Exploring the Roles of Pattern and Spatial Skills in Early Mathematics Development

Outline

- New Assessment: Early Patterning Assessment (EPA)
  - Textbook analysis
  - Design of new assessment
  - Results of Study 1d Fall 2019 assessment (EPA 2019)
  - Results of Study 1d Fall 2020 online assessment: (EPA 2020 - Online)
  - Results of Study 1d Spring/Summer 2022 in person (added at end)

Early Patterning Assessment (EPA)

Rittle-Johnson, B., Douglas, A., Zippert, E., Özel, S. & Tang, J. (2020) *Early Patterning Assessment.* Available from B. Rittle-Johnson, Vanderbilt University, Nashville, TN 37203.

Goal:

- Develop a valid and reliable measure of 4- to 6-year-old children's repeating and growing patterning knowledge that is faster and easier to administer than existing measures.
- Process:
    - Textbook analysis
    - Design of measure
    - Pilot Kindergarten students (in person, Fall 2019)
    - Revise measure
    - Convert to online measure
    - Pilot 4-6 year old children

Background: Textbook Analysis

- Reviewed kindergarten math textbooks from several major publishers for activities on repeating and growing patterns.
- After 2012, when Common Core was adopted, almost no patterning activities included in Envision Math or GOMath! curriculums.
- 2011 edition of Envision Kindergarten Math curriculum had many patterning task; 2005 edition of Houghton Mifflin Math Kindergarten curriculum was available and also had many. Did analysis of these patterning activities, which informed our new measure.
- Report on our project webpage

Textbook Analysis cont.

Pattern Type and Units

- Repeating patterns were common
  - Pattern units primarily AB, ABB, AAB and ABC
- Growing patterns were rare
  - Pattern unit almost all add 1

Task Type

- Extend items most common across pattern types, esp. growing
- Other common repeating pattern task:
  - Identify pattern unit
  - Abstract pattern
  - Create new pattern
  - Select missing item (pattern completion) was rare

EPA– Repeating Pattern Subscale

Fall 2019

- 5 task types, with 4 items each. Total of 20 items
- 5 Tasks: (see next slides for examples)
  - Existing: Completion, Extension, Abstraction, Identify pattern unit
  - New: Pattern identification (Is this a pattern?)
- Repeating Pattern Units
  - AB, AAB, ABB, ABC, AABB, AABC, ABCC, ABCD

Fall 2020

- Four task types, with 4 items each. Total of 16 items
  a. Identify pattern unit dropped due to difficulties administering online and other difficulties with item type. (would try again in-person)

