MEASURING REPEATING PATTERNING SKILL IN KINDERGARTEN

ERICA L. ZIPPERT, ASHLI-ANN DOUGLAS, & BETHANY RITTLE-JOHNSON
VANDERBILT UNIVERSITY

Thanks so much for being here. My name is Erica Zippert and I am a postdoc at Vanderbilt University. I'm excited to talk to you today about some measure development work that my colleagues and I have done in assessing patterning skills in kindergarten.

INTRODUCTION

- Early math predicts later math achievement (Duncan et al., 2007)
- Math theory and research primarily focus on the role of number skills
- Patterning skills:
  - Predict concurrent and later math knowledge (Rittle-Johnson, Hofer, Farran, & Cummings, 2016; Rittle-Johnson, Zippert, & Boice, 2018)
  - Develop in preK and K (Rittle-Johnson, Fyfe, McLean, & McEldoon, 2013; Sarama & Clements, 2009; Starkey, Klein, & Wakeley, 2004)
  - Are included as a central algebraic topic in consensus documents in math education (NCTM, 2000; NAEYC, 2014)
  - Are not currently included in the Common Core as a content standard at any grade level (CCSS, 2010).

First, I'll set the stage as to why patterning is important.

As my co-presenters have also indicated, children's math skills develop early, even before the start of kindergarten. These skills varies substantially, and this variation predicts later math achievement in school.

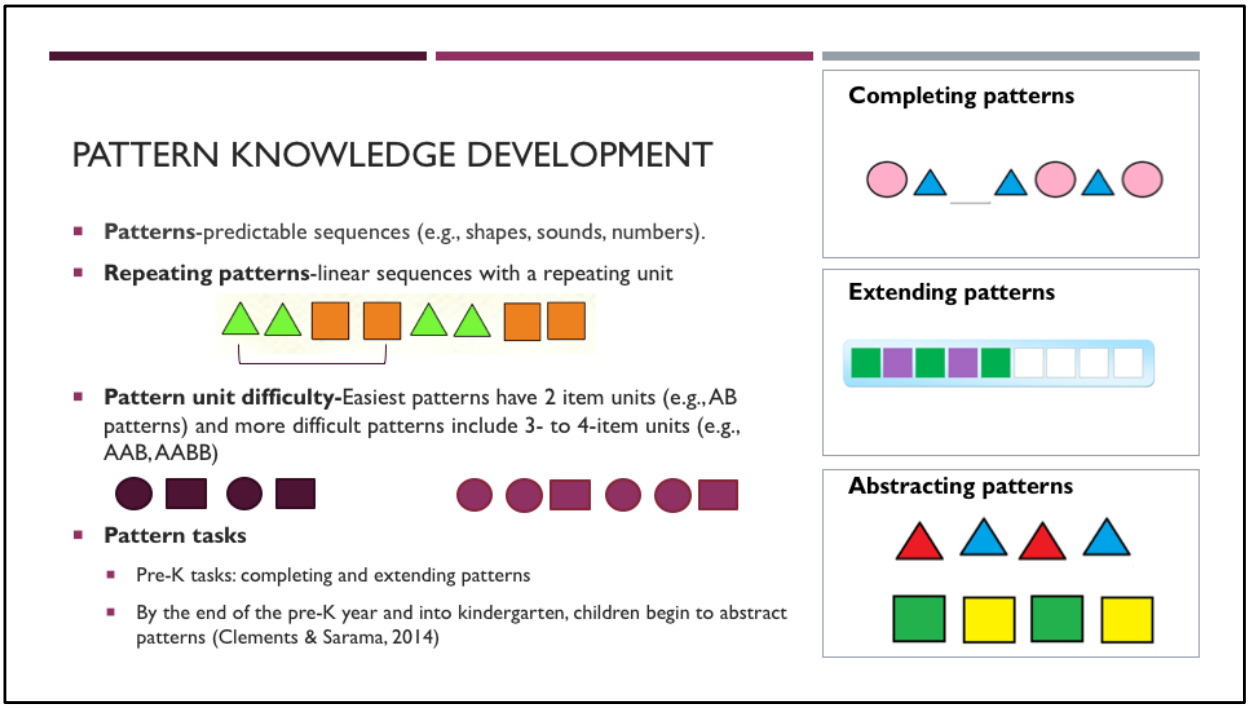
In looking to understand this math development, much research has focused on the contributions of numeracy skills.

