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The association between mathematical word problems and reading comprehension

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This study aimed to investigate the interplay between mathematical word problem skills and reading comprehension. The participants were 225 children aged 9–10 (Grade 4). The children's text comprehension and mathematical word problem-solving performance was tested. Technical reading skills were investigated in order to categorise participants as good or poor readers. The results showed that performance on maths word problems was strongly related to performance in reading comprehension. Fluent technical reading abilities increased the aforementioned skills. However, even after controlling for the level of technical reading involved, performance in maths word problems was still related to reading comprehension, suggesting that both of these skills require overall reasoning abilities. There were no gender differences in maths word problem-solving performance, but the girls were better in technical reading and in reading comprehension. Parental levels of education positively predicted children's maths word problem-solving performance and reading comprehension skills.

Keywords: math word problems; reading comprehension; good and poor readers; fourth graders

Overall performance in mathematics (Dowker, 1995; Geary, 2004; Gelman & Gallistel, 1978; Ginsburg, 1997) and reading (Ehri, 2000; Fitzgerald & Shanahan, 2000; Gough & Tunmer, 1986; Oakhill, 1993) has received much attention in previous research. Current interest in children's maths skills has also led to an increase in research into the association between mathematical performance and reading skills (Ackerman & Dykman, 1995; Chinn & Ashcroft, 1993; Light & DeFries, 1995; Räsänen & Ahonen, 1995) and between maths performance and text comprehension skills (Pape, 2004; Passolunghi & Pazzaglia, 2005). However, little is known about how linguistic processing and mathematical-logical reasoning are interrelated, and the role that technical reading plays in this relationship. The present study examined the association between performance on mathematical word problems and reading comprehension skills, and investigated whether children with and without technical reading difficulties differ in their performance in maths word problems and reading comprehension.

Mathematics performance and reading skills have been shown to be closely related. For example, Light and DeFries (1995) showed that difficulties in arithmetic were associated with reading ability development. Moreover, studies focusing on children with learning disabilities have shown that difficulties in reading and in maths often co-occur (e.g., Geary, 1996; Geary, Hamson, & Hoard, 2000; Jordan, Hanich, & Kaplan, 2003; Jordan, Kaplan, & Hanich, 2002; Jordan & Montani, 1997). For example, Jordan et al. (2002) found in a two-year longitudinal

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study that reading disabilities predicted children's progress in mathematics, but mathematics disabilities did not affect children's progress in reading. They also found that when demographic factors were held constant, the group with only mathematics difficulties progressed at a faster rate in mathematics than the group with reading difficulties. The groups progressed equally quickly in reading. Genetic studies have shown that the correlation between maths and reading abilities ranges from .47 to .76, and that the correlation between disabilities in math and reading is .53 (for a review, see Plomin & Kovas, 2005). The present study adds to previous research by examining the association between mathematical word problem-solving performance and reading comprehension skills.

Previous research has shown that maths word problem-solving performance and reading comprehension skills are both related to overall reasoning skills. The reasoning strategies behind these skills have frequently been discussed in the light of methods used for classifying maths word problem structures (Fuchs & Fuchs, 2002; Fuchs, Fuchs, & Prentice, 2004; Jordan & Hanich, 2000) and reading comprehension question types (Bowyer-Crane & Snowling, 2005; Graesser & Bertus, 1998; Lindeman, 2000; Magliano, Trabasso, & Graesser, 1999), respectively.

Maths abilities can be assessed by various methods, including, for example, arithmetic with oral or written instructions. One measure of maths ability in an educational context has traditionally been maths word problems (DeCorte & Verschaffel, 1987; Riley & Greeno, 1988). Children are usually asked to read (or listen to) the maths story or the problem presented, write down the mathematical operations necessary for completing the task, and then solve the problem and come up with an answer. One way to categorise maths word problems has been suggested by Jordan and Hanich (2000). They have categorised word problems into four item types, each type defined by the problem-solving strategy required: compare, change, combine, and equalise. This categorisation will be used in this study also, with some adjustments.

The skills needed for processing written information (e.g., literacy skills) have been considered a combination of decoding skills and reading comprehension (Ehri, 2000). Reading that usually also aims at understanding (e.g., reading comprehension) has been shown to operate on two main levels (Perfetti, 1985). First, the reader extracts the meaning of the sentences, and second, the reader applies prior general and specific knowledge on the subject at hand. In addition, the reasoning strategies used by readers at different age levels have been of interest to researchers (Bowyer-Crane & Snowling, 2005; Cain & Oakhill, 1999; Graesser & Bertus, 1998; Magliano et al., 1999). Lindeman (2000) has identified five different reading comprehension question types in a Finnish reading test (the ALLU Reading Test for Primary School). In the ALLU test, there are five categories of question type: cause–effect/structure, concept/phrase, conclusion/interpretation, main idea/purpose, and detail/fact. This categorisation will be used in this study, with some adjustments.

There are good reasons to assume that the logical reasoning patterns behind different reading comprehension question types are somewhat universal (see Gelman & Greeno, 1989). It has been suggested, however, that there are some differences in terms of reasoning strategies and overall problem-solving abilities between children with and without learning disabilities (Geary, 2003; Geary & Brown, 1991). Moreover, Cain and Oakhill (2006) found that children assigned to a poor text comprehenders' or a good text comprehenders' group differed in maths and literacy skills.

