MORE THAN NUMERACY, PATTERNING PREDICTS EARLY MATHEMATICS

ERICA L. ZIPPERT, KELSEY CLAYBACK, BETHANY RITTLE-JOHNSON,
VANDERBILT UNIVERSITY

CONTEXT

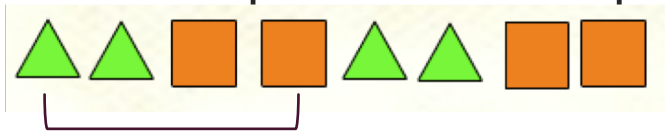
- Variation in children's math skills before school entry (Starkey, Klein, & Wakeley, 2004)
- Early math skills predict academic achievement in math *and* reading across primary and secondary school (Duncan et al., 2007; Jordan et al., 2009; Nguyen et al., 2016)
- Math theory and research primarily focus on the contributions of number skills (Sarama & Clements, 2004)

INTRODUCING PATTERNING SKILLS

- Develop in preK and K (Rittle-Johnson, Fyfe, McLean, & McEldoon, 2013; Sarama & Clements, 2009; Starkey, Klein, & Wakeley, 2004)
- Predict concurrent and later general math knowledge (Nguyen et al., 2016; Rittle-Johnson, Fyfe, Hofer, & Farran, 2015; Rittle-Johnson, Zippert, & Boice, 2018)
- Emphasized in math consensus documents and research-based early childhood math curricula (e.g., Sarama & Clements, 2004; NAEYC, 2014; NCTM, 2006; Starkey et al., 2004).
- No longer included in the Common Core as a content standard at any grade level (CCSS, 2010).

DEFINING PATTERNING

- **Pattern**- a predictable sequence (e.g., shapes, sounds, numbers).
- **Repeating patterns**-linear sequences with a repeating unit, preschool friendly



- **Pattern unit**
  - Easiest patterns have 2 item units (e.g., AB)

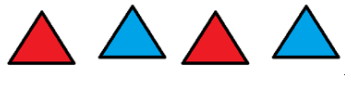
  - More difficult patterns include 3- to 4-item units (e.g., AAB)

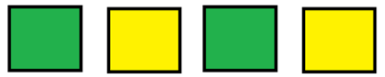
- **Pattern tasks**

Completing patterns

Copying patterns

Extending patterns





Abstracting patterns

THEORETICAL LINK BETWEEN PATTERNING AND MATH

- Patterning and math both involve identifying, extending, and describing predictable sequences in objects and numbers (Charles, 2005; Sarama & Clements, 2004)
- Math is considered the science of patterns (Steen, 1988)
- Patterning may be linked to early algebraic thinking due to its emphasis on awareness of regularities and structural relationships (e.g., Carraher, Schliemann, Brizuela, & Earnest)

THEORETICAL LINK BETWEEN PATTERNING AND MATH: CONT.

Patterning and shape knowledge (early geometry)

- Early shape knowledge involves:
  - Categorizing visual stimuli like dot patterns arranged as geometric shapes (Quinn & Eimas, 1986)
  - Deciphering geometric forms amongst patterns of dots (Quinn, Brown, & Streppa, 1997)

EMPIRICAL LINK BETWEEN PATTERNING AND MATH

Patterning in preschool predicts:

- Broad math and numeracy knowledge concurrently and 7 months later (Rittle-Johnson, Zippert, & Boice, 2018)
- Symbolic mapping and calculation knowledge in early elementary school (Rittle-Johnson et al., 2016)
- Math achievement in 5th grade (Nguyen et al., 2016)

Patterning in elementary school correlates with concurrent calculation knowledge (Fyfe, Evans, Matz, Hunt, & Alibali, 2017; MacKay & De Smedt, 2019)

PATTERNING AND GENERAL COGNITIVE ABILITY

- Pattern detection and completion tasks are common on IQ measures (e.g., Raven's Progressive Matrices; Wechsler, 2003)
- Patterning training theorized to improve fluid reasoning, which then influences math knowledge (Kidd et al., 2014; Pasnak et al., 2016)
- Patterning skills are predictive of and causally related to children's development in reading *and* math (Burgoyne et al., 2017)
- Patterning correlates with spatial and executive function skills in preK (Collins & Laski, 2015; Rittle-Johnson, Fyfe, McLean, & McEldoon, 2013; Rittle-Johnson, Zippert, & Boice, 2018)