However, more recent work, much of which was done by my co-presenters as well as my postdoc advisor Bethany Rittle-Johnson, has measured contributors of math more broadly than numeracy alone.

Patterning is one such non-numeracy skill, that has been shown to be predictive of concurrent and later math knowledge, and develop substantially in early childhood.

Further, it is included as a central algebra topic in consensus documents in math education, like those published from National Association for the Education of Young Children and the National Council of Teachers of Mathematics

However, patterning instruction is currently not part of the math content standards of the Common Core in any grade, so this work is important in helping to define patterning skills, and when reintroduced into curricula, providing easy ways for teachers to measure and teach them!



Now I'll define what I mean by patterning.

A pattern is a predictable sequence of objects, such as shapes, or sounds, and also involves functional relations between variables in its more complex form.

Repeating patterns are one type of pattern involving linear sequences of objects with a repeating unit. This type is of particular relevance for young children because no prior content knowledge is required. In fact, even kids with minimal verbal skills can understand patterning tasks! So as an example, I've included a pattern here with triangles and squares. Here triangle triangle square square (indicated by the bracket), is the unit that repeats over and over in this particular pattern

Repeating patterning problems vary in 2 main ways: ***the complexity of the unit, and the difficulty of the task***

To talk about pattern units, we often describe them with letters, so our example pattern with triangles and squares is an AABB pattern, because it includes 2 of one object, and 2 of another.

In terms of pattern development, young children start out working with AB patterns, with only 2 different items repeating over and over again. Our AABB pattern example has a much more difficult unit, as does our AAB example in the lighter purple

Next I'll define the different types of repeating pattern tasks of relevance to today's talk.

One of the easiest pattern task types is ***Completing*** patterns- and this involves filling in the missing pattern items, as you can see in the first example.

Extending pattern tasks are slightly more difficult, as they require children to continue patterns by at least one unit. Further, children can make errors if they do not continue the pattern with the right shape (such as putting a triangle instead of the rhombus next in the sequence in our pattern extension example)

More challenging still is ***abstracting*** patterns or recreating a pattern using different materials.

STUDY AIMS

- Create a pattern measure that is:
  - **Valid-** related to similar constructs but not to distant ones, item difficulties make sense theoretically
  - **Reliable**- high internal consistency and test-retest correlations
  - **Appropriate for kindergarteners**
  - **Teacher-friendly**-easy to assemble, administer, and score
- Extend current validated teacher-friendly preschool patterning measure into kindergarten

expand upon valid and reliable and appropriate for kindergarteners of different abilities

The goal of our study was to create a repeating patterning task for kindergarteners that is valid, reliable, and teacher-friendly. What I mean by teacher-friendly is that teachers can easily create, administer, and score the assessment. For a contrasting example, I'll describe what is involved in our existing researcher-developed pattern measure that we typically use in our lab takes. First, it takes hours to assemble and learn to give. Further, it takes 15-20 minutes to administer, and scoring is quite difficult and relies on stop criteria.

Having easily accessible teacher-friendly measures is imperative if teachers are to appropriately plan lessons and measure student learning (Purpura & Lonigan, 2015).

Currently, a valid and reliable teacher-friendly repeating pattern measure exists only for preschoolers, so we aimed to extend that measure into kindergarten.

PROCEDURE

Assessments		Time Administered		
Skill	**Measure name**	**Beginning of PreK (*n* = 77)**	**End of PreK (*n* = 73)**	**End of K (*n* = 65)**
General Math Knowledge	REMA-Brief (Numeracy and Geometry sections)	✓	✓	✓
Repeating Patterning	Teacher-friendly patterning	✓	✓	✓
	Research-based Patterning	✓		
Spatial Ability	WPPSI-IV Block Design	✓	✓	
Verbal Ability	NIH Toolbox Picture Vocabulary Test	✓		

Here is an overview of data collection for the study. We measured children's skills at 3 time points. Time 1 and Time 2 were at the beginning and end of preK, respectively, and time 3 was at the end of the Kindergarten year.