It has been further suggested that both maths word problem-solving performance and reading comprehension skills are associated with technical reading skills (Fletcher, 2005; Gough & Tunmer, 1986; Leppänen, 2006; Light & DeFries, 1995). For example, technical reading skills (i.e., flexible word recognition and decoding skills and the ability to adjust reading method and reading speed to the text at hand) have been shown to be connected to reading comprehension skills (Gough & Tunmer, 1986; Holopainen, 2002; Leppänen, 2006). In addition, mathematical abilities have been found to be related to technical reading skills. For example, Leppänen, Niemi, Aunola, and Nurmi (2006) found that kindergarten-aged children's counting ability predicted their text reading skills, word chain reading skills, and reading comprehension as fourth graders. Light and DeFries's (1995) results showed covariation between difficulties in arithmetic and phonologically-based problems in reading. In the present study we examined whether children with and without difficulties in technical reading would differ in terms of their performance in reading comprehension and on mathematical word problems.

Children's reading and spelling skills have been found to be associated with parental educational level (Lewis, 2000) and family socioeconomic status (Fergusson & Lynskey, 1997). SES has also been shown to be an important demographic factor behind mathematical thinking skills (Jordan, Kaplan, Olàh, & Locuniak, 2006). Some gender differences in reading comprehension skills have been reported, often in favour of girls (Wagemaker,1996). Results concerning gender differences in maths performance are mixed: some studies suggest that boys are better at mastering problem-solving tasks (Geary, 1996; Smedler & Torestad, 1996), but other studies have been unable to replicate this finding (Aunola, Leskinen, Lerkkanen, & Nurmi, 2004). It has to be taken into account, however, that there are component-level differences in maths performance between the genders (Jordan et al., 2003; Leahey & Guo, 2001). Relying on these previous findings, the present study investigated parental level of education and student gender as antecedents of mathematical word problem performance and text comprehension skills.

In the present study, the association between mathematical word problem-solving and text comprehension skills will be examined first, together with the role that technical reading skills play in this relationship. Our next focus is on whether children with and without technical reading difficulties differ in terms of their performance on mathematical word problems and in reading comprehension. Finally, the extent to which gender and parental level of education contribute to the fourth graders' text comprehension skills and mathematical word problem-solving performance will be examined.

Method

Participants and procedure

The participants in the present study came from the Jyväskylä Entrance into Primary School study cohort (JEPS; Nurmi & Aunola, 1999). The JEPS study investigated the development of cognitive, social, and motivational factors among kindergarten to school-aged children. The initial sample consisted of all those children born in 1993 ($n = 210$) in close proximity to a medium-size city in central Finland.

The original sample has grown over the years and therefore a total of 225 (107 girls, 118 boys) fourth graders (age $M = 75$ months, $SD = 3.3$ at the baseline in 1999) from one school district with demographically similar schools (19 classes altogether) participated in this study. One of the schools was situated in the city centre. Of the 205 children for whom data are available, 24.4% received some special educational services (e.g., part-time special education or an individualised learning plan in one or more school subjects). The classes were heterogeneous with respect to achievement level and therefore the results of this study may be generalised to the whole age group. The ethnic background of the participants was homogeneous, as usually is the case in Finnish schools outside the capital city region.

The families were sent a questionnaire in December 1999 which was returned by mail directly to the researchers. The overall response rate was 92.3%, but there are some missing data (e.g., parental educational level data are available for 182 mothers and 159 fathers only). Educational level was classified as follows: 1 = no vocational education, 2 = vocational school, 3 = higher education, 4 = university degree.

The children were assessed in group situations by fully trained experimenters. The testing took place at the end of their fourth grade in April, 2004. In their reading comprehension tests, the children were given two sets of texts (both expository or both narrative information) at a time. A time limit of 2 × 45–60 minutes was given, which included time for the instructions and the exercise items. The mathematical word problem test was carried out with other maths tasks during a normal lesson (duration 45 minutes). As we were interested in whether reading comprehension and performance in maths word problems were influenced by technical reading skills, the items were not read aloud by the data collectors in either of the tests (see Jordan & Hanich, 2000, for comparison).

Measurements

Text comprehension

Lindeman's (2000) ALLU primary school reading test (*ALLU-Ala-Asteen Lukutesti*) is a norm-referenced, group-administered device for diagnosing reading difficulties. It includes both technical reading and text comprehension subtests for grades 1–6. The test consists of two subtests based on narrative context and two subtests based on expository context (see also Sáenz & Fuchs, 2002). Each of the four different texts is followed by 12 multiple choice questions, and each question includes four answer options. One point is given for each correct answer, resulting in a maximum score of 48 for reading comprehension.

The questions in the test were categorised according to Lindeman's (2000) classification: cause–effect/structure (CS; e.g., 'You place flowers on the southern window that A) need sunlight, but do not like burning sun, B) like best being in shadow, C) like excessive sunlight, D) like to alter between being in shadow and in burning sun'); concept/phrase (CP; e.g. 'The phrase "specific plant light" included in the text means A) a light designed especially for plants, B) a very expensive light, C) a certain coloured and sized lamp, D) a light designed solely for outdoor use'); conclusion/interpretation (CI; e.g. 'It is most hard to ensure a suitable amount of plant light during A) early summer, B) when the winter is turning into spring, C) fall, D) middle of winter'); and finally, main idea/purpose (MP; e.g. 'The style of the text is A) informational, B) based on attitudes, C) primitive, D) emotional').

The item structures were similar in each of the four subtests, which varied only as regards the number of items within each question type category. Notably, in the four texts there were three items that were defined as belonging to the detail/fact category by Lindeman (2000), but they were excluded from further examination. After excluding these items, the maximum score on the test was 45. There were 10 items in the CS category, 13 items in the CP category, 13 items in the CI category, and 9 items in the MP category. Cronbach's alpha reliability for the whole test was .86, and reliabilities were .64, .69, .73, and .44 for the separate question type categories, respectively.