CURRENT STUDY AIMS

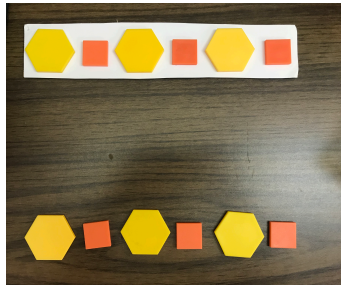
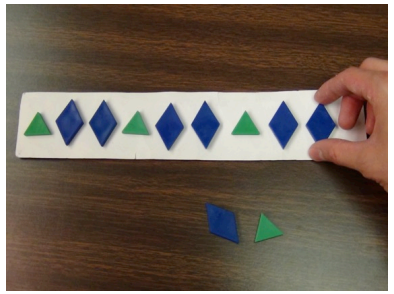
1. Distinguish patterning from general cognitive ability
2. Evaluate the link between patterning and math beyond general cognitive ability
3. Evaluate the link between patterning and specific math skills beyond general cognitive ability

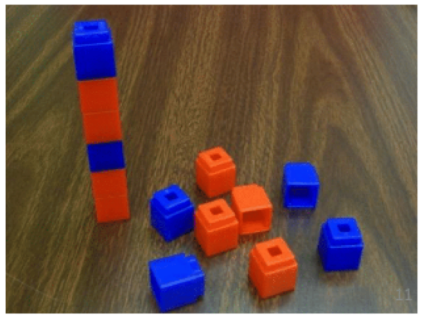
METHOD

- 66 preschool children (*M* = 4.54 years, *SD* = .36)
- 61% female
- Recruited from three private and two public preschools
- Measured the following skills at a single time point on two separate days
  - Repeating patterning skills
  - General math and numeracy knowledge
  - Fluid intelligence
  - Working memory
  - Specific numeracy skills (magnitude comparison and verbal calculation)

PATTERNING MEASURES

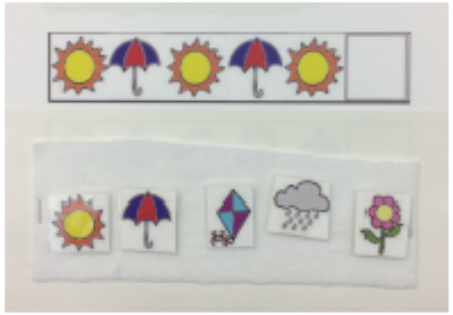
- **Research-based patterning:** consisted of nine items varying in difficulty, validated in previous studies (Rittle-Johnson et al., 2013; 2015)



- **Teacher-friendly patterning:** adapted from pre-existing patterning worksheets found on resource websites for early-childhood educators. 10-items, worth 1-point each

