

Different aspects of spatial skills and their relation to early mathematics

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Theoretical background

- Mathematical skills develop along a learning trajectory, highlighting the importance of a solid foundation in basic math competencies when entering formal schooling (Simon & Tzur, 2004)
- Domain-specific (quantitative knowledge, counting knowledge, Arabic number knowledge) and domain-general skills (e.g. language, intelligence, working memory) contribute to math development (e.g. Aunola et al., 2004; Passolunghi & Lanfranchi, 2012; Krajewski & Schneider, 2009; LeFevre et al., 2010; Purpura & Ganley, 2014; Deary et al., 2007; Holmes et al., 2008; Cragg & Gilmore, 2014)
- Role of **spatial skills** in mathematical development:
 - Spatial skills: multifaceted construct
 - Distinction of different aspects: spatial perception, spatial visualization, mental rotation (Linn & Petersen, 1985)
 - Visuo-motor integration (VMI) is a further spatial aspect involved in math development (Carlson et al., 2013; Pieters et al., 2012; Pitchford et al., 2016; Simms et al., 2016; Sortor & Kulp, 2003)
 - Different aspects of spatial skills have been associated with mathematical development (Mix & Cheng, 2012; Casey et al., 2015; Verdine et al., 2014; Zhang & Lin, 2015; Zhang et al., 2014)

But: not clear which particular aspects of spatial skills relate to early math development

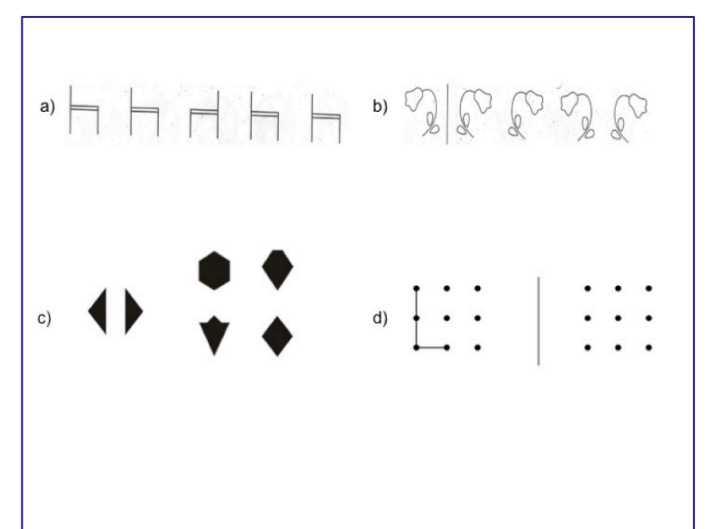
Research questions

- Do **spatial skills predict** early math outcomes when **considered concurrently** with domain-specific and domain-general skills?
- Do **different aspects** of spatial skills relate differentially to arithmetic and number line estimation in kindergarten children?

Method

Sample: **N = 125** kindergarten children, Age_{mean} = 5.49 years (Age range: 4 to 7 years)

- Assessment of predictor variables at t1:
 - Domain-specific skills** (quantitative knowledge [Panamath; Halberda et al., 2008], counting knowledge, Arabic Numeral knowledge)
 - Domain-general skills** (verbal STM, verbal intelligence)
 - Spatial skills** (spatial perception, spatial visualization, VMI)
- Assessment of outcome variables **4 months later** at t2:
 - Arithmetic** (adapted from Tedi-Math; van Nieuwenhoven et al., 2001)
 - Number line estimation 0 - 20 (NLE)** (percentage of absolute error)

