Does finger gnosia and fine motor skills predict arithmetic development through finger-counting ? A longitudinal investigation

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Introduction

Theories of embodied numerical cognition postulate that the development of numerical concepts is deeply rooted in the child's sensorimotor experiences (Barsalou, 2015). Finger gnosia and Fine Motor Skills (FMS) have been shown to be related to arithmetic skills in children aged 5 to 10 (e.g., Barnes, 2011, Neveu et al., 2023). Using a longitudinal approach, these two sensorimotor finger skills have also been shown to be specific predictors of arithmetic development in young children (Asakawa & Sugimura, 2014; Noël, 2005).

One hypothesis that might explain these associations is that sensorimotor finger skills and arithmetic abilities are linked by a functional relationship (Butterworth, 1999). Thus, the *functionalist hypothesis* postulates that sensorimotor finger skills would support Finger Counting (FC), which in turn would support the development of arithmetic processing. In 2011, Reeve & Humberstone showed that children aged 5 to 7 with poor finger gnosia were also those who made little use of FC and had poor arithmetic performance. This work remains insufficient to test the *functionalist hypothesis*, as It did not consider FMS which are crucial for FC (Neveu et al., 2024), and it failed to determine whether FC directly supports the development of arithmetic skills, since these variables were combined in their analysis.

The purpose of the study is to test the *functionalist hypothesis* in the context of arithmetic development.

? 1. To verify that the development of arithmetic skills can be predicted by developmental changes in sensorimotor finger skills
2. To determine the mediating role of FC on the possible relationship between sensorimotor and arithmetic skills development.

Method

Population

74 French speaking children (40 girls, Mean age = 6.2 ± 0.3 years at the first measurement time).
- Mainstream primary schools
- Official curricula which does not recommend nor discourage FC

Tasks

Arithmetic

Solve one- or two-digit arithmetic problems.
- 36 items of increasing difficulty
- 18 additions and 18 substractions
- Half of which involve a carry or a borrow.

Identification of strategies used to solve the problems
- Mental calculation
- Finger-counting

FC efficiency score
- Ratio of the number of items solved correctly with fingers to the number of items processed by the child in the arithmetic task

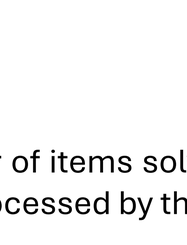
Fine motor skills (FMS)

MABC-II (Henderson et al. 2007): Placing pegs, threading lace and drawing trail subtests.

Timed tapping task: Reproduce finger movement sequences
- FMS score extracted from the four subtests by applying a Principal Component Analysis (PCA)

Finger Gnosia

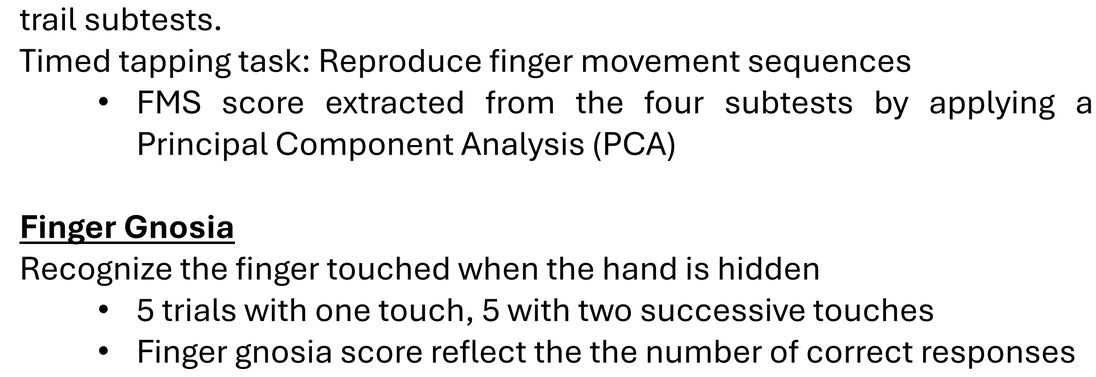
Recognize the finger touched when the hand is hidden
- 5 trials with one touch, 5 with two successive touches
- Finger gnosia score reflect the the number of correct responses



« Which finger did I touch ? »

Procedure

Children were assessed individualy in a quiet room in their schools



Results

Pearson's correlation

		Arithmetic				Finger Counting				FMS				Finger gnosia		
		T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3
Arithmetic	T1	—														
	T2	.22	—													
	T3	.33**	.46***	—												
	T4	.08	.18	.46***	—											
Finger Counting	T1	.07	.14	.06	.12	—										
	T2	-.04	.02	-.14	-.31*	-.03	—									
	T3	-.21	-.01	-.08	-.16	.07	.65***	—								
	T4	-.27*	-.04	-.11	-.11	.17	.51***	.67***	—							
FMS	T1	.09	.11	.21	.23	-.01	-.19	-.26*	-.18	—						
	T2	.18	.10	.20	.13	.03	-.14	-.28*	-.25*	.87***	—					
	T3	.15	-.09	.15	.06	.05	-.07	-.15	-.02	.66***	.67***	—				
	T4	.03	-.12	.26*	.17	-.02	-.06	-.16	-.04	.42***	.37**	.78***	—			
Finger Gnosia	T1	.05	.33**	.38**	.14	-.04	-.07	-.04	-.13	.08	.15	.16	.13	—		
	T2	-.03	.41***	.42***	.21	-.11	-.09	-.14	-.09	.16	.29*	.16	.11	.49***	—	
	T3	.34**	.19	.49***	.24	-.05	-.33**	-.43***	-.42***	.34**	.26*	.20	.23	.39**	.22	—
	T4	.30*	.19	.45***	.37**	-.01	-.34**	-.46***	-.41***	.37**	.36**	.25*	.20	.28*	.39**	.66***

Note. FMS: Fine motor skills, T: Time. * p<.05, ** p<.01, *** p<.001

Latent growth modeling

Predictive power of sensorimotor finger skills on arithmetic development

	FMS				Finger Gnosia			
	Initial value		Rate of change		Initial value		Rate of change	
Arithmetic Skills	β	S.E	β	S.E	β	S.E	β	S.E
Initial value	.06	.21	-	-	.32*	.16	-	-
Rate of change	.45	.33	.13	.30	.72***	.16	.24	.21

Note. FMS: Fine motor skills, S.E: Standard Error. * p<.05, ** p<.01, *** p<.001

Together, the initial value and the change of finger gnosia **explain 43%** of the arithmetic development.

Longitudinal mediating role of finger-counting on the sensori-motor/arithmetic relationship

Trajectory of change for FC efficiency :

→ Between T1 and T4, FC efficiency appear to be **stable** (Estimate=.005, p=.48)

As the FC measure was shown to be stable over time**, conducting multivariate analyses** to examine its predictive value on the development of children's arithmetic skills as well as its mediating role on the relationship between sensorimotor finger skills and arithmetic abilities **was not suitable**.

Discussion

Finger gnosia were shown to be a key predictor of arithmetic development.
- → The relationship between finger gnosia and arithmetic is not mediated by the efficiency of FC, which fails to support the *functionalist hypothesis*.
- → An alternative hypothesis would be that finger gnosia support arithmetic development through **finger patterns**, as proposed by Van Rinsvald et al. (2020).

No predictive value of **FMS** on arithmetic development was shown.
- → Minimal use of FC strategies : finger were used to solve 12 to 15% of the arithmetic problems
- → Due to the multidimentional nature, FMS tasks may have failed to capture the motor components involved in FC.