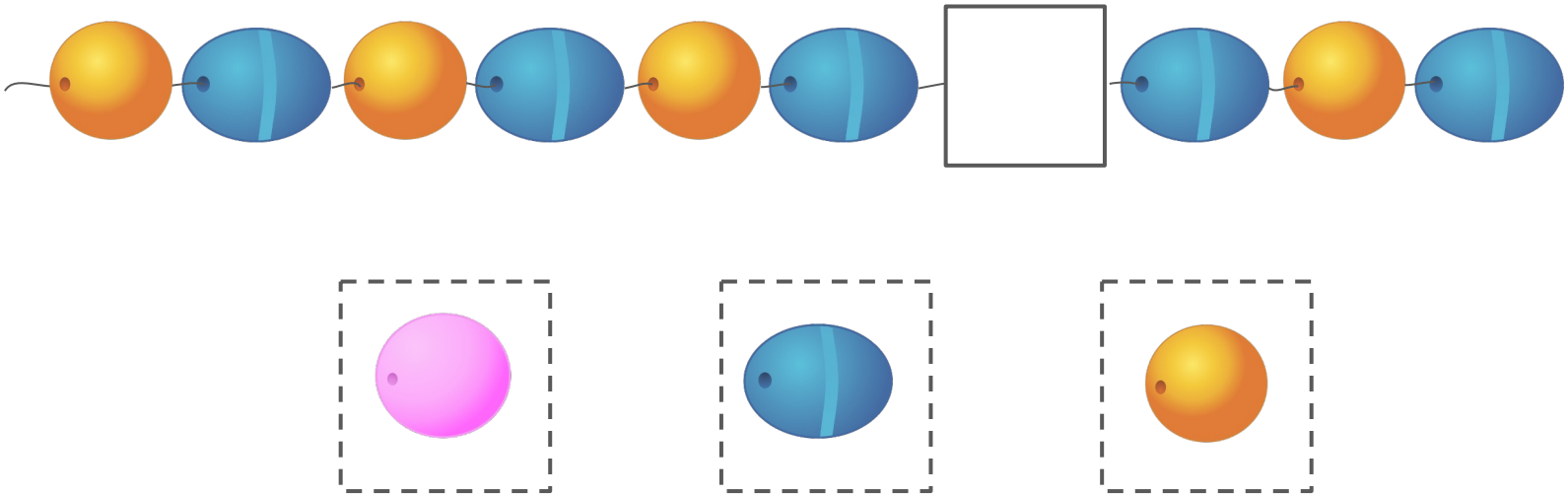
Repeating Subscale Example Items

Pattern Identification AABB

Identification Non Pattern

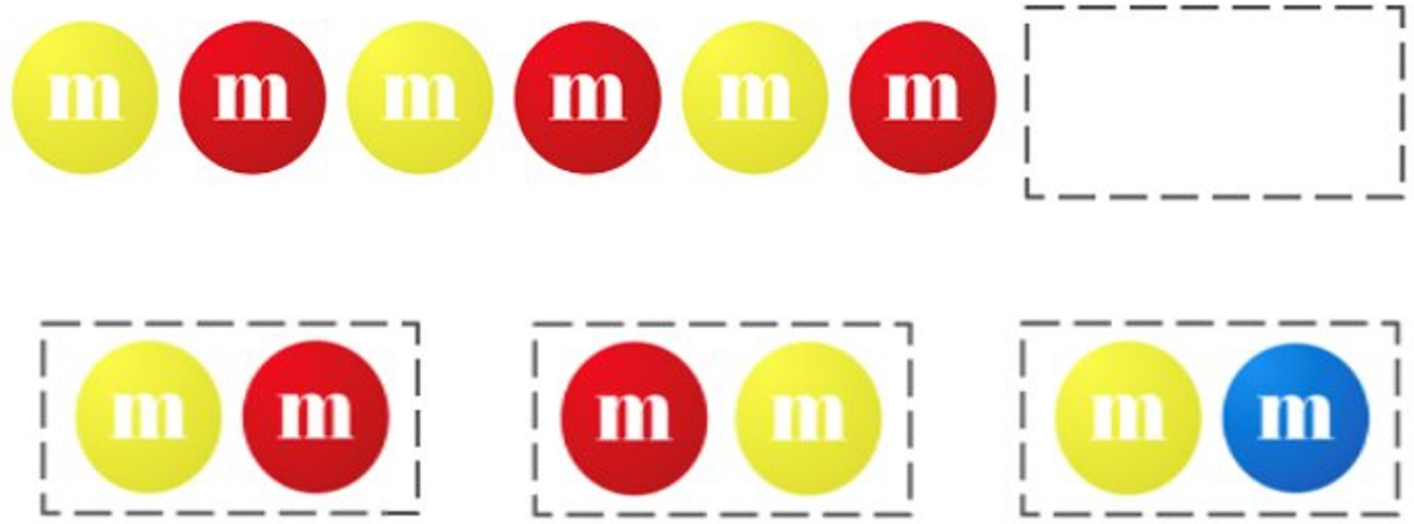
Repeating Subscale Example Items

Completion AB Pattern



Repeating Subscale Example Items

Extend AB Pattern



Repeating Subscale Example Items

Abstract AAB Pattern

EPA – Growing Patterns Subscale

Fall 2019

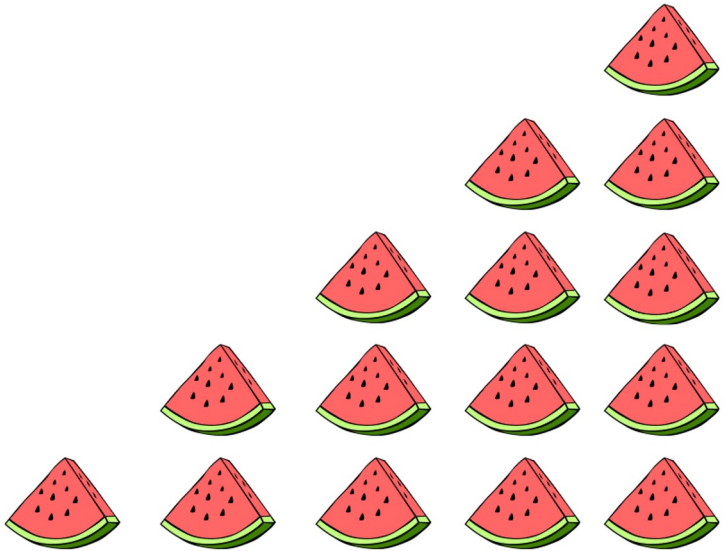
- Three task types, 4-5 items per type. Total of 14 items.
- 3 Tasks: (see next slides for examples)
  - Completion, Extension, Identify pattern unit
- 4 Growing Pattern units
  - Increasing vs. Decreasing; Change of 1 vs Change of 2
- Patterns created with Objects vs. Numerals

Fall 2020

- Four task types. Total of 18 items
  - Added pattern identification items (piloted 6 items to identify best 4 items. Then scored as a pair of items (1 pattern and 1 non-pattern).
  - Pattern unit identification decreased to two items because so difficult
  - Afterwards, dropped items from analyses due to poor item fit, identification of best pattern identification items and combined scoring of pairs of identification items.

