

## **Abstract Title Page**

**Title:** Measuring repeating patterning skill in Kindergarten

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## Abstract Body

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### Background

Children's math knowledge develops early to varying degrees and predicts later math achievement (Duncan et al., 2007). While math theory and research focus on the role of number skills (Sarama & Clements, 2004), patterning also predicts concurrent and later math knowledge (Rittle-Johnson, Zippert, & Boice, 2018). This research focuses on kindergarteners' skills with repeating patterns (i.e., linear patterns with a repeating unit, e.g., ABABAB).

Children's patterning skills become systematically more sophisticated in preschool and kindergarten (Rittle-Johnson, Fyfe, McLean, & McEldoon, 2013; Sarama & Clements, 2009; Starkey, Klein, & Wakeley, 2004). Children first learn to work with simple alternating AB patterns such as red-blue, and then learn to identify patterns with three and four item units (e.g., ABB/AABB). The earliest emerging patterning skill is *completing patterns*—identifying missing pattern items. A more difficult skill, *extending*, requires continuing patterns by at least one unit. A more difficult is *abstracting*—recreating a pattern using different materials. By the end of kindergarten, many children can extend and abstract patterns with more difficult units (Clements & Sarama, 2014).

### Purpose

A teacher-friendly, valid and reliable instrument currently does not exist for kindergarteners as it does for preschoolers (Rittle-Johnson, Fyfe, Loehr, & Miller, 2015). This is imperative for teachers to appropriately plan lessons and measure student learning (Purpura & Lonigan, 2015).

### Method

As part of a longitudinal study, children ( $n = 65$ ) were assessed near the end of Kindergarten. These children were also assessed during the initial (Time 1) and final (Time 2) quarter of their final preschool year. Participants were 51% female from public and private schools ( $M = 6$  years, 1 month,  $SD = 3.5$  months).

**Teacher-Based Patterning.** This 6-minute assessment, administered at all time points, was developed using pre-existing patterning worksheets found on websites with resources for early-childhood educators. Children were presented with 10-items, worth 1-point each, of pictures of model patterns and laminated pictures to complete the patterning task (see Figure 1). The first two pattern completion tasks were easier: (a) what comes next and (b) missing item. The third was extending patterns. The fourth was included because it potentially involved abstracting patterns (see Table 1 for a list of items). We generated item difficulty and ability estimates using a dichotomous Rasch model with a Laplace approximation and empirical Bayesian prediction method shown to be stable for sample sizes around 50 (Cho & Rabe-Hesketh, 2011).

**Research-based patterning.** This Time 1 assessment measures preschoolers' ability to extend, and abstract repeating visual patterns, and consisted of nine items varying in difficulty, described and validated in previous studies. IRT ability estimates were obtained using the aforementioned procedure.

**General Math knowledge (with Numeracy knowledge subtest).** The REMA Short-Form (assessed at all three time points) contains a subset of items from the *Research-Based*

*Early Mathematics Assessment.* IRT ability estimates were generated using a partial credit model for the overall measure and for the numeracy knowledge subtest.

**Specific numeracy skills.** These Time 3 measures involve noticing repeating patterns in numbers. (a) *Count sequence to 100.* (b) *Successor principle for large numbers 15 to 116.* Children determined the sum after adding 1 to a visible quantity of objects. Because at least half of children achieved a perfect score on both measures, scores were dichotomized into perfect performance (mastery) vs. not perfect.

**Spatial ability.** Block Design, a subtest of the WPPSI-IV, measured at Time 1 and 2, measured spatial ability.

**Verbal ability.** The Picture Vocabulary Test from version 1.6 of the *NIH Toolbox app* assessed children's receptive vocabulary at Time 1. Age-corrected standardized scores were used.

## Results

### *Reliability of Time 3 Teacher-Based Patterning Assessment*

Internal consistency was good for T3 (Cronbach's  $\alpha = .86$ ), comparable to those of Time 1 and 2 (Cronbach's  $\alpha = .83, .87$ , respectively). Further, T3 performance was somewhat stable over time, with a moderate test-retest correlation with T2  $r(63) = .38, p < .01$  and T1  $r(63) = .29, p < .02$ .

### *Validity of Teacher-Based Patterning Assessment*

First, we tested convergent validity by correlating students' T3 Teacher-Based patterning with T1 Research-Based patterning scores  $r(65) = .30, p < .01$ .