Mathematical word problems

Skills in solving mathematical word problems were assessed using a subtest from the NMART Counting Skills Test (*NMART-Laskutaidon Testi*; Koponen & Räsänen, 2003). The subtest consisted of 20 word problems. One point was given for each correct answer, resulting in maximum score of 20.

The original NMART test has no explicit item type categorisation. However, the items in this test are similar to those used by Jordan and Hanich (2000). Consequently, we expected to find a similar factor structure in NMART to that reported by Jordan and Hanich (2000). To examine the structure of the item types, and the extent to which it resembles the item type structure described by Jordan and Hanich (2000), we conducted exploratory factor analysis with oblimin rotation for all 20 items in the NMART word problems test. The factors were allowed to correlate. Item 1 was omitted after a preliminary factor analysis, based on its low factor loading (.22). This low loading was due to a full ceiling effect in this item; almost everyone knew the correct answer.

The final results revealed that there were four factors (with item loadings at least .30) within the NMART word problems test items: compare (items 9, 10, 12, 13, 14, 15, 16, 18, and 20; e.g., 'One book costs 6 euros and one comic book costs 4 euros. Pekka bought 3 books and 5 comic books. How much did he get back from a 50 euro bill?'); change (items 2, 3, and 8; e.g., 'Suvi has 9 liquorice candies and she eats 5 of them. How many liquorice candies does Suvi have now?'); combine (items 4, 5, 6, and 7; e.g., 'There are 7 girls in the class. What is the number of the boys, when there are 16 pupils in the class altogether?'); and focus (items 11, 17, and 19; e.g., 'An empty box weighs 2kg. When the box is half full of apples, the box with the apples weighs 9kg. How much will the apples in the full box weigh?').

The factor structure was very similar to that previously suggested by Jordan and Hanich (2000; see also Jordan et al., 2003), with three differences. First, one category defined by Jordan and Hanich (2000) was not identified among the items: equalise (e.g., 'Claire has 4 pennies. Ben has 9 pennies. How many pennies does Claire need to have as many as Ben?'). Instead, in this study, the equalise category was replaced by the focus category. This category included items that required multi-step processing of a linguistic nature, with a basic one-step calculation process. Third, there were tasks requiring more than a one-step calculation process: for example, item 16 required a three-step calculation ('Jussi has an old cupboard, which can contain 15 books in its shelves. Jussi intends to buy a new cupboard, which, in turn, can contain 10 books per shelve. How many shelves does Jussi have to reserve for the books?').

Cronbach's alpha reliability for the whole scale was .80. The reliability coefficients for the different factors were: compare .79, change .73, combine .72, and focus .82.

Screening

Because we were interested in whether children with different levels of technical reading would differ in terms of strategies in both the reading comprehension test and the mathematics story problems, participants were assigned to either a poor readers (PR) group or a good readers (GR) group, according to their level of technical reading skills.

Technical reading level was assessed using the word recognition subtest of the ALLU reading test (Lindeman, 2000). The word recognition subtest measures participants' speed and accuracy in separating words written in sets by marking lines between each word (e.g., 'kilpakohtiparialla' should become 'kilpa/kohti/pari/alla'; or 'racetowardspairunder' should become 'race/towards/pair/under'). The technical reading subtest designed for fourth-graders consists of six items for practice and 78 test item. Each test item contains one word chain of two to four words. The time limit for the test is three minutes 30 seconds. One point is given for each correctly separated, meaningful word; thus the maximum score for the test is 214.

Poor/good readers were identified using the test's criteria: readers with decoding levels of 1–3 (i.e., −1—2 *SD*) are poor readers, and readers at level 4–8 are good readers. If a child receives 0–48 points (out of 214) he/she is on level 1, 49–67 points is level 2, and 68–87 points is level 3. In contrast, 88 points or more (levels 4–8) indicates an average or high age-level decoding performance and a good reader.

Lindeman (2000) has reported that approximately 23% of the norm group children were categorised as having problems with technical reading. In this sample, 67 fourth-grade children (29.8%) were categorised as having recognisable problems with technical reading (levels 1–3, the PR group), according to the same criteria. Level 1 readers comprised 5.8% of the sample here (4% in the norm group; Lindeman, 2000); level 1 indicates substantial problems with technical reading skills. On the other hand, 158 children were categorised as good readers (levels 4–8, the GR group).

Table 1. Descriptive information.

	Reading group	
	GR	PR
	n	*n*
Total	158	67
Male	72	46
Female	86	21
Special education*	21	34
IEP	2	9

Note: GR = good readers; PR = poor readers; * = part-time special educational services in conduct problems, language, or other; IEP = individualised education program in one school subject.

A relatively high 24.4% of our participants received special educational services (e.g., part-time special education). This figure is typical of the Finnish special education system, and is possibly one reason for generally good reading skills among Finnish students. Part-time special educational services are available to children with even minor problems in reading, especially during their first school years. Part-time special education services vary between schools, but are usually periodical (a few weeks or months depending on the student's needs).

Descriptive information concerning gender and special educational status is shown in Table 1. Different aspects of performance, with effect sizes and ANOVA results, are shown in Table 2. The means and standard deviations of the main variables, such as the mathematical word problem item type scores, reading comprehension question type scores, technical reading, and mothers' education level, are shown in Table 3.

Analysis strategy

First, the measurement models for maths word problems and for reading comprehension were tested separately. Second, these models were combined to investigate how they are related to each other. Third, path analyses were carried out to investigate the extent to which technical reading level explains maths word problem-solving performance and reading comprehension

Table 2. Performance by reading group.