Growing Subscale Example Items

Identification Add 1 Object

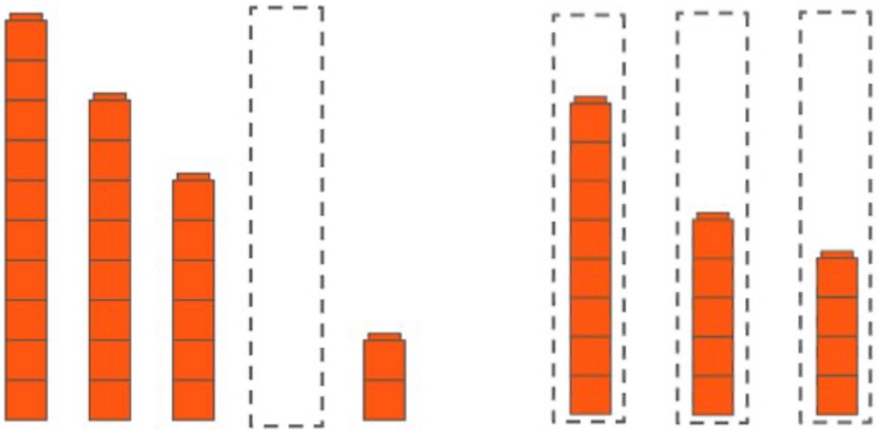


Identification Subtract 2 Numerals

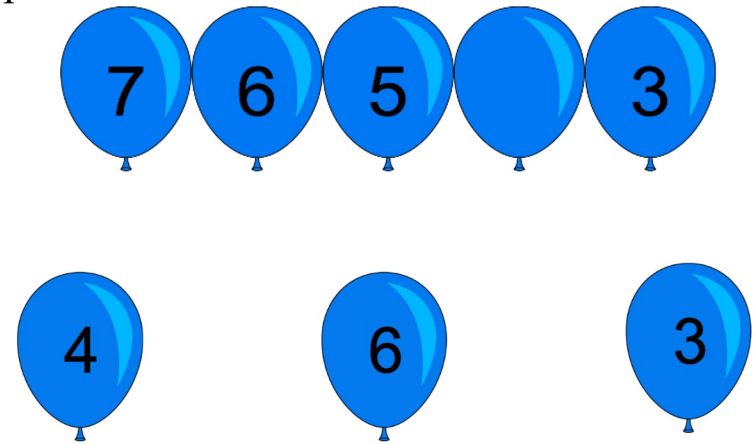
Identification Non Pattern

Growing Subscale Example Items

Completion Subtract 2 Objects



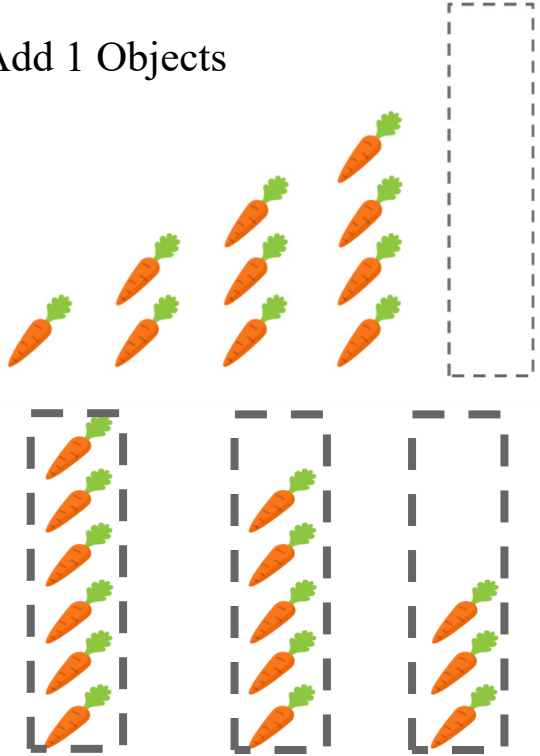
Completion Subtract 1 Numerals



Growing Subscale Example Items

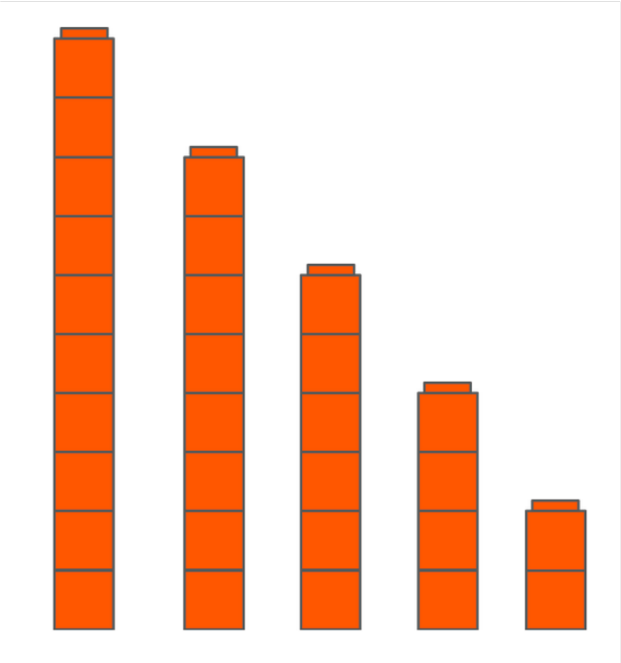
Extend Add 2 Numerals

Extend Add 1 Objects



Growing Subscale Example Items

Identify Pattern Unit: Subtract 2 Objects



Identify Pattern Unit: Add 2 Numerals

Method

Fall 2019 (in person)

- 5- to 7-year-olds attending local private school (first term of kindergarten)
  - 47 children (M = 5.90 years, SD = .40)
  - 53% female, 72% white, 66% no financial assistance to attend school, 98% English only at home, 81% no early intervention
- Repeating and growing patterning knowledge assessed
- Counterbalanced order of subscales administration
- Results to be presented at SRCD 2021

Revised Measure

Fall 2020

- Updated our early pattern assessment with improvements to items and change to online format
  - Assessment via Open Lab; used Zoom for a synchronous session
- Assessing preschool AND kindergarten students to examine fit across full target age range for assessment
- Link to Open Lab Assessment of EPA 2020 - online: https://open-lab.online/invite/EarlyPatterningAssessmentOnline/

Method

Fall 2020 (Online)