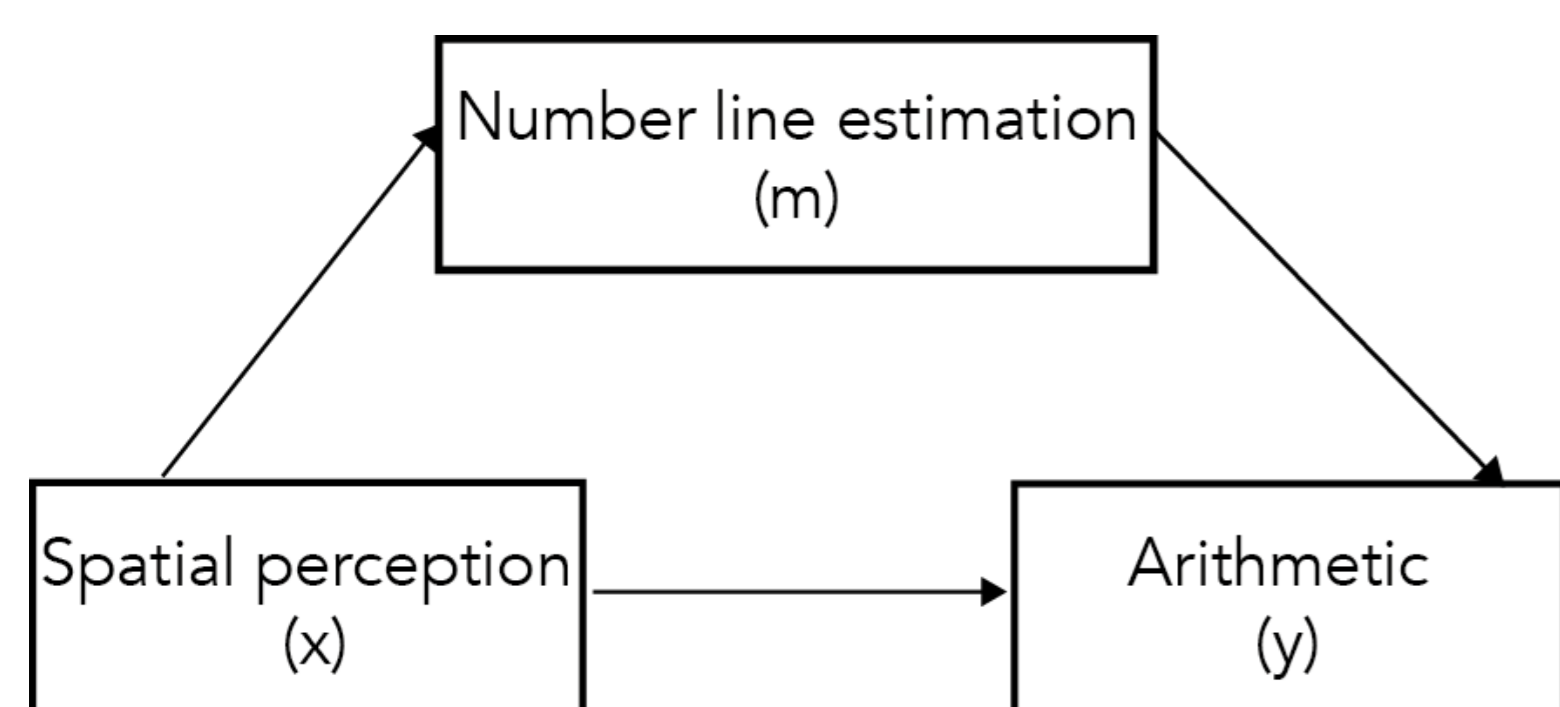


Results

A) Descriptive statistics and correlations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. School ^a	-													
2. Age (months)	-.09	-												
3. Gender ^b	-.00	.07	-											
4. Occupational level	.22*	.03	-.15	-										
5. Spatial perception	.06	.50**	.09	.27**	-									
6. Spatial visualization	-.17	.33**	.03	.36**	.51**	-								
7. Visuo-motor integration	.05	.52**	.09	.27**	.56**	.36**	-							
8. Quantitative knowledge (w)	.11	-.36**	.03	-.19*	-.43**	-.28**	-.32**	-						
9. Counting abilities	-.09	.55**	-.01	.32**	.57**	.47**	.53**	-.38**	-					
10. Arabic numeral knowledge	.12	.49**	.02	.31**	.63**	.42**	.49**	-.28**	.75**	-				
11. Verbal STM	-.09	.16	.06	.23*	.21*	.26**	.25**	-.32**	.47**	.38**	-			
12. Verbal intelligence	.06	.02	.03	.40**	.38**	.30**	.26**	-.09	.55**	.51**	.31**	-		
13. Arithmetic	.03	.38**	-.03	.30**	.64**	.38**	.59**	-.32**	.62**	.67**	.26**	.44**	-	
14. NLE	-.13	-.47**	.04	-.27**	-.60**	-.34**	-.44**	.34**	-.59**	-.65**	-.34**	-.32**	-.58**	-
Mean	37.6%	65.89	48.8 ^d	50.42	5.30	5.54	4.22	.35	9.67	15.75	4.5	.01 ^e	4.06	17.51
SD	-	7.60	-	15.73	2.00	2.69	2.25	.35	3.81	4.15	1.88	.99	1.79	11.19
Number of items	-	-	-	-	8	12	7	-	15	20	16	24	6	8