	GR			PR				
	n	*M*	*SD*	*n*	*M*	*SD*	*F*	*ES*
Maths word problems								
Total	158	11.97	3.15	67	9.25	2.69	37.95***	.15
Male	72	11.99	3.18	46	9.43	2.73	20.14***	.15
Female	86	11.95	3.15	21	8.86	2.61	17.33***	.14
Reading comprehension								
Total	150	3.29	0.49	65	2.68	0.68	55.48***	.21
Male	68	3.16	0.49	45	2.61	0.70	24.61***	.18
Female	82	3.40	0.47	20	2.83	0.64	20.27***	.17

Note: GR = good readers; PR = poor readers; ***$p < .001$; **$p < .01$; *$p < .05$; ES = effect size (partial η^2).

Table 3. Pearson's product-moment correlation matrix between the main variables and their means (*M*) and standard deviations (*SD*).

Variable	1	2	3	4	5	6	7	8	9	10	11
1. Gender[a]	–										
2. Mother's education	–0.02	–									
3. Technical reading (continuous)	0.27***	0.24***	–								
4. Compare	–0.11	0.22**	0.45***	–							
5. Change	0.07	0.34***	0.51***	0.83***	–						
6. Combine	–0.03	0.35***	0.51***	0.64***	0.83***	–					
7. Focus	0.01	0.22**	0.14*	0.15*	0.56***	0.26***	–				
8. Cause–effect/structure	–0.21**	0.28***	0.49***	0.44***	0.54***	0.46***	0.32***	–			
9. Concept/phrase	–0.28***	0.33***	0.50***	0.46***	0.53***	0.40***	0.31***	0.64***	–		
10. Conclusion/interpretation	–0.24***	0.37***	0.41***	0.44***	0.55***	0.45***	0.40***	0.71***	0.70***	–	
11. Main idea/purpose	–0.24***	0.22**	0.38***	0.34***	0.43***	0.40***	0.29***	0.49***	0.52***	0.54***	–
M	1.52	2.69	108.09	0.00	0.11	0.00	0.03	0.04	0.03	0.04	0.03
SD	0.50	0.90	39.05	0.96	0.14	0.89	0.67	0.19	0.18	0.20	0.17

Note: $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$; [a]1 = girl, 2 = boy; variables 4–7 = maths word problem types; variables 8–11 = reading comprehension question types.

skills. Fourth, gender and maternal education were added to the model to examine whether they explain maths word problem-solving performance and reading comprehension skills directly or indirectly via technical reading level. Fifth, a similar model using paternal education was tested.

The analyses were carried out using the Mplus statistical package (version 4.2; Muthén & Muthén, 1998–2007). Using the missing data method, we were able to use all the observations in the dataset to estimate the parameters of the models. The missing data method uses all available data to estimate the model using full information maximum likelihood. Each parameter is estimated directly without first filling in missing data values for each individual (Muthén & Muthén, 1998–2007). The parameters of the models were estimated using the maximum likelihood robust estimation (MLR) procedure, which is the default estimator for non-normal distributions (Muthèn & Muthèn, 1998–2007). Goodness-of-fit was evaluated using four indicators: χ^2/df, Bentler's (1990) comparative fit index (CFI), the Tucker-Lewis Index (TLI), and Steiger and Lind's (1980) root mean square of approximation (RMSEA; see Steiger, 1990).

Results

Differences between the reader groups

First, we investigated the basic differences and the impacts of differences (ES) between the reading groups in mathematical word problem-solving performance and reading comprehension. ANOVA results (see Table 2) showed statistically significant differences ($p < .001$) on both maths word problems and reading comprehension measures between reading groups and between gender groups. Children in the GR group performed better than children in the PR group on both maths word problems and reading comprehension. Moreover, both girls and boys in the GR group performed better on both these skills than the girls and boys in the PR group.

ANOVAs testing the difference between the girls and boys in maths word problems and reading comprehension by reading group found no statistically significant difference between genders in the GR group for mathematical word problem-solving performance ($F[1,156] = .004$, $p = .95$). However, a statistically significant difference was found in reading comprehension ($F[1,148] = 9.38$, $p < .01$). This result showed that the girls in the GR group were better at reading comprehension than the boys. There were no statistically significant gender differences in the poor readers' group for either maths word problems ($F[1,65] = 0.66$, $p = 0.42$) or for reading comprehension ($F[1,63] = 1.46$, $p = 0.23$).

Associations between mathematical word problem-solving and text comprehension skills

The first research question asked whether text comprehension skills and performance on mathematical word problems are interrelated. To answer this question, Pearson correlations were calculated between reading comprehension variables and maths word problem variables. The correlation matrix is shown in Table 3. Inspection of the correlations reveals an interrelation between all of the maths word problem item types and reading comprehension question types. Moreover, all variables also interrelate with technical reading. Of the maths word problem item types, focus showed the least relation to technical reading and to another maths word problem item type (compare).

Confirmatory factor analyses for maths word problems and reading comprehension

First, the measurement models for maths word problem items and reading comprehension items were tested separately. The schematic model is shown in Figure 1. The results are shown in Table 4.