At all 3 timepoints, we administered our teacher-friendly patterning measure. Also as a more similar construct, we also measured general math and numeracy knowledge with Doug and Julie's REMA brief measure

At time 1 only, we assessed patterning skills using an already validated but more complicated to administer and assemble measure. It was our hope that our teacher friendly measure would be highly correlated with this measure.

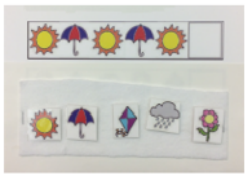
Also at time 1, as a more distant construct, we measured children's verbal ability using the NIH Toolbox Picture Vocabulary Test

At both Time 1 and 2, we measured spatial ability via the block design subtest of the WPPSI-IV. This was also to serve as a distant construct from patterning.

TEACHER-FRIENDLY PATTERN MEASURE

Pattern Completion

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 [experimen gestures to response options] to com the pattern [experimenter gestures a pattern]."

Extend Pattern AABB

"Can you complete the pattern [Experimenter gestures to circle 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.]

Now I'll talk about our teacher friendly patterning measure.

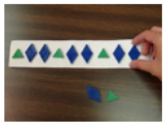
We developed this 6-minute assessment using pre-existing patterning worksheets found on resource websites for early-childhood educators, so the items were very easy to access and assemble (though we did make some modifications in line with previous research).

Children were presented with 10-items, worth 1-point each, of printed pictures of model patterns and laminated picture cutouts to fill in the blanks

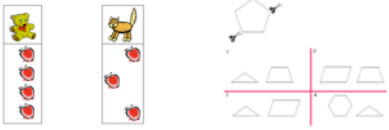
The task types included
completion items (or filling in missing items at the end or middle of the pattern),
extension (adding a unit's worth of items to the end of the pattern),
and what we aimed to be abstracting but turned out to be more like matching (duplicating the pattern with different materials).

OTHER MEASURES USED FOR RELIABILITY AND VALIDITY

- **Research-based patterning:** measured preschoolers' ability to duplicate, extend, and abstract repeating visual patterns at time 1, and consisted of nine items varying in difficulty, validated in previous studies (Rittle-Johnson et al., 2013; 2015).

- **General math knowledge** (with numeracy and shape knowledge subtest, & 1 patterning item): The REMA Short-Form contains a subset of items from the Research-Based Early Mathematics Assessment (Clements & Sarama, 2000)



Here is more specific information and sample items on the measures we used for validation and reliability of the teacher-friendly pattern measure.

For research-based pattern, like my previous examples, children duplicated, extended, and abstracted patterns using tangram shape blocks

Our General math measure contained both numeracy items, like this magnitude comparison problem, and shape knowledge items, like this decomposition problem here where children have to select which two shapes represent the target shape cut in a specific way

OTHER MEASURE DESCRIPTIONS

- **Spatial ability:** Block Design subtest of the WPPSI-IV

- **Verbal ability:** The Picture Vocabulary Test from version 1.6 of the NIH Toolbox app

The block design measure involved recreating model pictures by rotating and positioning these red and white blocks

The picture vocabulary test involved hearing a target word and picking the right picture out of 4 options

Finally, our numeracy measures included correct or incorrect counting to 100, and for successor principle measure, whether children knew that adding 1 to a quantity

PARTICIPANT DEMOGRAPHICS AT END OF KINDERGARTEN

- *n* = 65
- *M* = 6 years, 1 month, *SD* = 3.5 months
- 51% female
- Attended public and private kindergarten programs

We recruited 65 children who were about 6-years-old and finishing up their kindergarten year, about evenly distributed by gender, and attended a mix of public and private kindergarten programs.

