Relations between language and numerical abilities in low-performing children

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Introduction

Several authors stressed out the link between language and arithmetic

In the general population

- Role of phonological awareness as predictor of arithmetic performance (*Leather & Henry, 1994)*
- Assumption of a verbal representation of numbers (*Dehaene & Cohen, 1997)*

Through cultural aspects

- Effect of language on arithmetic skills (*Pica, Lemer, Izard, & Dehaene, 2004)* and effect of schooling on estimation acuity *(Piazza, Pica, Izard, Spelke, & Dehaene, 2013)* in the Munduruku population
- Effect of math education on the precision of approximate number skills in unschooled adults *(Nys et al., 2013)*

In dyslexia

- Phonological processing deficits of individuals with dyslexia are associated with aspects of arithmetic relying on the manipulation of the verbal code (*Simmons & Singleton, 2007)*
- Role of phonological awareness as link between weak phonological processing and less arithmetic fact retrieval in individuals with dyslexia (*De Smedt & Boets, 2010)*

In Specific Language Impairment (SLI)

- Identification of poor phonological skills as an important factor in the relation between SLI and poor arithmetic (*Nys, Leybaert, & Content, 2012)*

Recent studies with pathological populations suggest a link between poor phonology and low arithmetic performance. The aim of the present project is to gain a better, developmental understanding of the relation between language and numerical skills in non-pathological children.

Method

Participants:

188 children from 11 classes in six schools (mean age: 7;6 years, 94 males) in the second year of primary school have been collectively assessed for language, numerical skills and other cognitive aspects. All participants went through 3 test sessions (S1, S2, S3).

Tasks and design:

Language	Target	Number skills	Target	Cognitive factors	Target
EVIP	*Vocabulary*	Transcoding	*Number representations*	Alpha span	*Short-term memory*
ECOSSE	*Morphosyntax*	KRT	*Simple mathematical problems*	Alpha span-reversed	*Central executive*
THaPho	*Metaphonology*	TTR	*Arithmetic facts*	Visuo-spatial span	*Visuo-spatial memory*
Minimal pairs	*Phonology*	Non-symbolic comparison	*Approximate number system*	Raven matrices	*I.Q.*
				Code task (WISC)	*Speed of processing*

Results

Simple and partial correlations between tasks

Variables	Evip	Ecosse	Thapho Syllable	Thapho Phoneme	Minimal pairs	Krt	Tr. Dots To Arabics	Tr. Arabic To Dots	Tr. Dictation	TTR Addition	TTR Subtraction	TTR Multiplication	Non symbolic comparison	Alpha span	Alpha span - reversed	Visuospatial span	Raven matrix	Code task (WISC)	Age	Mean (raw)	Standard Deviation	Mean (%)
Evip		,470	,229	,097	,126	,281	-,030	,209	,248	,158	,216	,168	,264	,220	,155	,138	,244	,135	-,071	45,4	3,91	83
Ecosse	,411		,356	,285	,135	,370	,049	,165	,228	,172	,205	,181	,199	,148	,226	,278	,321	,153	-,102	23,8	2,57	85
Thapho Syllable	,170	,302		,352	,233	,329	,148	,248	,274	,232	,192	,199	,238	,258	,154	,208	,366	,158	-,032	4,1	1,48	34
Thapho Phoneme	,048	,200	,234		,066	,257	,012	,119	,113	,064	,051	,048	,115	,250	,166	,163	,242	,130	-,069	2,6	1,39	22
Minimal pairs	,136	,109	,102	-,048		,195	,187	,267	,180	,217	,100	,068	,216	,241	,228	,187	,232	,206	,076	104,9	8,98	85
Krt	,146	,254	,207	,157	,052		,148	,333	,529	,585	,586	,530	,209	,358	,342	,354	,412	,261	-,064	10,8	4,54	43
Tr. Dots To Arabics	-,163	-,084	,066	-,085	,092	-,023		,070	,054	,176	,226	,169	,194	,043	,034	,082	,190	,185	-,029	5,1	17,58	51
Tr. Arabic To Dots	,229	,089	,115	,045	,177	,263	-,015		,315	,354	,334	,379	,233	,275	,286	,152	,250	,367	,096	9,3	9,99	93
Tr. Dictation	,194	,146	,186	,076	,043	,443	-,092	,170		,490	,496	,423	,232	,291	,323	,315	,357	,214	,069	15,1	14,09	89
TTR Addition	,125	,113	,130	,002	,051	,534	,071	,222	,372		,697	,568	,211	,388	,321	,359	,233	,382	,055	13,5	3,67	34
TTR Subtraction	,152	,167	,078	,000	-,037	,534	,135	,233	,416	,665		,577	,163	,356	,329	,264	,204	,315	-,023	10,8	3,89	27
TTR Multiplication	,123	,109	,090	,010	-,080	,462	,082	,256	,301	,483	,513		,171	,338	,248	,230	,236	,302	,023	7,5	2,89	19
Non symbolic comparison	,203	,086	,148	-,007	,114	,063	,085	,129	,108	,074	,074	,083		,178	,232	,242	,251	,238	,048	58,0	11,39	73
Alpha span	,159	,092	,205	,188	,156	,318	-,062	,194	,267	,298	,301	,288	,141		,471	,236	,056	,338	,065	5,7	2,12	48
Alpha span - reversed	,122	,136	,124	,115	,094	,236	-,114	,148	,207	,210	,293	,162	,138	,433		,236	,271	,315	,091	4,0	1,75	45
Visuospatial span	,074	,227	,250	,152	,161	,306	-,014	,026	,257	,263	,190	,152	,144	,168	,074		,233	,286	,050	5,6	2,31	47
Raven matrix																		,161	-,039	16,8	3,93	70
Code task (WISC)																			,088	78,6	17,85	44
Age																						