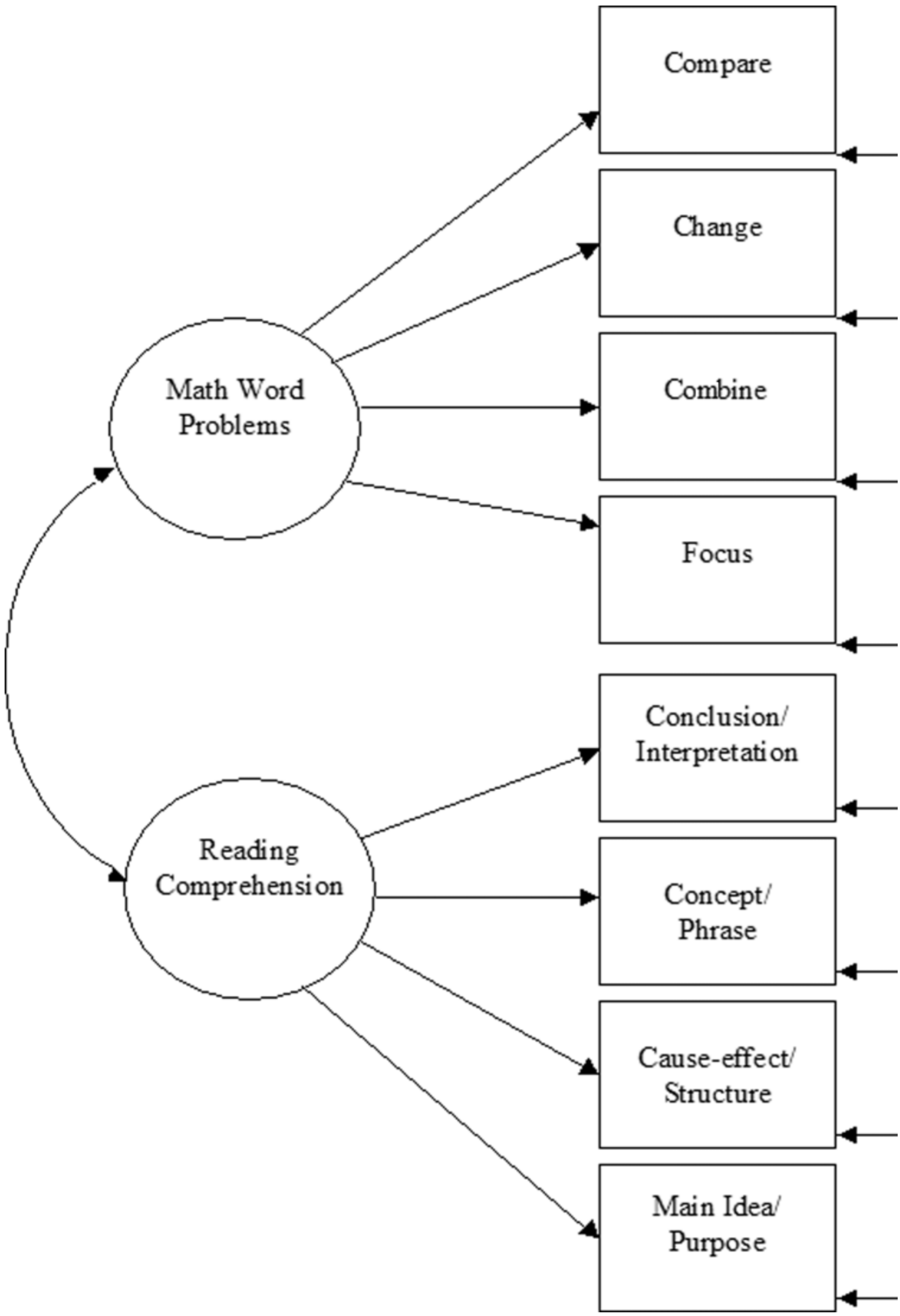

Figure 1. Schematic representation of the confirmatory factor analysis model.

Table 4. Parameter estimates for the manifest variables.

	Maths word problem-solving				Reading comprehension		
Variable	β	R^2	Error term	Variable	β	R^2	Error term
Compare	.64	.64	.60	CS	.82	.68	.32
Combine	1.00	1.00	.00*	CP	.78	.61	.39
Focus	.26	.07	.93	CI	.87	.75	.25
				MP	.63	.39	.61

Note: * = fixed.

In the measurement model for mathematical word problems, one of the observed variables, change, showed a strong ceiling effect. This variable was excluded from the final analyses. The excluded change variable included basic one-step calculation tasks which almost all the children were able to solve correctly. Consequently, the final factor model for maths word problems included three observed variables: compare, combine, and focus. As initial results showed that the residual term for combine was negative, this residual was further fixed to zero. After this specification, the model fitted the data well ($\chi^2[1] = .16$, $p = .69$; *CFI* = 1.00; *TLI* = 1.02; *RMSEA* = 0.00). The results showed that the latent factor '(performance in) maths word problems' explained best the variance of compare and combine and least the variance of focus, suggesting that focus had the most unique variance not shared with other item types.

The tested model for reading comprehension included four observed variables: cause–effect/structure (CS), concept/phrase (CP), conclusion/interpretation (CI), and main idea/purpose (MP). The model fitted the data well ($\chi^2[2] = .20$, $p = .91$; *CFI* = 1.00, *TLI* = 1.02; *RMSEA* = .00). The results showed that the latent factor 'reading comprehension' explained the variance of all the reading comprehension question types well.

Next, the association between mathematical word problem item types and the latent factor maths word problem-solving and reading comprehension item types and the latent factor reading comprehension was investigated by combining the previous models. In this model, the covariance between latent factors was estimated.

Results showed that the model did not fit the data well ($\chi^2[14] = 53.50$, $p = 0.00$; *CFI* = 0.93; *TLI* = 0.90; *RMSEA* = 0.11). Inspection of the modification indices suggested that the model's fit would be increased by setting the residual variance of the item type combine free and estimating the path from latent reading comprehension to the maths word problem type focus. After these specifications, the fit of the model was good ($\chi^2[13] = 31.01$, $p = .003$; CFI = .97; TLI = .95; RMSEA = .08). However, the results showed that maths word problem no longer explained the variance in focus. Consequently, the final model, including only statistically significant factor loadings, was constructed by excluding the path from maths word problems to focus ($\chi^2[13] = 13.64$, $p = .40$; CFI = 1.00; TLI = 1.00; RMSEA = .02). This final model is shown in Figure 2.

