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Longitudinal predictors of early mathematics: Number-specific versus domain-general mechanisms?

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Introduction

What is a good basis for developing mathematical competencies?

While some authors propose that number-specific abilities primarily contribute to early math development, other authors suggest that domain-general abilities are key.

- *The number-specific perspective emphasizes the role of nonverbal and symbolic number sense for math development* [1; 2] .
- *The domain-general perspective emphasizes the role of domain-general mechanisms such as working memory, language processing, processing speed and abstract reasoning in early number and math development* [3 - 5] .

Hypothesis

Number-specific and domain-general abilities both contribute to kindergarten numeracy and Grade 1 math development.
However these underlying mechanisms might contribute differentially to early numeracy and math outcomes.

Aim

This longitudinal study investigates the concurrent contributions of number-specific and domain-general abilities as assessed in kindergarten on individual differences in early numeracy (kindergarten) and in math competencies (Grade 1).

Method

2 measurement waves

In kindergarten:

- N= 165
- Mean age = 6 years, 3 months; SD = 4 months
- Parental socio-economic background was diverse
- 35.2% first language = Luxemburgish
- 50.9% boys
- Individual testing (2 sessions, see measures in table 1)
- Raven's Colored Progressive Matrices
- British Picture Vocabulary Scale

In grade 1:

- N=151
- Mean age = 7 years, 2 months; SD = 4 months
- Group testing (2 sessions, see measures in table 2)

Table 1. Measures in kindergarten

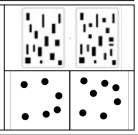
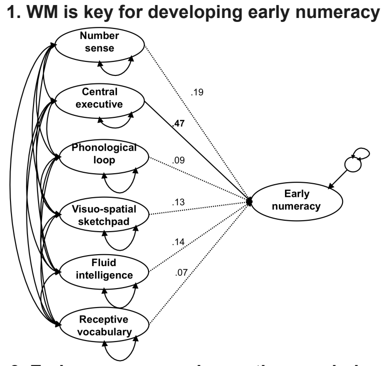
Construct	Subtest	Item example
Early numeracy	Verbal counting	Count up to 50
		Count up from 8
		Count backwards from 23
		Count 2 steps from 5
	Dot counting	Count an array of 6 dots
	Arabic number comparison	What number is the largest, 5 or 4?
Working memory	Phonological loop	Digit recall *6 9 4 - 6 9 4*
		Pseudoword recall *TA NU PI - TA NU PI*
	Central executive	Backward Digit span *8 1 4 - 4 1 8*
		Backward Colour span *gréng giel blo - blo giel gréng* (green yellow blue)
	Visuo-spatial sketchpad	Free recall of a sequence of 2, 3, 4 positions of a dwarf on a gridded screen
		Free recall of a sequence of 2, 3, 4 positions of a dwarf on a screen without grid
Nonverbal number sense	numerosity comparison	

Table 2. Measures in grade 1

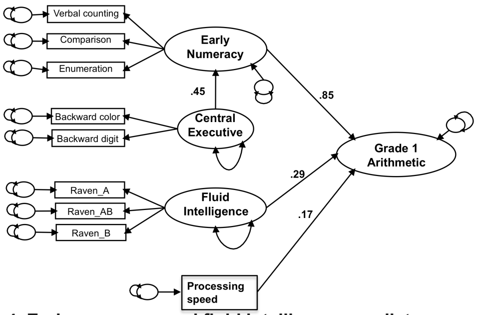
Construct	Subtest	Content and example of item
Math outcomes Grade 1	Arithmetic from HRT 1-4	Addition 1 + 6 =
		Subtraction 4 – 1 =
		Equation __ + 4 = 8
		Arabic Number comparison (< > =) 11 ___ 12
	Problem solving from HRT 1-4	Length estimation The child estimates the length of a set of lines by comparing them with the length of 3 presented lines corresponding each to the length of 1, 5 or 10 steps.
		Cubes counting The child has to find out how many cubes build a figure. The difficulty relies in taking cubes into account that are not directly visible because covered by another cube.
		Number sequence 1 2 1 2 1 2 __ __ __ The child has to find out the rule or pattern of a sequence of numbers.
	Number line estimation	Position simple tens (e.g., 20) on a physical number line from 0 to 100
		Position more complex tens (e.g., 69) on a physical number line from 0 to 100