Pattern Completion



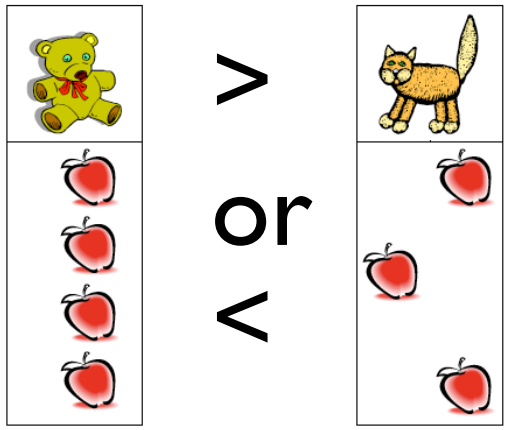

Pattern Extension

Pattern Abstract

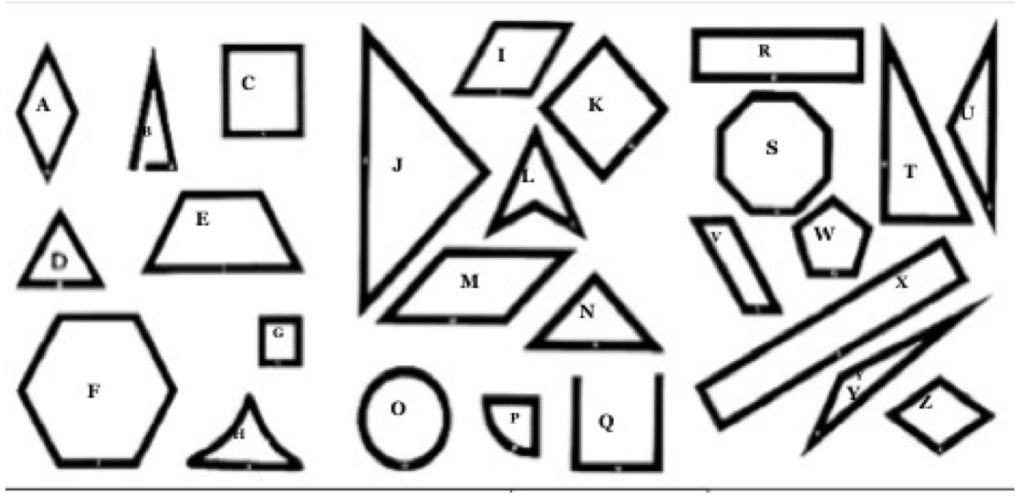
GENERAL MATH MEASURE

- **General math knowledge** (with numeracy and shape knowledge subtest): The REMA Short-Form contains a subset of items from the Research-Based Early Mathematics Assessment (Clements & Sarama, 2000; Weiland et al., 2012)

Numeracy example

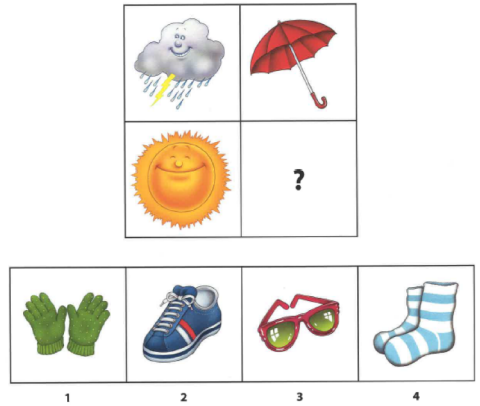


Shape knowledge example



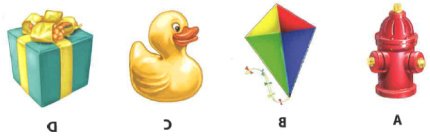
GENERAL COGNITIVE ABILITY MEASURES

- Fluid reasoning-Matrix Reasoning subtest (WPPSI-IV; Wechsler, 2012)



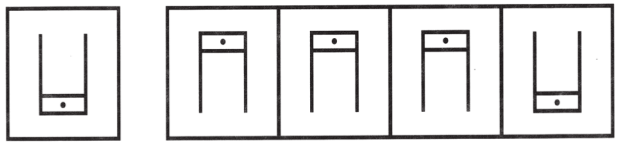
- Working memory- Picture Memory subtest (WPPSI-IV; Wechsler, 2012)

Target items



Response options

- Spatial skill of form perception-Position in Space subtest of the Developmental Test of Visual Perception (Hammill, Pearson, & Voress, 1993



SPECIFIC MATH MEASURES

- General numeracy and shape knowledge (Clements & Sarama, 2000; Weiland et al., 2012)
- Specific math skills (The Preschool Early Numeracy Scales; Purpura & Lonigan, 2015)
  - Magnitude comparison
    - "which is most/least"

1 4 3 2

Five, two, seven, one

  - Verbal calculation scales
    - "If Hugh does not have any cookies, and his mom gives him two cookies, how many cookies does Hugh have now?".

AIM 1 RESULTS: PATTERNING & GENERAL COGNITIVE ABILITY

Variable	Patterning
1. Age	.33**
2. Fluid Reasoning	.47**
3. Working Memory	.34**
4. Spatial Skills	.54**
**$p < .01$.	