The results showed, first, that the structure of the maths word problems factor was not as clear as the structure of the reading comprehension factor proved to be. Only two of the four original item types were explained by the latent variable maths word problem-solving. Furthermore, one of the item types (focus) in the maths word problems test was found to represent better the reading comprehension factor than maths performance, although it was explained less ($R^2 = .18$) than the other item types measuring reading comprehension. Second, the results showed that the covariance between performance on maths word problems and reading comprehension was strong (standardised estimate = .67): the better the children's reading comprehension skills, the better their performance on maths word problems.

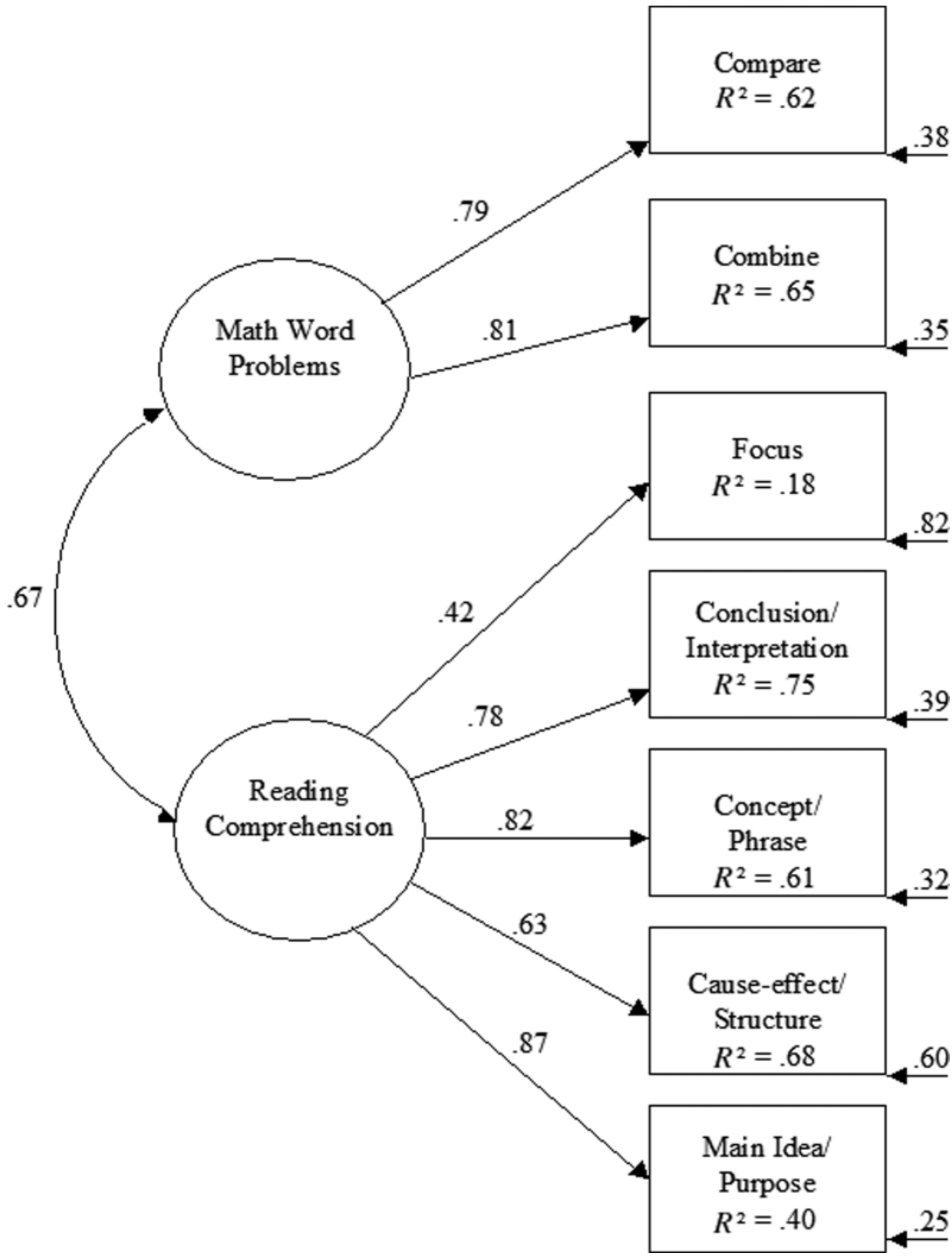

Figure 2. Results of the confirmatory factor analysis representing the latent structure of maths word problem types and reading comprehension question types.

Technical reading level, maths word problem-solving, and reading comprehension

The second research aim was to examine the extent to which good and poor readers differ in terms of their mathematical word problem-solving performance and text comprehension skills. This was tested by adding a dichotomous technical reading skills level variable into the previous model (Figure 2) and estimating the path from technical reading skills to both latent factors (i.e., to performance in maths word problems and reading comprehension). The model fitted the data well ($\chi^2[18] = 21.65$, $p = .25$; *CFI* = .99; *TLI* = .99; *RMSEA* = .03).

Results showed that technical reading ability predicted performance both on maths word problems (standardised estimate = .42, $p < .001$, $R^2 = .18$) and on reading comprehension (standardised estimate = .47, $p < .001$, $R^2 = .23$). Inspection of the modification indices suggested no significant paths from technical reading to specific maths word problem types or specific reading comprehension question types. The results also showed that after controlling for technical reading level, the covariance between latent maths word problem-solving and latent reading comprehension was still statistically significant (standardised estimate = .47, $p < .001$), suggesting that their association was not explained by technical reading level.