- 4- to 6-year-olds recruited from research database and Nashville schools
    - 96 children (M = 5.1 years, SD=.65)
    - 51% girls, 88% white, 94% English only at home, 91% not receiving early intervention, 97% no financial assistance to attend school
    - Grade level: 57 pre-k, 36 kindergarten, 3 other (e.g. not attending school due to COVID)
- Repeating subscale always completed before growing subscale because repeating scale confirmed to be easier in Fall 2019 data

Results – Fall 2019 Descriptive Statistics Kindergarten children only

	Growing (12 items)	Repeating (20 items)	Total (32 items)
Mean (SD)	.50 (.22)	.75 (.17)	.64 (.16)
Median	.50	.75	.67
Minimum	.07	.35	.32
Maximum	.93	1.00	.97
Cronbach's Alpha	.74	.76	.81

Results – Fall 2019 (Kindergarten children only)

- Children's repeating and growing patterning knowledge were positively correlated, $r(45) = .39$, $p < .01$.
- Children were significantly better at completing repeating than growing patterning tasks, $t(46) = 7.79$, $p < .001$.
- Notably, accuracy was higher among children who completed repeating patterns first than among children who completed growing patterns first (15% higher on growing items and 7% higher on repeating items).

Results – Fall 2019 - Wright Map

Note: Easiest items at top

2019 Wright Map Conclusions (Kindergarten children only)

- Repeating patterns:
  - Easiest task: Identifying repeating patterns (Is this a pattern?)
  - Completion and extend items did not differ substantially in difficulty,
  - Abstract items were harder, but not a lot harder
  - Pattern units with three and four unique elements (i.e., ABCD and ABC/AAB) had similar IRT difficulty estimates
- Growing patterns:
  - Most difficult: Identifying the pattern unit
  - Similar performance on items with objects versus numerals
  - Growing patterns with a change-by-2 pattern rule were more difficult than ones with a change-by-1 rule for missing and extend items

Results – Fall 2020 Descriptive Statistics PreK & K students

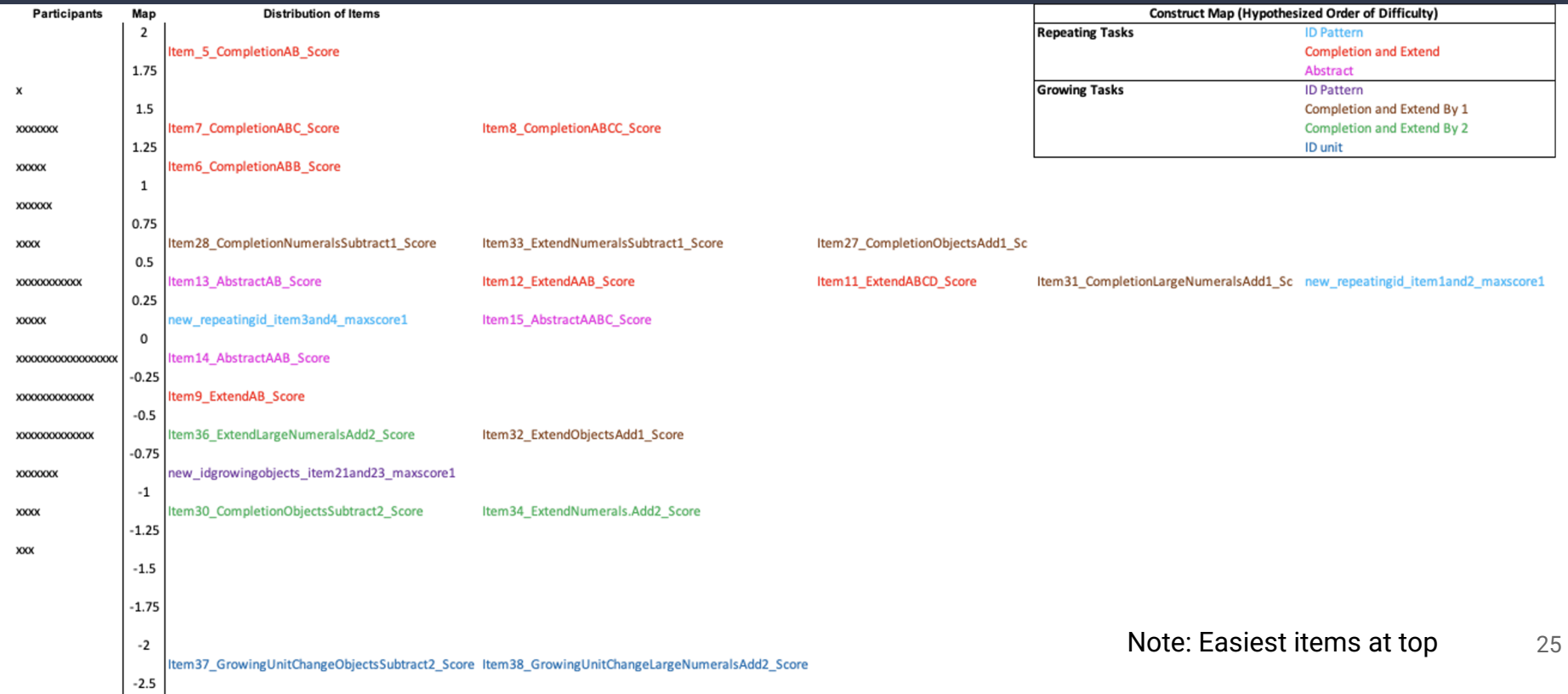
	Growing (11 items)	Repeating (12 items)	Total (23 items)
Mean (SD)	.49 (.13)	.67 (.20)	.57 (.14)
Median	.50	.69	.56
Minimum	.22	.19	.33
Maximum	.83	1.00	.88
Cronbach's Alpha	.48	.73	.74

