Does the development of digital skills influence cardinal meaning development in 3- to 4-year-old children ?

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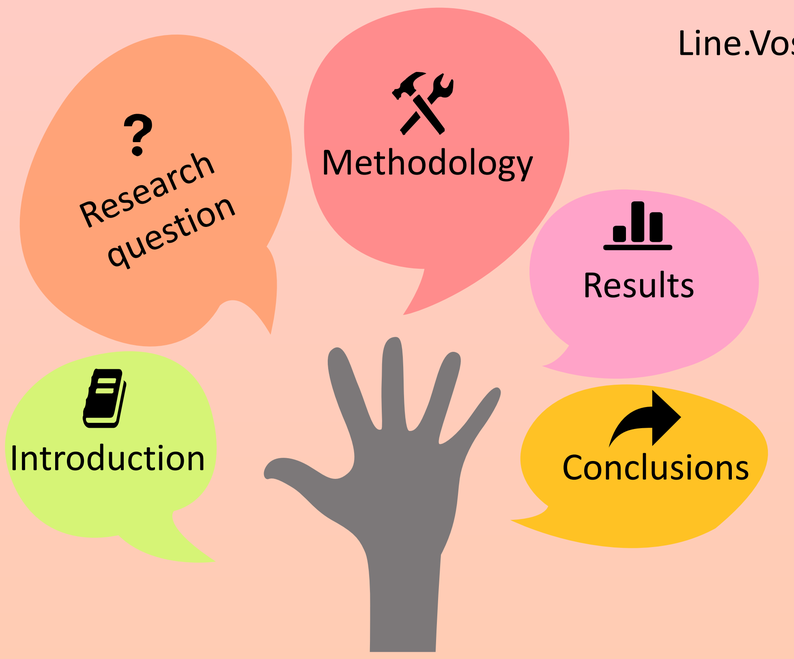


Many studies have shown that gestures support verbal number knowledge (Di Luca & Pesenti, 2011; Roesch & Moeller, 2015). Finger pointing and finger counting allow children to keep a visual track while reciting the verbal number sequence (Fuson, Richards & Briars, 1982; Saxe & Kaplan, 1981; Alibali & Di Russo, 1999). Fingers are usually used by young children to resolve arithmetic tasks (Fuson et al., 1982).

Finger gnosia are a good predictor of performance in arithmetics and problem-solving in primary school children (Fayol, Barrouillet & Marinthe, 1998; Noël, 2005). However, the role of fingers in the understanding of the concept of cardinality is less studied in children and is still a matter of debate. Nicoladis, Pika & Marentette (2010) found that preschoolers (2-, 3-, 4- and 5-year olds) had no advantage of number gestures compared to number words in *How many* & *Give-a-number* tasks. In contrast, Gunderson, Speapen, Gibson, Goldin-Meadow & Levine (2015) showed that children who did not master the cardinal meaning of number words (assessed with the *Give-a-number* task) were more accurate at estimating numbers with gestures than with words. Not only are these results contradictory, but these studies present an important limitation. The understanding of cardinality has never been examined using a longitudinal design that permits a precise assessment of the developmental curve of children. Moreover, no study has ever determined what component of digital skills really influence the numerical development: gnosia or fine motor skills ?

1. **Does the progress in the understanding of the cardinal meaning of number gestures contribute to the progress in the understanding of the cardinal meaning of number words ?**

2. **Does the development of digital non-numerical skills contribute to the progress in the understanding of the cardinal meaning of number words ?**

Multilevel models examining whether progress in the « Give-a-number » task in digital modality explain progress in the « Give-a-number » task in verbal modality (HLM)

	Model 0	Model 1
Fixed effects		
Intercept	3.06 (0.17)**	3.06 (0.12)**
Intra-individual level (level 1)		
- Age		0.12 (0.08)
- Score in 'Give-a-number task' in digital modality		-0.01 (0.11)
- Progress in 'Give-a-number task' in digital modality in the studied age range (score*age)		0.11 (0.02)**
Inter-individual level (level 2)		
- Initial state in 'Give-a-number task' in verbal modality		0.61 (0.07)**
- Initial state in 'Give-a-number task' in digital modality		-0.04 (0,06)
Random effects - Variance component		
Intra-individual level	21%	
Inter-individual level	79%	
Total variance accounted for		69%