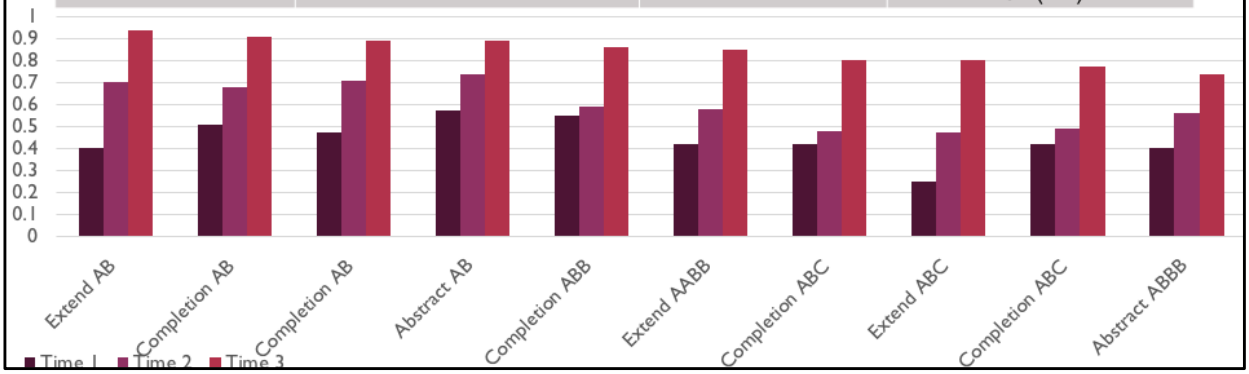
RESULTS: RELIABILITY OF TEACHER-FRIENDLY PATTERNING MEASURE

Now I'll talk about overall performance on our teacher-friendly patterning measure and evidence of reliability with kindergarteners

TEACHER-FRIENDLY PATTERN PERFORMANCE

Descriptive Statistics for Items on Teacher-Friendly Patterning Measure at all Timepoints

	Proportion correct (SD)		
	Time 1	Time 2	Time 3
Total score	.44 (.31)	.59 (.31)	.84 (.24)



Here we have descriptive statistics for total and individual items scores on our teacher friendly patterning measure across timepoints. For total scores, we saw a moderate but significant increase from time 1 to time 2, and a large improvement by the time kids were assessed at the end of kindergarten.

This trend is also reflected in the graph of proportion correct for individual items across the 3 timepoints
However, you will note that many children hit ceiling by the time they were finishing kindergarten. Specifically, 48% of children solved all items correctly. This limited the extent to which this measure was able to covary with other measures.

Paired Samples Test

		Paired Difference						
		Mean	SDEV	SEM	Lower	Upper	*t*	*df*	*p* <
Pair 1	T3_WSPattern_PropCorrect - T2_WSPattern_PropCorrect	.25231	.31480	.03905	.17431	.33031	6.462		

	64	.000			
Pair 2	T3_WSPattern_PropCorrect - T1_WSPattern_PropCorrect				.40615
	.33208	.04119	.32387	.48844	9.861
	64	.000			
Pair 3	T2_WSPattern_PropCorrect - T1_WSPattern_PropCorrect				.15385
	.26105	.03238	.08916	.21853	4.751
	64	.000			

RELIABILITY OF TEACHER-FRIENDLY PATTERN MEASURE

Internal Consistency and Test-Retest Correlation

Teacher-Friendly Patterning Scores	**Cronbach's α**	T3	T2	T1
Time 3	.86	-		
Time 2	.87	.37**	-	
Time 1	.83	.30*	.65***	-

*p<.05. **p<.01. ***p<.001. *Note*. For all patterning tasks, ability estimates were generated 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).

Taking a look at our Cronbach's alpha column, you can see that internal consistency was good for Time 3 teacher-friendly patterning, and this was comparable to those of Time 1 and 2.

