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 children³

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 <u>our project webpage</u>

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

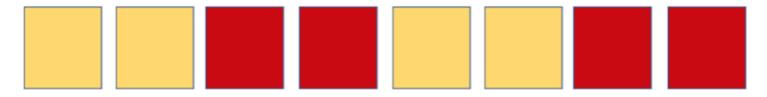
Fall 2019

- 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)

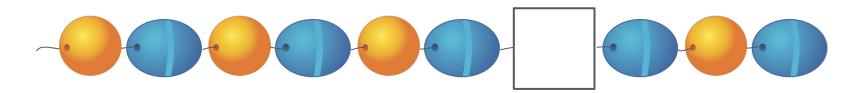
Pattern Identification AABB

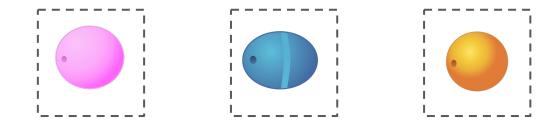


Identification Non Pattern



Completion AB Pattern



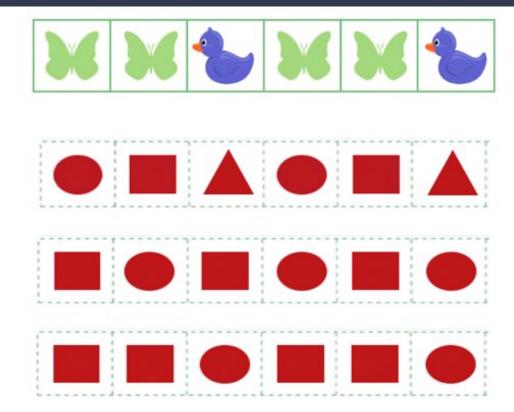


Extend AB Pattern





Abstract AAB Pattern



EPA – Growing Patterns Subscale

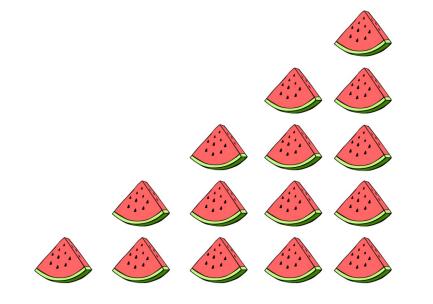
Fall 2019

- 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.

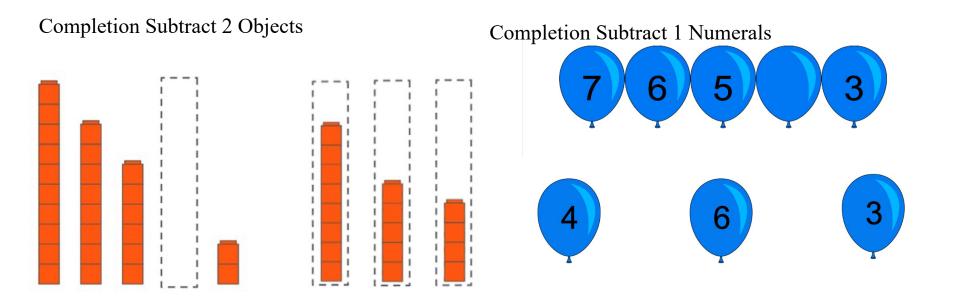
Identification Add 1 Object



Identification Subtract 2 Numerals

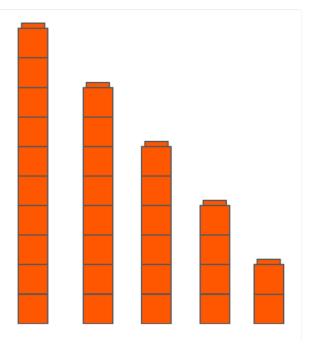


Identification Non Pattern





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: <u>https://open-lab.online/invite/EarlyPatterningAssessmentOnline/</u>

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	Repeating	Total
	(12 items)	(20 items)	(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 19