The role of gender and parental education

Next, the extent to which gender and parental education contribute to text comprehension skills and mathematical word problem-solving, either directly or indirectly via technical reading level, was examined by adding these variables into the model. The schematic model is shown in Figure 3. First, direct paths from gender and maternal education to latent maths word problem-solving and latent reading comprehension, as well as indirect paths via technical reading level, were estimated. The final model, including only statistically significant paths, is shown in Figure 4 ($\chi^2[28] = 38.16$, $p = 0.10$; *CFI* = .99; *TLI* = .98; *RMSEA* = .04).

Gender predicted the level of reading comprehension and technical reading skills: the girls were better than the boys in reading comprehension and also more likely to be in the GR group than boys. No gender differences were found in maths word problem-solving.

Maternal education level had a direct impact on children's maths word problem-solving skills and reading comprehension: the higher the maternal education level, the better the children's maths word problem-solving and reading comprehension. Maternal educational level also predicted the children's maths performance and reading comprehension via technical reading fluency: the higher

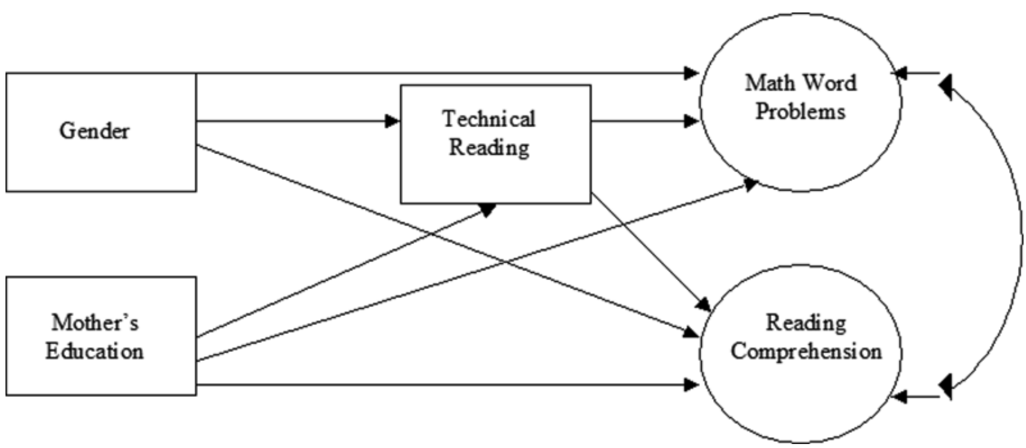

Figure 3. Schematic representation of the path models.

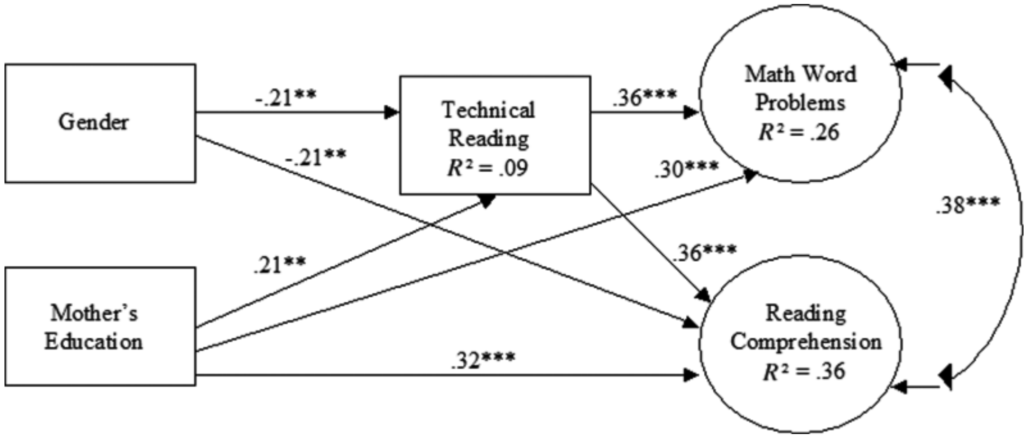

Figure 4. Statistically significant path coefficients assessing the interrelations between maths word problem-solving, reading comprehension, technical reading level (poor or good), gender, and maternal education level (note: the coefficients are standardised values (beta); ***$p < .001$; **$p < .01$; *$p < .05$).

the maternal education level, the more likely the children were to be in the GR group and therefore to have a higher level of reading comprehension and performance in maths word problems.

The same model was then tested using level of paternal education. The final model ($\chi^2[29] = 32.94$, $p = .28$; $CFI = .99$; $TLI = .99$; $RMSEA = .03$) included the same statistically significant paths as did the model with maternal education. The results are summarised in Table 5, and show that paternal education also positively predicted the children's maths word problem-solving and reading comprehension. However, paternal education had lower overall effects on these skills than did maternal education (R^2 for technical reading = .09; mathematical word problems = .22; reading comprehension = .29).

Discussion

This study investigated the interplay between mathematical word problem-solving skills and reading comprehension in fourth graders. It also investigated the role of children's technical reading level and its impact on performance in maths word problems and reading comprehension. Overall, the results revealed technical reading fluency to be crucial to both maths word problem-solving and reading comprehension (see also Fuchs et al., 2004). However, even after controlling for level of technical reading, the maths word problems were closely related to reading comprehension, suggesting that both also require overall reasoning strategies (Gelman & Greeno, 1989).

Table 5. Beta values for the statistically significant paths in the paternal model.