Further, end of kindergarten performance was somewhat stable over time, with a moderate test-retest correlation with end of preschool at time 2 $r(63) = .38$, $p < .01$ and beginning of preschool at time 1 $r(63) = .29$, $p < .02$. We anticipate that these correlations would have been stronger had we had more variability in our teacher-friendly pattern measure

RESULTS: VALIDITY OF TEACHER-FRIENDLY PATTERNING MEASURE

Next I'll talk about validity evidence for the teacher-pattern measure

VALIDITY OF TEACHER-FRIENDLY PATTERNING MEASURE

Convergent and Concurrent Validity of Teacher-friendly Patterning end of Kindergarten				
Variables	1	2	3	4
1. T3 Teacher-friendly patterning scores	-			
2. T1 Research-Based patterning scores	.30*	-		
3. T3 Broad Math	.39**	.42**	-	
4. T3 Numeracy	.40**	.40**	.89***	-

*p<.05. **p<.01. ***p<.001. *Note*. Broad math and numeracy measures are both from the REMA brief.

change text to reflect what we left out

We tested convergent validity by correlating students' Time 3 Teacher-friendly patterning with T1 Research-Based patterning scores, and found a moderate .30 correlation

Concurrent and predictive validity was established by correlating our Time 3 Teacher Pattern measure with general math and numeracy knowledge at all 3 timepoints.

The correlations with general math was significant for time 2 and 3

The correlations with numeracy knowledge were also significant.

RESULTS: DISCRIMINANT VALIDITY

Discriminant Validity of Teacher-friendly Patterning at Time 3				
Variables	1	2	3	4
1. T3 Teacher-friendly patterning	-			
2. T1 Verbal Ability	.20	-		
3. T2 Spatial Ability	.12	.35**	-	
4. T1 Spatial Ability	.24	.23	.46***	-
**p<.01. ***p<.001.				

We tested discriminant validity by correlating time 3 teacher pattern scores with more distant measures of children's skills. As expected, we found that teacher pattern at time 3 did not significantly correlate with language ability at time 1 or spatial ability at time 1 or 2.

RESULTS: CONSTRUCT VALIDITY TEACHER PATTERN AT END OF K (T3)

Descriptive Statistics for Items on Teacher-friendly Patterning Assessment at end of Kindergarten

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

Next we looked at construct validity of the teacher pattern measure

I've ordered the items by difficulty and proportion correct, and as you can see, 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, also regardless of the task. The one exception was the abstract AABB item, which was the hardest item

Overall, ceiling effects of many items limited variability in item difficulty. Specifically, 48% of children solved all items correctly.

ITEM INFORMATION ON TEACHER PATTERN END OF PRE-K (TIME 2)

Descriptive Statistics for Items on Teacher-friendly Patterning Assessment at end of PreK

Item number, type, and pattern unit	Proportion correct (SD)	Item-total correlation	Item difficulty (SE)
9. Abstract AB	.74 (.44)	.52	-.65 (.29)
1. Complete AB	.71 (.45)	.65	-.51 (.29)
6. Extend AB	.70 (.46)	.78	-.44 (.28)
3. Complete AB	.68 (.46)	.73	-.37 (.28)
5. Complete ABB	.59 (.49)	.43	.09 (.28)
7. Extend AABB	.58 (.49)	.83	.15 (.28)
10. Abstract ABBB	.56 (.50)	.62	.22 (.28)
2. Complete ABC	.49 (.50)	.66	.53 (.27)
4. Complete ABC	.48 (.50)	.51	.59 (.27)
8. Extend ABC	.47 (.49)	.64	.65 (.27)

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

ITEM INFORMATION ON TEACHER PATTERN AT TIME 1

Descriptive Statistics for Items on Teacher-friendly Patterning Assessment at end of PreK

Item number, type, and pattern unit	Proportion correct (SD)	Item-total correlation	Item difficulty (SE)
9. Abstract AB	.57 (.50)	.46	-.60 (.26)
5. Complete ABB	.55 (.50)	.40	-.54 (.26)
3. Complete AB	.51 (.50)	.60	-.38 (.26)
1. Complete AB	.47 (.50)	.49	-.09 (.26)
2. Complete ABC	.42 (.50)	.34	-.04 (.26)
4. Complete ABC	.42 (.50)	.40	.08 (.26)
7. Extend AABB	.42 (.50)	.78	.14 (.26)
6. Extend AB	.40 (.49)	.77	.19 (.26)
10. Abstract ABBB	.40 (.49)	.42	.19 (.26)
8. Extend ABC	.25 (.44)	.60	.87 (.27)