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

Participants	Мар	Items			Construct Map (Hypo	thesized Order of Difficulty)
	2.5				Repeating Tasks	ID if pattern
		CBP_15_completion_AB_score	CBP_27B_IDpattern_itemB_score (not pattern)			Completion & Extend
	2					Abstract
хх		CBP_27A_IDpattern_itemA_score (ABC pattern)	CBP_27C_IDpattern_itemC_score (not pattern)			ID Pattern Unit
		CBP_18_completion_ABCD_score	CBP_19_extend_AB_score		Growing Tasks	Completion & Extend by 1
	1.5					Completion & Extend by 2
XXXXXXX						ID rule
		CBP_22_extend_ABCD_score				
	1					
XXXXXXXX		CBP_16_completion_ABB_score	CBP_20_extend_AABB_score			
		CBP_23_abstract_AAB_score				
	0.5					
XXXXXX		CBP_2_completion_sub1_score_numerals	CBP_27D_IDpattern_itemD_score (ABB Pattern)			
		CBP_1_completion_add1_score_objects	CBP_5_completion_sub1_score_numeral_bigger			
XXXXX		CBP_7_extend_sub1_score_numeral	CBP_25_abstract_ABC_score			
	0					
		CBP_24_abstract_ABBB_score	CBP_6_extend_add1_score_objects	CBP_17_completion_ABC_sco	CBP 21 extend ABCC score	CBP_30_IDpatternunit_ABC_score
		CBP_29_IDpatternunit_AABB_score				
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX						
XXXXXX		CBP_4_completion_sub2_score_objects				
	-0.5					
		CBP_8_extend_add2_score_numerals				
XXXXX						
		CBP_31_IDpatternunit_ABCD_score				
x		CBP_10_extend_add2_score_Numerals_bigger	CBP 26 abstract ABCD score			
	-1					
хх		CBP_9_extend_sub2_score_objects				
xx						
		CBP_3_completion_add2_score_numerals				
	-1.5					
хх		CBP_12_IDPatternRule_sub2_score_objects				
x						
		CBP_11_IDPatternRule_add1_score_objects				
x	-2					
~	-	CBP_13_IDPatternRule_add2_score_Numerals				
	-2.5				A.I	F
	2.5	CBP_14_IDPatternRule_sub1_score_Numerals			Note:	Easiest items at te
		CBP_28_IDpatternunit_AB_score				
	-3					

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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	Repeating	Total
	(11 items)	(12 items)	(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 (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

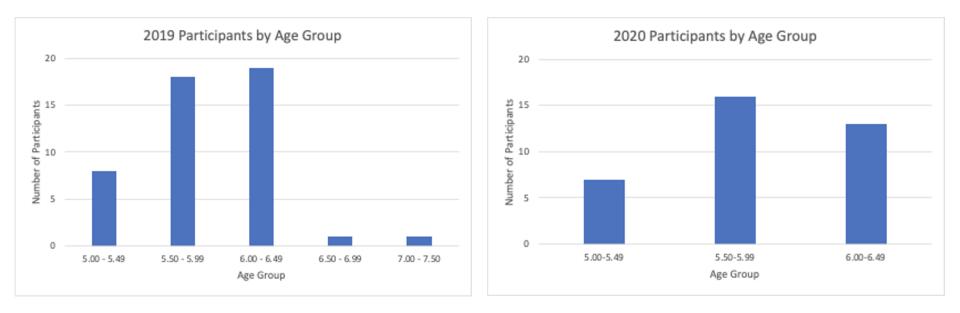
Results – Fall 2020 – Wright Map

Participants	Мар	Distribution of Items			Construct Map (Hypothes	sized Order of Difficulty)	
. al a copanio	2				Repeating Tasks	ID Pattern	
		Item_5_CompletionAB_Score				Completion and Extend	
	1.75					Abstract	
x					Growing Tasks	ID Pattern	
	1.5					Completion and Extend By 1	
X000000X		Item7_CompletionABC_Score	Item8_CompletionABCC_Score			Completion and Extend By 2	
	1.25					ID unit	
XXXXXX		Item6_CompletionABB_Score					
	1						
X00000X	0.75						
2000	0.75	Item28_CompletionNumeralsSubtract1_Score	Item33_ExtendNumeralsSubtract1_Score	Item27_CompletionObjectsAdd1_Sc			
XXXXX	0.5	ttem28_completionwumeraisSubtract1_Score	temss_extendivumeraissubtracti_score	nem27_completionobjectsAdd1_3c			
X000000000X	0.5	Item13_AbstractAB_Score	Item12_ExtendAAB_Score	Item11_ExtendABCD_Score	Item31_CompletionLargeNumeralsAdd1_Sc	new repeatingid item1and2 maxsco	vre1
10000000000	0.25				tempi_completionizargentanciabilitati_be	hen_hepean.Bra_hemzanaz_heroso	
X0000X		new_repeatingid_item3and4_maxscore1	Item15_AbstractAABC_Score				
	0						
x0000000000000000000000000000000000000		Item14_AbstractAAB_Score					
	-0.25						
X00000000000X		Item9_ExtendAB_Score					
	-0.5						
X0000000000X		Item36_ExtendLargeNumeralsAdd2_Score	Item32_ExtendObjectsAdd1_Score				
	-0.75						
X000000X		new_idgrowingobjects_item21and23_maxscore1					
	-1	Item30_CompletionObjectsSubtract2_Score	lana 24 Estas delum anda Add2 Casar				
XXXXX	-1.25	Item 30_CompletionObjectsSubtract2_Score	Item34_ExtendNumerals.Add2_Score				
XXXX	-1.25						
200	-1.5						
	2.0						
	-1.75						
	-2				Note: Easiest	items at top	25
		Item37_GrowingUnitChangeObjectsSubtract2_Score	Item38_GrowingUnitChangeLargeNumeralsAdd2_Score	1		•	
	-2.5						