TIME

T1	T2	T3	T4	T5
N = 60 3 years 0 months	N = 60 3 years 4 months	N = 60 3 years 8 months	N = 60 4 years 0 months	N = 60 4 years 4 months
Verbal Tasks Digital Tasks Non-num. Tasks	Verbal Tasks Digital Tasks Non-num. Tasks	Verbal Tasks Digital Tasks Non-num. Tasks	Verbal Tasks Digital Tasks Non-num. Tasks	Verbal Tasks Digital Tasks Non-num. Tasks

Multilevel models examining whether the development of digital non-numerical skills explain progress in the 'Give-a-number' task in verbal modality (HLM)

	Model 0	Model 1	Model 2	Model 3
Fixed effects				
Intercept	2.85 (0.15)**	2.85 (0.09)**	2.85 (0.09)**	2.85 (0.09)**
Intra-individuel level (level 1)				
- Age		0.46 (0.26)	-0.02 (0.20)	0.32 (0.14)*
- Score in finger gnosia		-0.05 (0.05)		
- Progress in finger gnosia in the studied age range (score*age)		0.03 (0.02)		
- Score in finger dissociation task			-0.07 (0.04)	
- Progress in finger dissociation skills in the studied age range (score*age)			0.05 (0.01)**	
- Score in finger coordination task				-0.15 (0.09)
- Progress in finger coordination skills in the studied age range (score*age)				0.10 (0.02)**
Inter-individuel level (level 2)				
- Initial state in Give-a-number task in verbal modality		0.87 (0.09)**	0.84 (0.09)**	
- Initial state in finger gnosia		-0.04(0.05)		
- Initial state in dissociation skills			-0.03 (0.03)	
- Initial state in coordination skills				
Random effects - Variance components				
Intra-individuel level	51%			
Inter-individuel level	49%			
Total variance accounted for		40%	44%	45%

Verbal Tasks

Assessment of the understanding of cardinal meaning

***« Give-a-number »* task**

*« Can you give me **/THREE/** tokens? »*

- *The child received 10 tokens*
- *Cardinal development level = the largest numerosity accurately identified by the child two out of three times*

  →0-knowers, 1-knowers, 2-knowers, 3-knowers, 4-knowers,
  →Cardinal-Principle-knowers

Digital Tasks

Assessment of the understanding of cardinal meaning

***« Give-a-number »* task**

« Can you give me  *tokens? »*

- *The child received 10 tokens*
- *Cardinal development level = the largest numerosity accurately identified by the child two out of three times*

  →0-knowers, 1-knowers, 2-knowers, 3-knowers, 4-knowers,
  →Cardinal-Principle-knowers

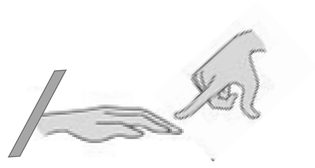
Digital non-numerical Tasks

Assessment of finger gnosia, dissociation skills and coordination skills

Finger gnosia assessment

« Can you tell me which finger I'm touching ? »

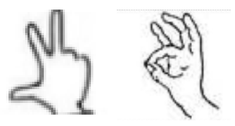
- *8 touches for each hand behind a screen*



Dissociation assessment

« Can you do the same as my fingers ? »

- 10 digital configurations to imitate for each hand
- Presentation mirrored by the assessor



Coordination assessment

« Can you do the same as my fingers ? »

- *3 praxia to reproduce for each hand*
- Presentation mirrored by the assessor

The development of the understanding of number gestures cardinal meaning significantly influences **the development number words cardinal meaning.** Moreover, this influence grows with age : the older the children, the more important is the influence of digital on verbal number representation in an identical task.

Moreover, **dissociation and coordination skills** but not **finger gnosia** significantly influence the performance of children in **the understanding of number words cardinal meaning.** This influence increases as children become older.

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