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

DISCUSSION

- The teacher-friendly patterning measure is reliable and valid for the end of K because it:
  - Correlates with valid measures of patterning and mathematics (especially numeracy)
  - Does not correlate significantly with measures of more distant constructs
- Like end of pre-K (Zippert, Loehr, & Rittle-Johnson, 2018):
  - Pattern unit complexity drove item difficulty
- Unlike beginning of pre-K:
  - task type influenced item difficulty much less
- Harder items need to be added to achieve more variation in kindergarteners

We found evidence for reliability and validity of the teacher-friendly patterning measure in kindergarten given that it

correlates with other patterning and math measures

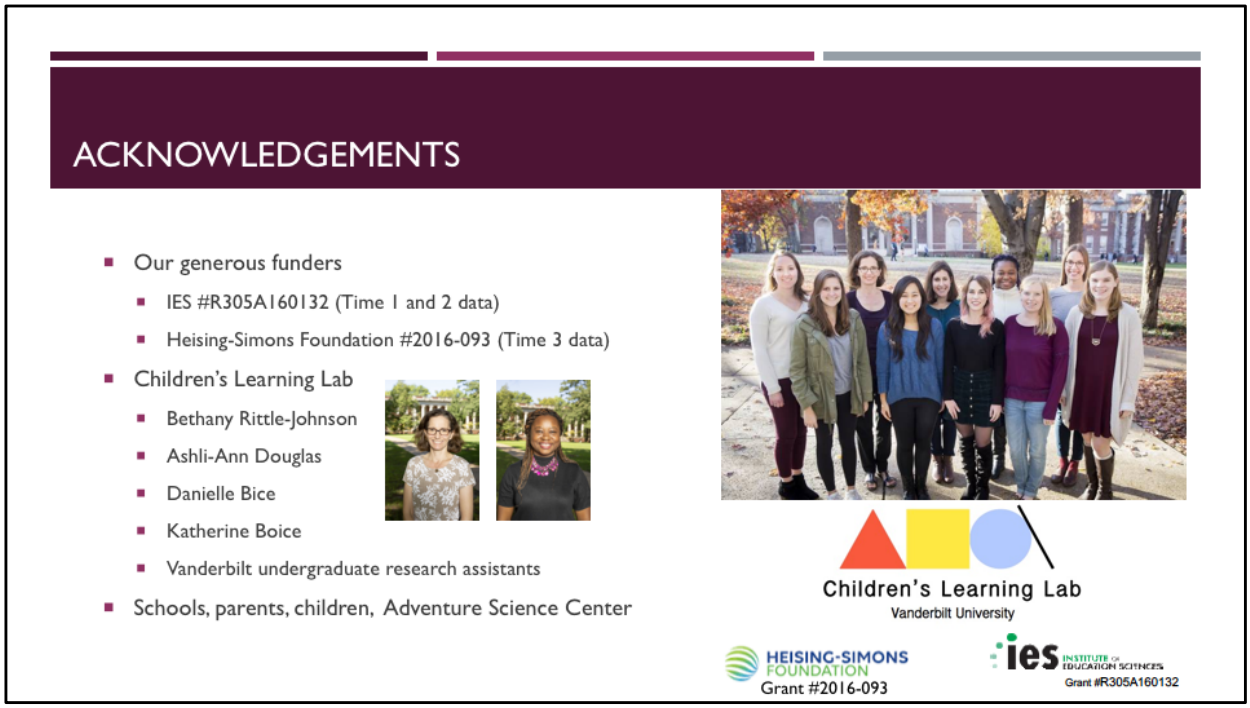
It does not relate to more distant constructs

Similar to performance on this measure at Time 2, pattern unit complexity drove student performance

However, unlike the beginning of prek

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.

However, ceiling effects suggest the need for more difficult items for kindergarteners.



I'd like to thank our generous funders Heising-Simons for funding the collection and analysis of our Time 3 data, and IES for our Time 1 and 2 data.

Thanks also to my post doc advisor Bethany, the doc student in the lab Ashli-Ann Douglas, all of the amazing students and staff in the Children's learning Lab at Vanderbilt, and of course to the schools, parents, and children who participated their time, space, and their data!

QUESTIONS?