Wright Map Conclusions

- Repeating patterns:
 - $\circ \quad \text{Easiest task: Completion} \\$
 - 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 changeby-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)

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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

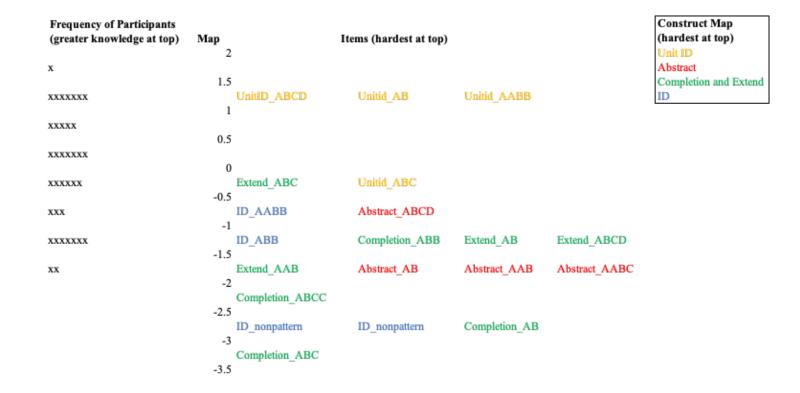
- Goal: further refine our **repeating patterning** measure
- 39 5- and 6-year-olds (*M* = 6.51, *SD* = 0.38) at two schools in metropolitan Nashville completed the measure in person
- Spring data collection occurred at an affluent private school in a metropolitan setting
- Summer data collection occurred 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: <u>https://peabody.vanderbilt.edu/departments/psych/research/research_labs/c</u> <u>hildrens_learning_lab/IESprojects-and-materials.php</u>

Supplemental Slides

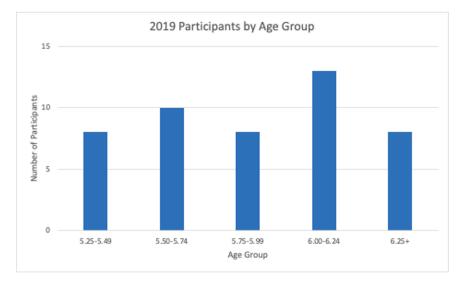
Results – Fall 2020 – Wright Map (reflect analyses without dropping items)