Concurrent and predictive validity was established by correlating T3 Teacher-Based patterning scores with general math knowledge at all time points,  $r_{\text{mathT3}}(65) = .39, p < .01$ ,  $r_{\text{MathT2}}(65) = .28, p < .025$ ,  $r_{\text{MathT1}}(65) = .23, (ns)$ , numeracy knowledge at all time points  $r_{\text{NumT3}}(65) = .40, p < .01$ ,  $r_{\text{NumT2}}(65) = .33, p < .01$ ,  $r_{\text{NumT1}}(65) = .28, p < .03$ . T-tests showed that children with perfect successor function scores but not counting skills had significantly higher Time 3 teacher-based patterning scores.  $t_{\text{successorfunction}}(63) = 3.77, p < .01$ ,  $t_{\text{counting}}(63) = 1.34, (ns)$ .

Discriminant validity was tested by correlating T3 Teacher-Based patterning with more distant constructs of language (T1) and spatial ability (T1, T2),  $r_{\text{Language}}(65) = .20, (ns)$  and  $r_{\text{T1spatial}}(65) = .24, (ns)$ ,  $r_{\text{T2spatial}}(65) = .12, (ns)$ .

To examine construct validity, we considered T3 item difficulties (see Table 1). AB patterns were generally easier for children than patterns with more complex pattern units, and by the end of Kindergarten, most children had mastered AB patterns, regardless of the task. ABC patterns were generally the hardest for children, regardless of the task. The one exception was the abstract AABB item, which was the hardest item at T3. Overall, ceiling effects of many items limited variability in item difficulty. Indeed, 48% of children solved all items correctly.

## Conclusions

The teacher-based patterning measure is reliable and valid for children near the end of kindergarten, although ceiling effects suggest the need for additional difficult items for kindergarteners. It correlates with valid measures of patterning and mathematics (especially numeracy), but not measures of more distant constructs. By the end of Kindergarten, the complexity of the pattern unit consistently related to item difficulty, similarly to the end of preschool (Zippert, Loehr, & Rittle-Johnson, 2018). In contrast, at the beginning of preschool,

task type (e.g., copy/extend) also influenced item difficulty. This suggests that younger children were still learning skills for solving the tasks, while older children had learned the strategies but had difficulty implementing them with more complex pattern units.

## References

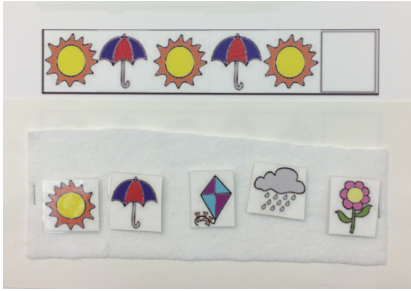
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Table 1: *Descriptive Statistics for Items on Teacher-Based Patterning Assessment Time 3*

Item number, type, and pattern unit	Proportion correct (SD)	Item-total correlation	Item difficulty (SE)
6. Extend AB	.94(.24)	.56	-.69(.42)
3. Missing AB	.91(.29)	.74	-.38(.41)
1. What's Next AB	.89(.31)	.70	-.23(.40)
9. Abstract AB	.89(.31)	.45	-.23(.40)
5. Missing ABB	.86(.35)	.62	.04(.39)
7. Extend AABB	.85(.36)	.57	.17(.38)
4. Missing ABC	.80(.40)	.38	.53(.36)
8. Extend ABC	.80(.40)	.67	.53(.36)
2. What's Next ABC	.77(.43)	.61	.78(.36)
10. Abstract ABBB	.74(.44)	.49	.96(.35)

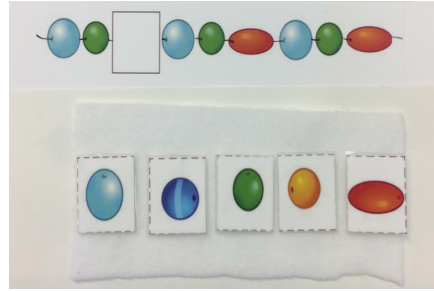
*Notes.* Items are listed in order of item difficulty. Negative item difficulty values are easier.

### What's Next Pattern AB



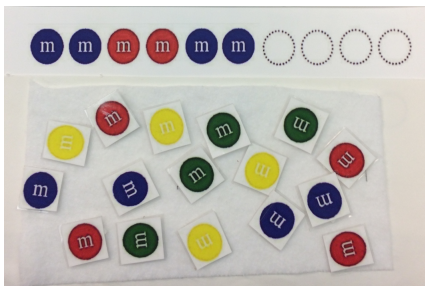
“What comes next in the pattern? Use one of these.” [Experimenter gestures to response options.]

### Missing Item Pattern ABC



“Find the missing bead [experimenter gestures to response options] to complete the pattern [experimenter gestures across pattern].”

### Extend Pattern AABB



“Can you complete the pattern?” [Experimenter gestures to circles on the right of the pattern.]

### Abstract Pattern ABBB



“Can you make the same kind of pattern using your pictures?” [Experimenter gestures to boxes below the model pattern.]

Figure 1. Sample Items on the Teacher-Based Patterning Assessment