(numbers reflect analyses after dropping items with very poor item fit and selection of pattern identification items)

Results – Fall 2020

- Children's repeating and growing patterning ability estimates were positively correlated, $r(95) = .40$, $p < .001$
  - Children's repeating and growing pattern ability estimates were somewhat positively correlated after controlling for age, $r(93) = .19$, $p = .067$
- Children were significantly better at completing repeating than growing patterning tasks, $t(85) = 11.41$, $p < .001$

Results – Fall 2020 - Wright Map



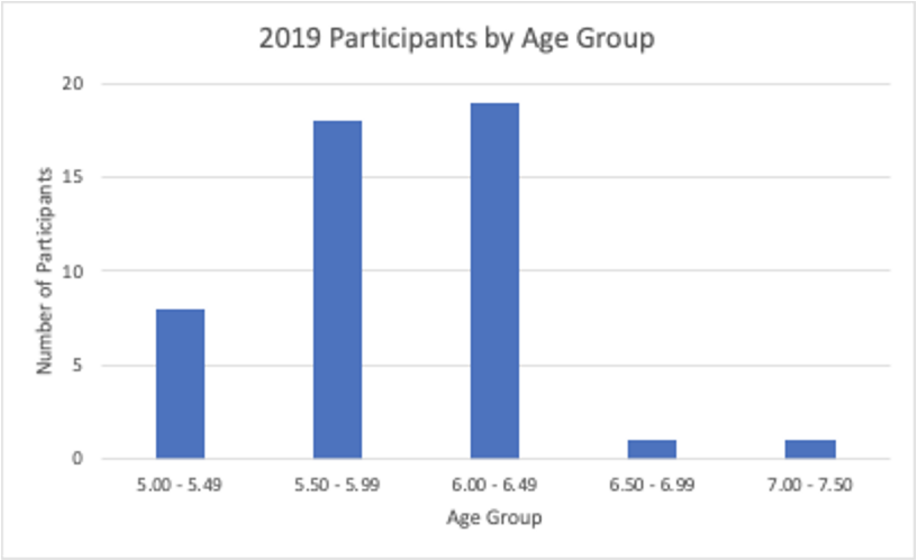
Construct Map (Hypothesized Order of Difficulty)	
Repeating Tasks	ID Pattern
	Completion and Extend
	Abstract
Growing Tasks	ID Pattern
	Completion and Extend By 1
	Completion and Extend By 2
	ID unit

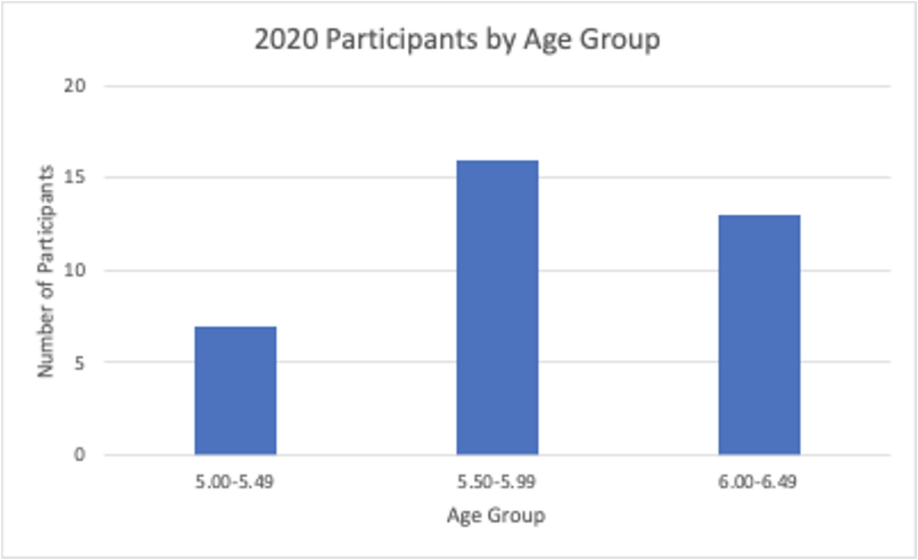
Note: Easiest items at top

Wright Map Conclusions

- Repeating patterns:
  - Easiest task: Completion
    - Pattern Identification was not easiest, as it had been in 2019 data (Note: somewhat easier when items are scored separately, but not the full reason)
  - Completion easier than Extend, unlike in 2019; in line with Clements & Sarama (2009)
  - Extending and Abstracting repeating patterns similar difficulty, unlike 2019 where Extend items were easier than Abstract items
- Growing patterns:
  - Trends similar to 2019
    - Most difficult items were Pattern unit identification
    - Growing patterns with a change-by-2 pattern rule were more difficult than ones with a change-by-1 rule for completion and extend items
    - No clear distinction that objects items were easier than numeral items

In-person vs Online Participants in Kindergarten





In-person vs. Online Participants in Kindergarten – Accuracy for Repeating patterning items

	In-Person	Online
Task Type	**Accuracy Mean % (SD)**	**Accuracy Mean % (SD)**
Pattern Identification	90.8 (15.2)	83.3 (23.1)
Completion	85.9 (20.2)	91.4 (15.0)
Extend	84.2 (21.9)	73.8 (26.9)
Abstract	66.3 (33.0)	72.2 (30.6)