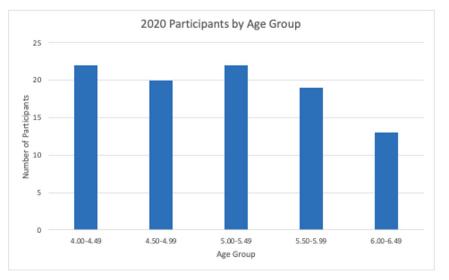
Participants	Мар	Distribution of Items				Construct Map (Hypothesized Order of Difficulty)		
	2					Repeating Tasks	ID Pattern	
		Item24_GrowingNonpattern_Score					Completion and Extend	
	1.75						Abstract	
						Growing Tasks	ID Pattern	
	1.5						Completion and Extend By 1	
		Item_5_CompletionAB_Score					Completion and Extend By 2	
	1.25						ID unit	
XXX	- 1	Item7_CompletionABC_Score						
XXXXXXX	1	Item8_CompletionABCC_Score	Item2_RepeatingIDNonpattern_Score	Item4 RepeatingIDPattern Score	Item23_GrowingNonPattern_Score	Item22_GrowingNonPattern_Score	Item6 CompletionABB Score	
~~~~	0.75	terro_completionAbcc_bcore	nemz_nepeatingiononpattern_score	territ_repeatingion atterri_ocore	tem25_drowingiton attem_5core	tem22_orowingitoin attem_boore	temo_completionxbb_bcore	
xxxxxxxxxxxxxx		Item3_RepeatingIDNonpattern_Score						
		Item26_GrowingNonpattern_Score						
XXXXXXXXX			Item16 AbstractABCD Score	Item1_RepeatingIDPattern_Score	Item33_ExtendNumerals Subtract1_Score			
	0.25							
X0000000000000000000000000000000000000		Item27_CompletionObjectsAdd1_Score	Item13_AbstractAB_Score	Item12_ExtendAAB_Score	Item11_ExtendABCD_Score	Item10_ExtendABC_Score	Item31_CompletionLargeNumeralsSubtr	ract1_Score
	0							
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX		Item15_AbstractAABC_Score						
	-0.25	Item29_CompletionNumeralsAdd2_Score						
x0000000000000000000000000000000000000		Item14_AbstractAAB_Score	Item21_GrowingObjectsAdd1_Score	Item9_ExtendAB_Score				
	-0.5							
X000000X	I	Item36_ExtendLargeNumeralsAdd2_Score						
	-0.75	Item25_GrowingNumeralsSubtract2_Score	Item32_ExtendObjectsAdd1_Score					
XXXXX		Item25_GrowingNumeraisSubtract2_Score	Item32_ExtendObjectSAdd1_Score					
	-1							
	-1.25							
		Item30_CompletionObjectsSubtract2_Score	Item34_ExtendNumerals Add2_Score	Item35_ExtendObjectsSubtract2_Score				
	-1.5							
	-1.75							
	-2	Item37_GrowingUnitChangeObjectsSubtract2_Score						
	-2.5	items/_growingonitenangeObjectsSubtract2_Score						
		Item38_GrowingUnitChangeLargeNumeralsAdd2_Score			•	lata, Casiaat itan		
	-3				N	lote: Easiest iten	is at top	36
	-1						-	

#### 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

Participants	Map Distribution of Items			Construct Map (Hypothesized Order of Difficulty)		
	1.5			Repeating Tasks	2 total elements: AB	
		Item_5_CompletionAB_Score			3 total elements: ABC, ABB, AAB	
	1.25				4 total elements: ABCD, AABC, ABCC, AABB	
XXXX		Item7_CompletionABC_Score			Non-patterns	
XXXXXX	1	Item8_CompletionABCC_Score	Item2_RepeatingIDNonpattern_Score	Item4_RepeatingIDPattern_ABB_Score	Itom Completion APP Coore	
	0.75		tem2_repeatingibitionpattern_score	item4_repeatingibrattem_Abb_score	terro_completionABB_3core	
X000000000X		Item3_RepeatingIDNonpattern_Score				
	0.5					
X00000X		Item16_AbstractABCD_Score	Item1_RepeatingIDPattern_AABB_Score			
	0.25					
X0000000000000000X		Item13_AbstractAB_Score	Item12_ExtendAAB_Score	Item11_ExtendABCD_Score	Item10_ExtendABC_Score	
	0					
X00000000000000X		Item15_AbstractAABC_Score				
	-0.25		Harro Estanda Carro			
x0000000000000000000000000000000000000	-0.5	Item14_AbstractAAB_Score	Item9_ExtendAB_Score			
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	-0.5					
7000000	-0.75					
XXXXX						
	-1					

#### Repeating Only Wright Map – Number of Distinct Elements in Pattern

Participants	Мар	Distribution of Items		Construct Map (Hypoth	esized Order of Difficulty)
	1.5 1.25	Item_5_CompletionAB_Score		Repeating Tasks	2 distinct elements: AB, ABB, AAB, AABB 3 distinct elements: ABC, AABC, ABCC 4 distinct elements: ABCD
хох	1	Item7_CompletionABC_Score			Non-patterns
X0000X	0.75	Item8_CompletionABCC_Score	Item2_RepeatingIDNonpattern_Score	Item4_RepeatingIDPattern_ABB_Score	Item6_CompletionABB_Score
200000000000000000000000000000000000000	0.5	Item3_RepeatingIDNonpattern_Score			
X00000X	0.25		Item1_RepeatingIDPattern_AABBScore		
x0000000000000000000000000000000000000	0		Item12_ExtendAAB_Score	Item11_ExtendABCD_Score	Item10_ExtendABC_Score
200000000000000000000000000000000000000	-0.25		1		
x0000000000000000000000000000000000000	-0.5	Item14_AbstractAAB_Score	Item9_ExtendAB_Score		
X000000X	-0.75				
X000X	-1				

#### In-person vs Online Participants