C) Mediation analysis (similar to Gunderson et al., 2012)



- Standardized total effect spatial perception → arithmetic: .64 (SE = .05, p = .00)
- Standardized indirect effect spatial perception → arithmetic: .19 (SE = .05, p = .00)
- Standardized direct effect spatial perception → arithmetic: .45 (SE = .08, p = .00)

Partial mediation of the relation between spatial perception and arithmetic through number line estimation.

B) Prediction of early math outcomes

- Model 1 includes control variables, domain-specific skills and domain-general skills
- Model 2 additionally includes spatial skills

Arithmetic				NLE				
	Model 1	Estimate	SE	p	Model 1	Estimate	SE	p
Intercept		-.05	.75	.95		5.62	.64	.00
Gender		-.03	.07	.96		.04	.07	.53
Age		.03	.09	.74	Age	-.18	.08	.03
School		-.03	.07	.62	School	-.12	.07	.07
Occupational level		.09	.07	.20	Occupational level	-.04	.07	.61
Verbal STM		-.08	.07	.21	Verbal STM	-.08	.07	.27
Verbal Intelligence		.10	.09	.28	Verbal Intelligence	-.01	.10	.92
Quantitative knowledge (w)		-.11	.07	.11	Quantitative knowledge (w)	.09	.08	.22
Counting abilities		.16	.13	.23	Counting abilities	-.14	.16	.40
Arabic numeral knowledge		.47	.11	.00	Arabic numeral knowledge	-.37	.14	.01
R ²		.50	.07	.00	R ²	.49	.06	.00
Arithmetic				NLE				
	Model 2	Estimate	SE	p	Model 2	Estimate	SE	p
Intercept		.57	.74	.44	Intercept	5.62	.70	.00
Gender		-.05	.06	.40	Gender	.07	.07	.30
Age		-.12	.09	.16	Age	-.12	.10	.20
School		-.08	.07	.35	School	-.11	.07	.11
Occupational level		.05	.07	.43	Occupational level	-.03	.08	.68
Verbal STM		-.05	.06	.40	Verbal STM	-.12	.07	.09
Verbal Intelligence		.03	.08	.66	Verbal Intelligence	.04	.10	.71
Quantitative knowledge (w)		-.02	.08	.83	Quantitative knowledge (w)	.02	.08	.80
Counting abilities		.10	.12	.97	Counting abilities	-.13	.17	.42
Arabic numeral knowledge		.36	.12	.00	Arabic numeral knowledge	-.27	.14	.06
Spatial perception		.26	.09	.00	Spatial perception	-.29	.10	.01
Spatial visualization		-.04	.07	.52	Spatial visualization	.04	.07	.60
VMI		.29	.08	.00	VMI	.00	.09	.98
R ²		.61	.06	.00	R ²	.53	.05	.00

Discussion

- Differentiation within the construct of spatial skills
- Differential role of spatial aspects for predicting different aspects of early mathematics
- Major limitation: use of single measures to assess different aspects of spatial skills

Future outlook

- Follow-up when children are in 1st grade: results of the Luxembourgish national school monitoring ("ÉpStan")
- Determine predictive value of spatial skills in kindergarten for mathematical achievement in 1st grade

Conclusion

- Important to:
- differentiate within the construct** of spatial skills
 - Foster **spatial perception** and **VMI** in kindergarten to provide children with a sound foundation for later mathematical learning

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