In-person vs. Online Participants in Kindergarten - Accuracy for Growing patterning items

	In person	Online
Cronbach's Alpha	.74	.50
Task Type	**Accuracy Mean % (SD)**	**Accuracy Mean % (SD)**
Completion	63.5 (25.8)	64.3 (23.9)
Extend	58.2 (31.2)	42.2 (26.1)
Identify Pattern Unit	24.4 (28.1)	19.4 (34.4)

EPA Overall Conclusions – Fall 2019 & 2020

New Assessment: Early Patterning Assessment (EPA)

- Dissemination of measure
  - Repeating patterning measure is reliable across ages and formats and can be used and shared.
  - Growing patterning subscale needs future revision and development, although is ok to include if don't use subscale score.
  - No clear, systematic differences in assessment difficulty with adaption to online version.
- Repeating pattern subscale performance across 2019 and 2020:
  - Identification and completion items appear to be easiest, followed by extend items, followed by abstract items
- Growing pattern subscale performance across 2019 and 2020:
  - Completion and extend similar performance and easier than ID pattern unit items. New pattern identification items need further refinement.
- Your thoughts and suggestions?

Method: EPA-Repeating Revision Spring/Summer 2022

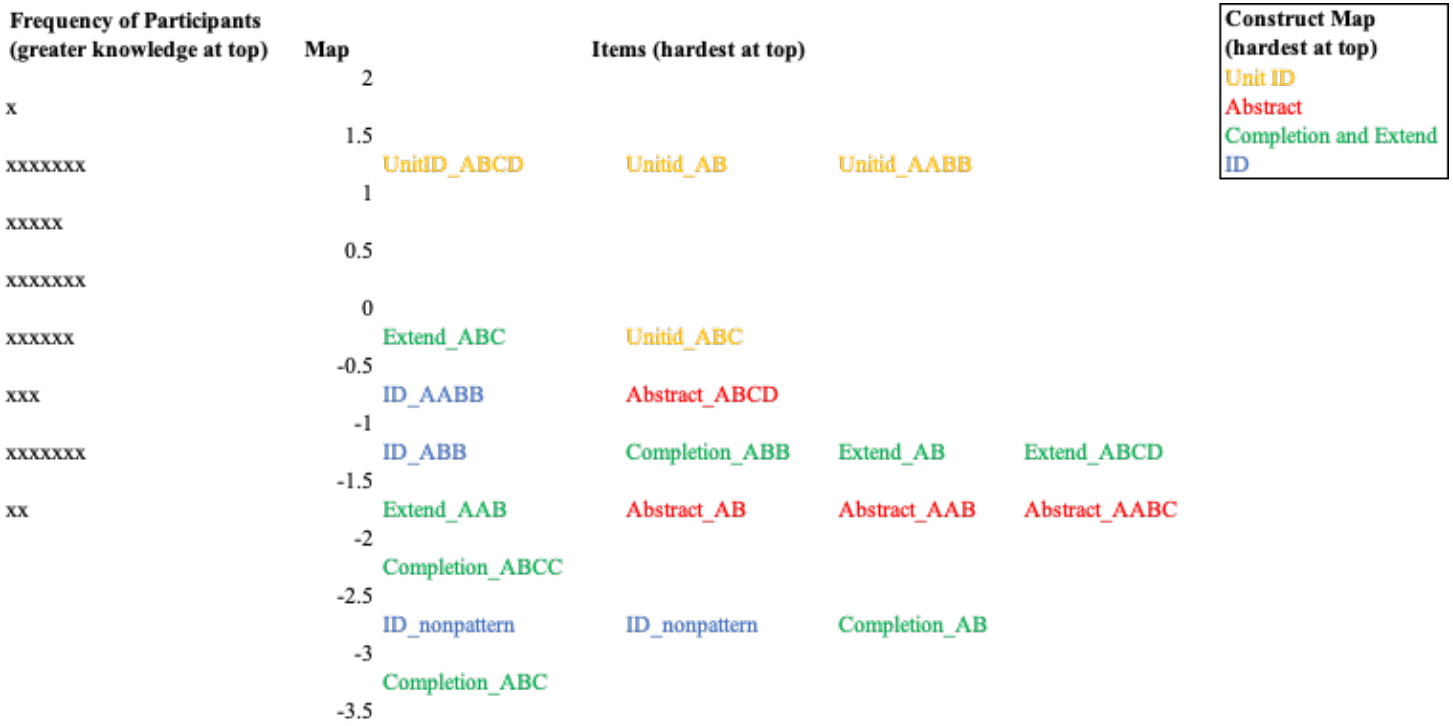
- Goal: further refine our **repeating patterning** measure
- 39 5- and 6-year-olds (*M* = 6.51, *SD* = 0.38) at two schools in metropolitan Nashville completed the measure in person
- Spring data collection occurred at an affluent private school in a metropolitan setting
- Summer data collection occurred during a summer program at a Title I metropolitan school
- 54% White, 28% children of Color, and 17% choosing not to report
- 20% of participants' parents indicated they do not speak English in the home
- Time 2 occurred approximately 2 weeks later after students had received 5 patterning + numeracy tutoring sessions. Only involved students who did not pretest out, defined as at or above 80% correct on both patterning and numeracy (SENS) pretest.

