & Gardner, 1994); however, these scores are not norm-referenced, which makes interpretation difficult. For ease of interpretation, we provide the percentile conversion of these scores where appropriate.