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Title: More Than Numeracy, Patterning Predicts Early Mathematics Knowledge

Authors: Erica Zippert, Kelsey Clayback, & Bethany Rittle-Johnson

Abstract:

Math knowledge develops rapidly in the preschool years, varies substantially, and is strongly predictive of later math and reading achievement (Duncan et al., 2007; Starkey & Klein, 2004). While theory, research, and education standards on math development have concentrated primarily on the contributions of numeracy skills (Sarama & Clements, 2004, Common Core Standards, 2010), children's patterning skills also predict concurrent and later math knowledge (Rittle-Johnson, Fyfe, Hofer, & Farran, 2015; Rittle-Johnson, Zippert, & Boice, in press). However, little is known about how patterning skills relate to general cognitive ability or specific numeracy skills, nor whether patterning uniquely contributes to general math knowledge over and above fluid reasoning, working memory, and specific numeracy skills. For example, patterning skill may be a proxy for the influence of fluid reasoning (Burgoyne et al., 2017). The current study addressed two aims:

1. Evaluate the relation between patterning skills and general cognitive ability, specific numeracy skills, and general mathematics and numeracy knowledge in preschool
2. Determine how patterning independently predicts concurrent general math and numeracy knowledge in preschool beyond general cognitive and numeracy skills

Sixty-six preschool children (M = 4.54 years, SD = .36; 61% female) were recruited from three private and two public preschools. General math and numeracy knowledge and patterning, specific numeracy, and general cognitive skills were assessed in the fall of the preschool year (see Table 1.1 notes on measure details).

To address aim 1, raw and partial correlations controlling for age were run between the measures (see Table 1.1). Patterning skills were not correlated with fluid reasoning or working memory after controlling for age, but were correlated with spatial, numeracy, and math measures. To address aim 2, a hierarchical linear regression analysis was conducted to determine how patterning was related to general math and numeracy knowledge (see Table 1.2). In the first step, general cognitive skills were entered, and only spatial skill was predictive of general math and numeracy knowledge. When specific numeracy skills were added, fluid reasoning was significantly predictive of general math knowledge, and spatial skill and verbal arithmetic skill significantly predicted general numeracy knowledge. In the final step, when patterning was added to the model, only patterning and fluid reasoning predicted general math and numeracy knowledge.

These findings suggest that patterning is important for early math and numeracy knowledge, over and above the effects of general cognitive abilities, including fluid reasoning. Patterning skills are related to specific numeracy skills, magnitude comparison and verbal arithmetic, suggesting that patterning skills may help children notice and learn numeracy skills. As evidence suggests that patterning training improves numeracy knowledge (Kidd, et al., 2014; Papic, Mulligan & Mitchelmore, 2011), repeated patterning instruction may be important for promoting numeracy and general math development. The current findings further suggest that patterning should be included in early math standards and theories.

Table 1.1

Correlations Between General Math and Numeracy Knowledge, General Cognitive, Specific Numeracy, and Patterning Skills

Variable	*M*	*SD*	1.	2.	3.	4.	5.	6.	7.	8.
1. General Math Knowledge	-1.41	1.17	---	.89**	.36**	.50**	.47**	.42**	.43**	.61**
2. General Numeracy Knowledge	-1.02	1.55	.89**	---	.38**	.49**	.58**	.49**	.50**	.64**
3. Working Memory	11.06	5.20	.35**	.36*	---	.24	.26*	.17	.27*	.16
4. Fluid Reasoning	8.45	3.82	.45**	.47**	.27*	---	.52**	.31*	.25	.31*
5. Spatial Skill	6.27	3.45	.45**	.55**	.24	.51**	---	.43**	.31*	.41**
6. Magnitude Comparison	1.80	1.62	.37**	.44**	.15	.21	.40**	---	.53**	.59**
7. Verbal Arithmetic	2.88	1.94	.38**	.52**	.30*	.17	.32*	.55**	---	.54**
8. Patterning Skills	.04	1.40	.57**	.62**	.17	.19	.38**	.52**	.51**	---

Notes. Raw bivariate correlations are shown above the diagonal, and partial correlations controlling for age are shown below the diagonal. The Research-Based Early Mathematics Assessment (REMA)–Short Form IRT ability estimates assessed general math knowledge, including a numeracy subscale that was used to separately measure General Numeracy Knowledge (Weiland et al., 2012). Total scores on magnitude comparison and verbal arithmetic subscales of The Preschool Early Numeracy Scales (Purpura & Lonigan, 2015) measured specific numeracy skills. Patterning skills were assessed by averaging students' IRT ability estimates on two previously validated repeating pattern measures (Miller, Rittle-Johnson, Loehr, & Fyfe, 2016; Rittle-Johnson, Zippert, & Boice, in press). General cognitive abilities included the spatial skill of form perception (using the Position in Space subtest of the Developmental Test of Visual Perception-II; Hammill, Pearson, & Voress, 1993), and working memory and fluid reasoning were measured using Picture Memory and Matrix Reasoning subscales of the Wechsler Preschool and Primary Scale of Intelligence-IV, respectively (Wechsler, 2012).
*p < .05. **p < .01.

Table 1.2

General Cognitive Skills and Individual Numeracy and Patterning Skills Predicting General Math and Numeracy Knowledge

	General Math Knowledge			General Numeracy Knowledge		
Model Variables	*B*	β	ΔR^2	*B*	β	ΔR^2
Step 1: General Cognitive Ability			.37**[a]			.41**[a]
Age	.48(.38)	.14		.23(.49)	.05	
Working Memory	.05(.03)	.21		.06(.03)	.20	
Fluid Reasoning	.08(.04)	.27		.09(.05)	.22	
Spatial Skill	.09(.04)*	.26		.18(.05)**	.40	
Step 2: Specific Numeracy Skills			.05[b]			.11**[b]
Age	.18(.40)	.05		-.31(.48)	-.07	
Working Memory	.04(.03)	.16		.04(.03)	.13	
Fluid Reasoning	.08(.04)*	.28		.10(.05)	.23	
Spatial Skill	.06(.04)	.17		.12(.05)*	.27	
Magnitude Comparison	.09(.10)	.12		.10(.12)	.10	
Verbal Arithmetic	.11(.08)	.12		.25(.10)*	.31	
Step 3: Patterning skills			.11**[c]			.10**[c]
Age	-.07(.37)	-.02		-.61(.44)	-.14	
Working Memory	.04(.02)	.17		.04(.03)	.13	
Fluid Reasoning	.09(.04)*	.28		.10(.04)*	.24	
Spatial Skill	.03(.04)	.10		.09(.05)	.21	
Magnitude Comparison	-.00(.10)	-.01		-.02(.11)	-.02	
Verbal Arithmetic	.04(.08)	.06		.15(.09)	.19	
Patterning Skill	.36(.11)**	.44		.46(.13)**	.42	

Notes. Standard errors are in parentheses. [a] $df = (4, 58)$ [b] $df = (2, 56)$ [c] $df = (1, 55)$.
*p < .05. **p < .01