EPA Revision Spring/Summer 2022 - Results

Pattern Type	Mean Accuracy (SD)
Pattern Identification	81% (0.39)
Completion	86% (0.35)
Extend	80% (0.45)
Abstract	78% (0.42)
Unit ID	34% (0.47)

- Internal reliability of EPA-Repeating was good, Cronbach's alpha = 0.81
- Test-retest reliability was good, $r(17) = 0.71$.
- At pretest, patterning and numeracy knowledge (SENS) significantly correlated, $r(36) = .464$, $p < .01$

Spring/Summer 2022 – Results – Wright Map



Spring/Summer 2022 – Conclusions

- EPA-Repeating is a reliable measure and can be used and shared with others
- Children's repeating patterning knowledge, as measured via the EPA-Repeating, was concurrently positively related to children's numeracy knowledge
- Unit ID items appear to be the most challenging, while no clear distinctions are seen between ID, completion, extend, and abstract items
- Revisions made based off this round of data collection: any items that varied by only one dimension (e.g., color), were revised to vary along two dimensions (e.g., color and shape)
- Updated version of the EPA-Repeating can be found on our website: https://peabody.vanderbilt.edu/departments/psych/research/research_labs/childrens_learning_lab/IESprojects-and-materials.php

Supplemental Slides

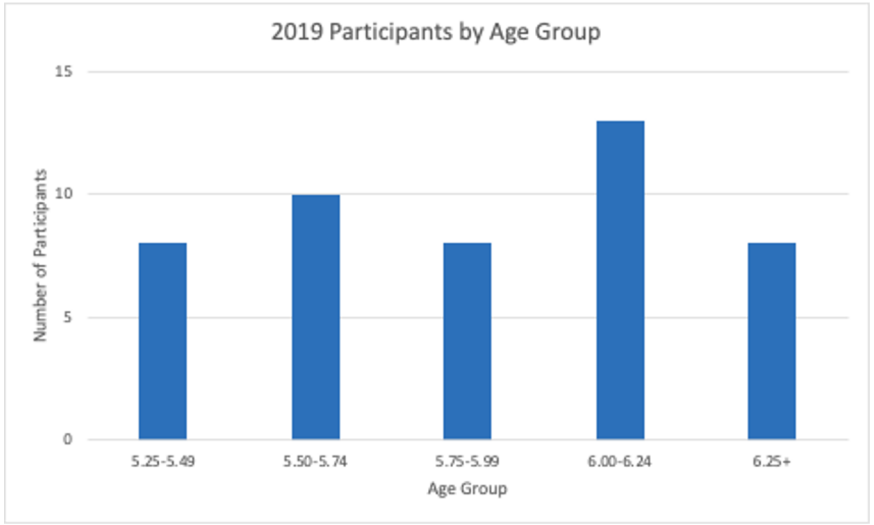
Results – Fall 2020 - Wright Map (reflect analyses without dropping items)