AIM 2 RESULTS: PATTERNING UNIQUE PREDICTOR OF BROAD MATH

	Broad Math Knowledge		
Variable	B	β	ΔR^2
Step 1 [a]			.37**
Age	.45	.14	
Fluid reasoning	.08	.27*	
Working memory	.05	.22*	
Spatial skills	.09	.26*	
Step 2 [b]			.22**
Age	.00	.00	
Fluid reasoning	.06	.19†	
Working memory	.02	.07	
Spatial skills	.01	.02	
Pattern skills	.51	.61**	

*p < .05. **p < .01.

[a] df = (4, 61). [b] df = (1, 60). † p < .1.

AIM 3 RESULTS: PATTERNING LINKED TO SPECIFIC MATH SKILLS

	Numeracy Knowledge		
Variable	B	β	ΔR^2
Step 1 [a]			.42**
Age	.26	.06	
Fluid reasoning	.09	.22†	
Working memory	.06	.20†	
Spatial skills	.18	.41**	
Step 2 [b]			.17**
Age	-.27	-.67	
Fluid reasoning	.06	.15	
Working memory	.02	.07	
Spatial skills	.09	.20†	
Pattern skills	.60	.54**	

*p < .05. **p < .01.

[a] df = (4, 61). [b] df = (1, 60). † p < .1. *p < .05. **p < .01.

RESULTS: PATTERNING LINKED TO SHAPE KNOWLEDGE

	Shape Knowledge		
Variable	B	β	ΔR^2
Step 1 [a]			.15*
Age	.45	.18	
Fluid reasoning	.06	.27†	
Working memory	.01	.08	
Spatial skills	-.01	-.02	
Step 2 [b]			.05†
Age	.28	.13	
Fluid reasoning	.06	.23	
Working memory	.00	.01	
Spatial skills	-.03	-.13	
Pattern skills	.19	.29†	

*p < .05. **p < .01.

[a] df = (4, 61). [b] df = (1, 60). † p < .1. *p < .05. **p < .01.

RESULTS: PATTERNING LINKED TO SPECIFIC MATH SKILLS: VERBAL CALCULATION

	Verbal Calculation		
Variable	B	β	ΔR^2
Step 1 [a]			.20**
Age	1.49	.28*	
Fluid reasoning	-.02	-.04	
Working memory	.10	.25*	
Spatial skills	.13	.23	
Step 2 [b]			.11**
Age	.97	.18	
Fluid reasoning	-.05	-.09	
Working memory	.06	.14	
Spatial skills	.04	.06	
Pattern skills	.59	.43**	

*p < .05. **p < .01.

[a] df = (4, 61). [b] df = (1, 60). † p < .1. *p < .05. **p < .01.

RESULTS: PATTERNING LINKED TO SPECIFIC MATH SKILLS: NUMBER COMPARISON

	Number Comparison		
Variable	B	β	ΔR^2
Step 1 [a]			.26**
Age	1.25	.28*	
Fluid reasoning	.00	.01	
Working memory	.02	.06	
Spatial skills	.17	.37**	
Step 2 [b]			.17**
Age	.69	.15	
Fluid reasoning	-.03	-.06	
Working memory	-.03	-.08	
Spatial skills	.08	.16	
Pattern skills	.63	.54**	

*p < .05. **p < .01.

[a] df = (4, 61). [b] df = (1, 60). † p < .1. *p < .05. **p < .01.

DISCUSSION

- Patterning is:
  - Unique from general cognitive ability (e.g., fluid reasoning)
  - Important for early math knowledge above the effects of general cognitive abilities
  - Predictive of general numeracy knowledge and specific skills of magnitude comparison and verbal arithmetic
    - Role of rules and regularities
  - Either unrelated to shape knowledge, or link not detected due to measurement issues
- The benefits of patterning training to general math knowledge may be extended to specific math skills as well (Kidd, et al., 2014; Papic, Mulligan & Mitchelmore, 2011)
- Further evidence that the role of patterning should be reintroduced into theory and curricula on mathematics (e.g., Common Core State Standards)

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