Upper diagonal figures: simple correlation coefficients
Lower diagonal figures: partial correlation coefficients, controlled for I.Q. and speed of processing
Age is not significantly correlated with tasks

Dependent variables

- Composite score for TTR (arithmetic facts for addition, subtraction and multiplication): components are significantly highly correlated (Pearson's r = .697, .568, .577, p< .001)
- Composite score for Transcoding (Dots to Arabics, Arabics to Dots, Dictation): 2 subcomponents (ATD and Dictation) are highly correlated (Pearson's r = .315, p< .001)*
  *Due to methodological issues related to the DTA subcomponent, the following results are based on a Transcoding composite score based only on the ATD and dictation subcomponents
- Standardized score for KRT (simple mathematical problems)
- All 3 dependent variables are significantly highly correlated (Pearson's r = .576, .658, .524, p< .001)

Independent variables

- Standardized scores for Minimal pairs, Thapho syllable, Thapho phoneme, Evip and Ecosse

Partial correlations controlled for the effects of I.Q., speed of processing and classes

Variables	Evip		Ecosse		Minimal pairs		Syllabic segmentation		Phoneme segmentation		Alpha span		Alpha span - reversed		Visuospatial span		Dot comparison	
	Pearson's r	p-value	Pearson's r	p-value	Pearson's r	p-value	Pearson's r	p-value	Pearson's r	p-value	Pearson's r	p-value	Pearson's r	p-value	Pearson's r	p-value	Pearson's r	p-value
TTR	.145	.076									.365	<.001	.189	.023	.164	.044	.137	.09
Transcoding	.158	.049			.171	.036	.175	.030			.236	.003	.159	.046	.169	.038	.133	.1
KRT	.209	.009	.202	.011			.199	.015	.221	.007	.381	<.001	.167	.036	.147	.072	.110	.174

Discussion

Main results

1. A relation between language-related tasks and arithmetic-related tasks is found
2. Specifically:
   - Metaphonological tasks -both at the syllable and phoneme levels-, as well as vocabulary and morphosyntax tasks are related to the mathematical problems task (KRT)
   - Phonological, metaphonological and vocabulary tasks are related to the transcoding task
3. Strong correlations between memory tasks and arithmetic-related tasks
4. The non symbolic numerosity comparison task is not correlated with precise, arithmetic-related tasks

Conclusions

1. Verbal, language-related components are linked with arithmetic operations (*see Dehaene & Cohen, 1997*)
2. The use of different codes to manipulate numerosity (transcoding operations) is associated with phonological and metaphonological abilities as well as with vocabulary
3. Non symbolic comparison task not related to arithmetic-related tasks: in line with actual debate on the non-linguistic nature of the approximate number system

Previous studies in the general as well as in pathological populations stressed out the link between language and arithmetic and specifically identified phonological skills as predictors of arithmetic performance.

→ These observations in a general population of young primary school pupils suggest that language-related skills are related to arithmetic performance, pointing out that phonology, metaphonology, morphosyntax and vocabulary account in explaining arithmetic performance. As such, knowing whether a language-related training can improve arithmetic achievement appears as an interesting question.

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