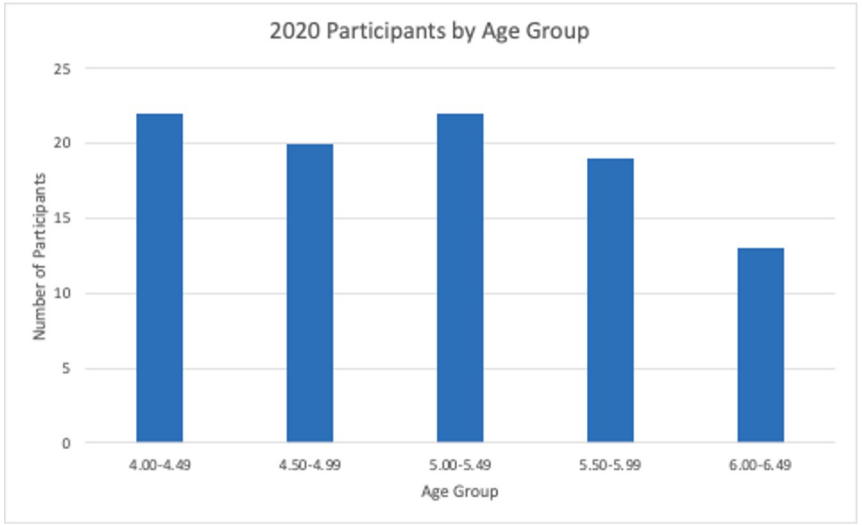
Note: Easiest items at top

Wright Map Conclusions

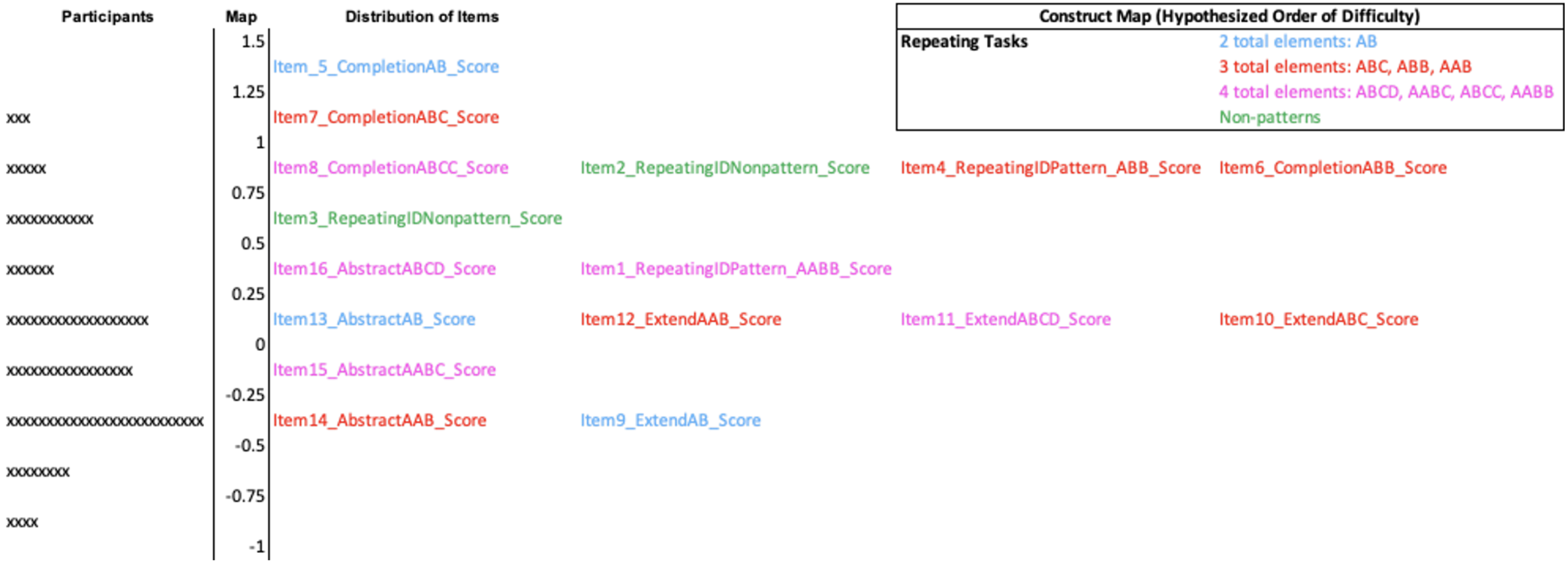
- Suggests the easiest task was identifying repeating patterns while the most difficult was identifying the pattern rule of growing patterns
- Contrary to predictions:
    - Completion still seems easier than extend (but in line with Clements' research e.g., Clements & Sarama, 2009 and is not surprising since we include 4-year-olds)

Age Bins Comparison In- person vs Online



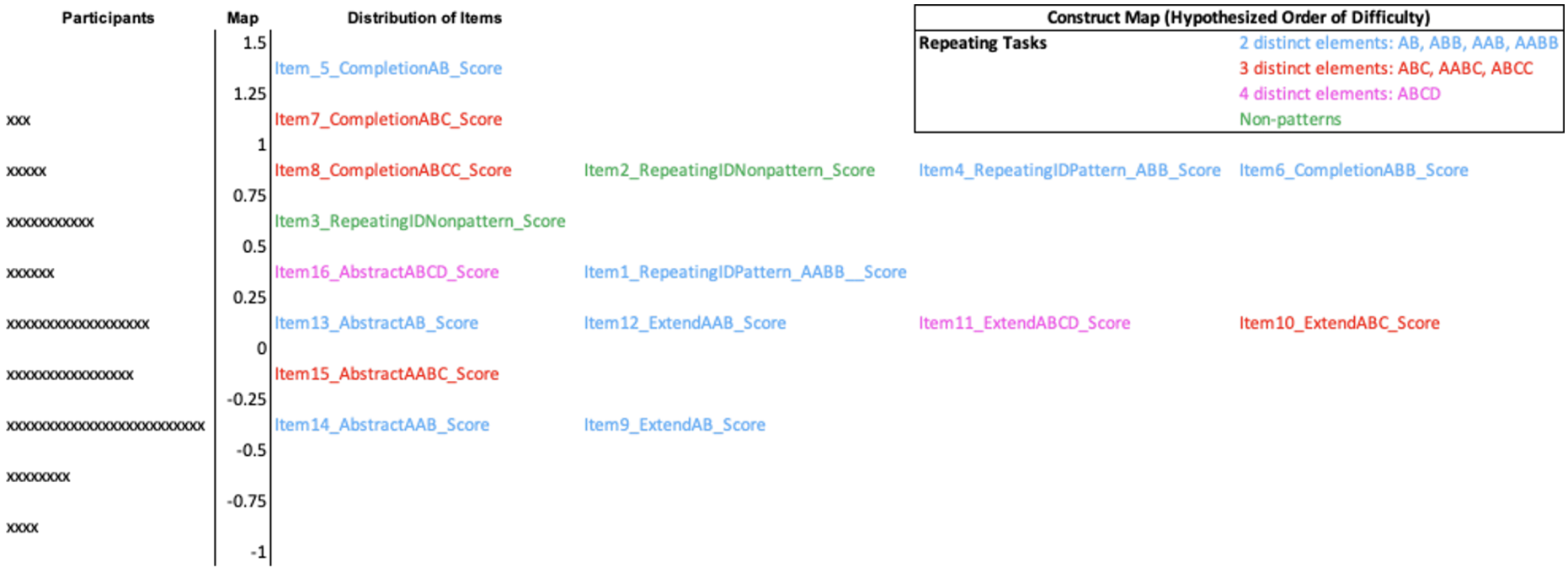


Repeating Only Wright Map - Number of Total Elements in Pattern



Note: easiest items at top.

Repeating Only Wright Map - Number of Distinct Elements in Pattern



Note: easiest items at top.

In-person vs Online Participants