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Comparison and number line estimation performance: relation with mathematics achievement

Introduction

It has been suggested that young infants have an awareness of numerical magnitudes. These basic numerical abilities are considered to be key precursors of mathematical development. Several measures of numerical magnitude representation have been used in children, e.g. a comparison task and a number line estimation task. Only few studies have administered a comparison task and a number line task in one study and related the performance on these tasks with mathematics achievement. However, in these studies, only symbolic stimuli were used and it remains unclear whether the performance on these tasks administered with symbolic and non-symbolic stimuli is equally related to mathematics achievement. Furthermore, the above-referenced studies typically focus on one particular age group. The present study tried to address these issues, by administering a comparison task and number line estimation task in both symbolic and non-symbolic formats in kindergarteners, first-, second- and sixth graders. The aim of the present study is to investigate to which extent each of these measures of numerical magnitude representation is related to performance on a curriculum-based standardized mathematics achievement test.

Method

❖ **Subjects**
118 primary school children: 26 kindergarteners, 30 first graders, 29 second graders and 33 sixth graders.

❖ **Experimental tasks: stimuli and procedure**
Participants had to conduct a comparison task (decide which of two simultaneously presented stimuli is the largest) and a number line estimation task (positioning of digits and dot collections ranging from 0-10 and/or 0-100 on a 25 cm number line), with both symbolic (Arabic digits) and non-symbolic stimuli (dot collections).

❖ **Standardized tests**
The curriculum-based standardized achievement test for mathematics from the Flemish Student Monitoring System was used for the elementary school children. The mathematics achievement level of the kindergarteners was assessed by the 'Numerical understanding, start last year of kindergarten'. In addition, all kindergarteners and first graders completed a simple test to measure their knowledge of the Arabic digits 1-9 and the numerosities they represent.

Results

❖ **Results comparison task**

- Comparison distance effect: decreasing with increasing age in both the symbolic and non-symbolic condition.
- Use of the adjusted RTs (= RT/accuracy) because of the presence of a Speed Accuracy Trade Off.

	M	SD
Symbolic condition		
Kindergarteners	-134.72	188.75
First graders	-84.80	56.83
Second Graders	-53.34	34.78
Sixth graders	-29.41	22.18
Non-symbolic condition		
Kindergarteners	-172.27	73.63
First graders	-157.65	86.48
Second Graders	-116.65	52.39
Sixth graders	-67.58	21.64

Table 1: mean slope and standard deviation of the adjusted reaction times per grade, for both the symbolic and non-symbolic condition of the comparison task.
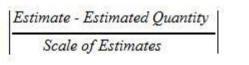
❖ **Results number line estimation task**

-The percent absolute error (PAE) was computed per child, according to the following equation (Siegler & Booth, 2004):

$$\frac{|Estimate - Estimated\ Quantity|}{Scale\ of\ Estimates}$$

-There was a significant increase in accuracy of estimation with grade, both in the symbolic ($\eta_p^2 = .52$) and the non-symbolic condition ($\eta_p^2 = .38$).
- To analyze the pattern of estimates, fits of linear and logarithmic functions were computed for each grade:

Grade	Best fitting model (linear or logarithmic)	
	Symbolic condition	Non-symbolic condition
Kindergarten 0-10	$R^2_{lin} = .63$; $R^2_{log} = .47$; $t(25)=6.12$, $p < .001$	$R^2_{lin} = .72$; $R^2_{log} = .62$; $t(25)=5.29$, $p < .001$
First grade 0-10	$R^2_{lin} = .80$; $R^2_{log} = .65$; $t(29)=12.81$, $p < .001$	$R^2_{lin} = .83$; $R^2_{log} = .67$; $t(29)=21.32$, $p < .001$
0-100	$R^2_{lin} = .81$; $R^2_{log} = .76$; $t(29)=-1.71$, $p = .10$	$R^2_{lin} = .88$; $R^2_{log} = .76$; $t(29)=-5.45$, $p < .001$
Second grade 0-100	$R^2_{lin} = .91$; $R^2_{log} = .87$; $t(28)=2.56$, $p = .02$	$R^2_{lin} = .84$; $R^2_{log} = .83$; $t < 1$
Sixth grade 0-100	$R^2_{lin} = .99$; $R^2_{log} = .84$; $t(32)=33.03$, $p < .001$	$R^2_{lin} = .92$; $R^2_{log} = .86$; $t(32)=3.98$, $p < .001$

Table 2: Best fitting model (linear or logarithmic) and the corresponding paierd sample t-tests per grade, for both the symbolic and non-symbolic condition of the number line estimation task.

❖ **Correlations with mathematics achievement**

	Kindergarten (n = 26)	First grade (n = 30)	Second grade (n = 29)	Sixth grade (n = 33)
Comparison				
Symbolic adjusted RT	-.54**	-.07	-.08	-.17
Symbolic slope	.48*	-.11	.26	.12
Non-symbolic adjusted RT	-.41*	-.06	.05	-.29
Non-symbolic slope	.13	-.04	.32	-.10
Number line estimation				
Symbolic mean PAE 0-10 line	-.26	-.24		
Symbolic mean PAE 0-100 line		-.17	-.56**	-.26
Nonsymbolic mean PAE 0-10 line	-.11	-.00		
Nonsymbolic mean PAE 0-100 line		-.11	-.46*	-.44*

* Correlation is significant at the .05 level (2-tailed).
** Correlation is significant at the .01 level (2-tailed).

Table 3: correlations between experimental tasks and mathematics achievement level, per grade.

❖ **Correlations between experimental tasks**

	1	2	3	4	5	6	7
1. Symbolic comparison slope							
2. Symbolic comparison adjusted reaction times	-.49**						
3. Non-symbolic comparison slope	.08	-.04					
4. Non-symbolic comparison adjusted reaction times	-.26**	.65**	-.30**				
5. Symbolic mean PAE 0-10 line	-.13	.09	.12	.09			
6. Symbolic mean PAE 0-100 line	-.16	.49**	.02	.29**	.47**		
7. Nonsymbolic mean PAE 0-10 line	-.03	.15	.13	.13	.55**	.38*	
8. Nonsymbolic mean PAE 0-100 line	.11	.18	-.06	.13	-.12	.33**	-.04

Note: The number of subjects on which the correlations are based, differ for the diverse correlations, dependent on which grades performed the various tasks. * Correlation is significant at the .05 level (2-tailed). ** Correlation is significant at the .01 level (2-tailed).

Table 4: correlations between experimental tasks, controlled for grade.

Conclusions & further research

- In kindergarten, especially the performance on the comparison task (both with symbolic and non-symbolic stimuli) is related to mathematics achievement.
- In older children (i.e. from second grade onwards), mathematics achievement is more related to the performance on the (especially symbolic) number line estimation task.

➔ Further longitudinal research with the same tasks in the same subject sample is required to make predictions about which of these measures of numerical magnitude representation can be considered as a key predictor for later mathematics achievement at a certain age. We are planning to do this in March 2011 and March 2012.

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