Path	β
Gender–technical reading	–0.21**
Gender–reading comprehension	–0.21**
Technical reading–maths word problem-solving	0.22**
Technical reading–reading comprehension	0.39**
Father's education–technical reading	0.21*
Father's education –maths word problem-solving	0.22*
Father's education–reading comprehension	0.17*

Note: ***$p < .001$; **$p < .01$; *$p < .05$.

The first aim of the study was to investigate whether these children's text comprehension skills and mathematical word problem-solving performance were interrelated. The results revealed that they were. Moreover, there was a strong interrelation between all the maths word problem types and reading comprehension question types. All these variables also showed an interrelation with technical reading. These results are in line with those of previous studies, especially concerning the role of technical reading skills in reading comprehension (e.g., Gough & Tunmer, 1986; Juel, Griffith, & Gough, 1986).

However, the structure of the mathematical word problem-solving factor was not as clear as that of the reading comprehension factor. Notions about question type-level differences in comprehension strategies have been grounds for developing tests that include classification of reading comprehension question types (Bowyer-Crane & Snowling, 2005; Van Keer & Verhaege, 2005) and maths word problem types (Fuchs & Fuchs, 2002), in order to make it easier to locate the precise type of reasoning strategy children have trouble with. However, in this study evidence was found that some maths word problem types have more components of reading comprehension than mathematics. For example, the items in the focus category contained multi-step directions of a linguistic nature, but they did not require complex maths skills. In other words, maths word problems that required multi-step calculations were more relevant to the maths word problem-solving factor than those items that required detailed linguistic information processing, such as focus.

The results also showed that only the compare and combine item types proved to be more mathematical in nature, although items in the combine category may well be contrasted with reading comprehension question types such as cause–effect/structure, conclusion/interpretation, and main idea/purpose, in terms of required reasoning strategies. The items included in the cause–effect/structure (CS) question type measure the extent to which the readers understand connections between items (Paris, Wasik, & Turner, 1991), and how they arrange the information obtained from the text. The ability to combine prior and current text-based information (Palinscar, David, Winn, & Stevens, 1991) is crucial in the conclusion/interpretation question type. In contrast, the main idea/purpose question type involves extracting the main ideas of the text (Stevens, Slavin, & Farnish, 1991).

The second aim of the study was to investigate the extent to which connections between children's text comprehension skills and mathematical word problem-solving performance are attributable to their technical reading skills. After controlling for level of technical reading, performance in mathematical word problems continued to be related to reading comprehension, suggesting that both of these skills involve an overall reasoning component as well (see also Gelman & Greeno, 1989). However, in addition, the results revealed that technical reading skill level was related to both maths word problem-solving and reading comprehension. Fluent technical reading skills may work as a 'capacity enhancer', helping the reader to maximise her/his prior knowledge on the subject at hand (Van Keer & Verhaeghe, 2005); a reader with poorer decoding skills struggles more with the text itself, resulting in poorer performance in tasks requiring logical reasoning strategies.

The third aim of the study was to investigate the extent to which gender and parental education contribute to fourth graders' text comprehension skills and mathematical word problem-solving performance. First, girls had better linguistic skills than boys but, as expected (Aunola et al., 2004), no gender differences were found in maths word problem-solving. Second, in accordance with previous findings (Lewis, 2000), maternal education level positively predicted the children's maths performance and reading comprehension, via the children's technical reading fluency. The higher the maternal education level, the more likely it was that children would be in the high technical reading skills group and, consequently, that they would have higher levels of reading comprehension and performance on maths word problems. Paternal level of education also positively predicted the children's maths word problem-solving and reading comprehension skills.

The results also showed, however, that even after controlling for the impact of gender and parental education, reading comprehension and maths word problem-solving were interrelated, suggesting that the association was not solely due to these background variables. It should also be noted that parental education levels possibly reflect the family's interest in reading and other activities that may have had an impact on the children's reading motivation and, thus, overall reading acquisition.

Limitations

There are at least five reasons for caution regarding any attempt to generalise the results of the present study. First, based on previous literature on the development of logical thinking strategies (Rupley & Willson, 1996), a cross-lagged study would have given a more precise picture of how to proceed in teaching later on into the use of more specialised thinking strategies in maths word problem-solving and reading comprehension tasks. Second, familiarity with the contexts of maths word problems (Cooper & Harries, 2002) and reading comprehension tasks (Perfetti, 1985) has been shown to be important for performance in such tasks. Hence, using multiple contexts, especially concerning the maths word problems, would have given more specific information about the problems children were having. Third, there is a growing need for future research to find out more about the causal directions (Graesser & Bertus, 1998) of maths and reading skills from a developmental perspective (see Paris et al., 1991); this research should also analyse the possible interplay between logical thinking strategy development and maths and reading skills. Fourth, measures of IQ and overall linguistic comprehension were not included to this study. These measures would have provided an opportunity to assess the interrelation between overall logical reasoning ability, maths word problem-solving, and reading comprehension. Fifth, the test of technical reading fluency used in this study is not the only way to measure it; there are possibly other aspects of technical reading not measured here. It is recommended that future studies should use tests that also include measures of reading accuracy and spelling, for example.

Conclusions

Technical reading fluency has been shown to predict reading comprehension skills (e.g., Tunmer & Hoover, 1992). The present study adds to the literature by showing that technical reading level also contributes to maths word problem-solving performance and reading comprehension (see also Fuchs et al., 2004). The study has also shown that a detailed analysis of question type structures in maths word problems and reading comprehension tasks is important in order to understand the accuracy of measures as well as the interplay between these skills. In a pedagogical sense, the results indicate the importance of prioritising fluency in technical reading skills before shifting the main focus of teaching to more comprehensive reading strategies relevant for both reading comprehension and maths word problems.

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