Results

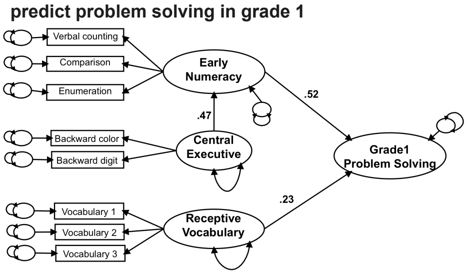
1. WM is key for developing early numeracy



2. Early numeracy, fluid intelligence and processing speed predict arithmetic in grade 1



3. Early numeracy and receptive vocabulary predict problem solving in grade 1



4. Early numeracy and fluid intelligence predict symbolic number sense (number line) in Grade 1

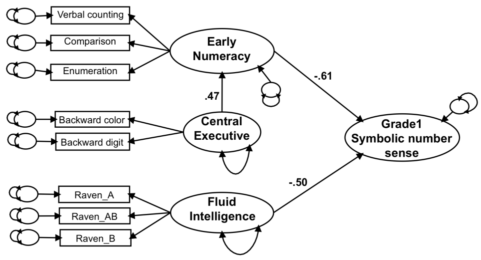


Table 3. Model fit statistics and model parameters

Model Fit Statistics and Model Parameters

	Model: Kindergarten predictors for early math	Model fit: χ^2	df	CFI	RMSEA	SRMR	Model parameters: β	SE	R^2
1	***Early numeracy in kindergarten***	159.30	98	.96	.06	.05			
	Number sense						.19	.10	
	Central executive						.47	.11	
	Phonological loop						.09	.09	.78
	VS sketchpad						.13	.10	
	Fluid intelligence						.14	.11	
	Receptive vocabulary						.07	.08	
2	***Arithmetic in Grade 1***	249.83	175	.96	.05	.05			
	Early numeracy						.85**	.19	
	Number sense						-.05	.11	
	Central executive						-.22	.15	
	Phonological loop						.09	.09	
	VS sketchpad						-.14	.10	.78
	Fluid intelligence						.29*	.12	
	Receptive vocabulary						.01	.08	
	Processing speed (first grade)						.17**	.06	
3	***Problem solving in Grade 1***	218.10	155	.96	.05	.05			
	Early numeracy						.52**	.21	
	Number sense						-.10	.12	
	Central executive						.02	.17	
	Phonological loop						.11	.10	
	VS sketchpad						.04	.11	.78
	Fluid intelligence						.18	.14	
	Receptive vocabulary						.23**	.09	
	Processing speed (first grade)						.11	.07	
4	***Symbolic number sense in Grade 1***	188.41	136	.97	.05	.05			
	Early numeracy						-.61*	.27	
	Number sense						-.04	.15	
	Central executive						.07	.12	
	Phonological loop						.20	.12	
	VS sketchpad						.21	.14	.78
	Fluid intelligence						-.50**	.16	
	Receptive vocabulary						-.18	.10	
	Processing speed (first grade)						.06	.08	

Note. χ^2 = chi-square goodness-of-fit statistic; *df* = degrees of freedom; CFI = comparative fit index; RMSEA = root-mean-square error of approximation; SRMR = standardized root-mean-square residual; β = standardized Beta values; SE = Standard Error; CI = Confidence Interval; R^2 = overall variance explained by the independent variable(s); Both models met the cutoff criteria for acceptable to good fit. ** significant, p< .01; * significant, p<.05.

Conclusions

The present results emphasize:

(a) the influence of WM on early numeracy skills [5; 6]
(b) the predictive power of early numeracy skills for Grade 1 math outcomes [1; 7]
(c) the importance of verbal processing for problem solving [4]
(d) the predictive power of fluid intelligence for arithmetic and symbolic number sense
(e) the role of processing speed for arithmetic performance

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