The development of flexibility in working memory

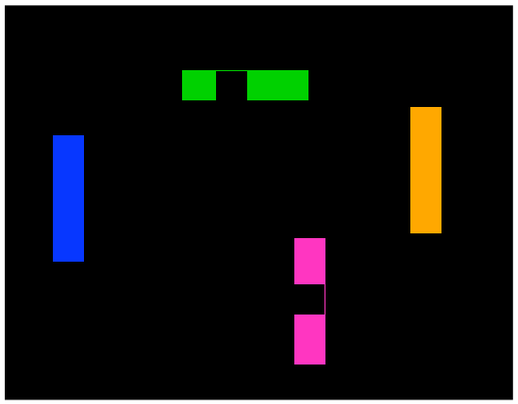
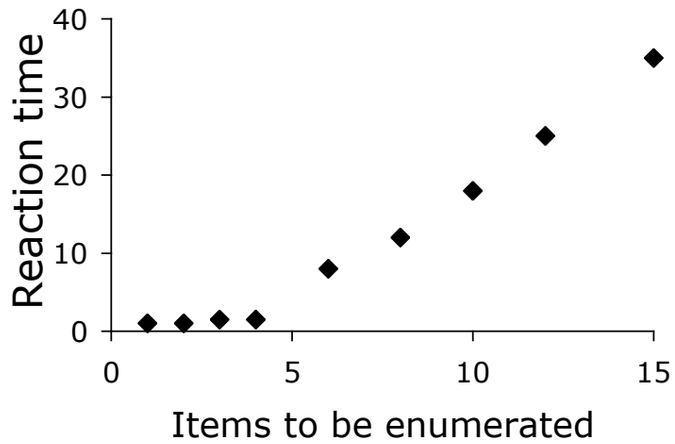
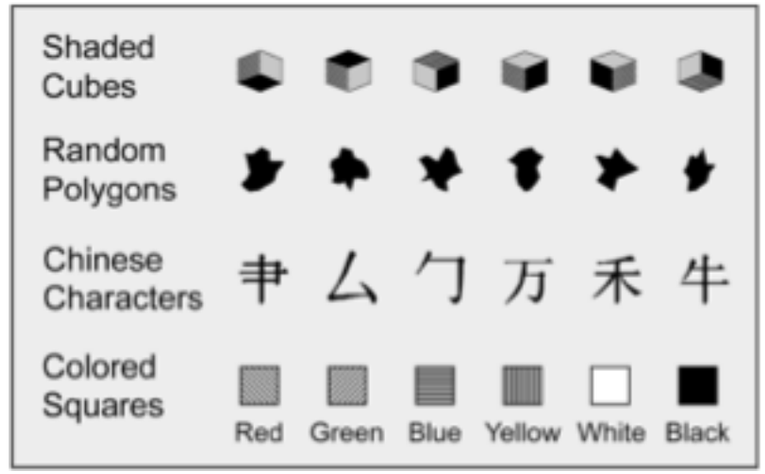
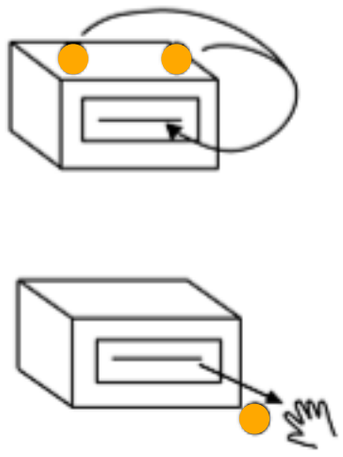
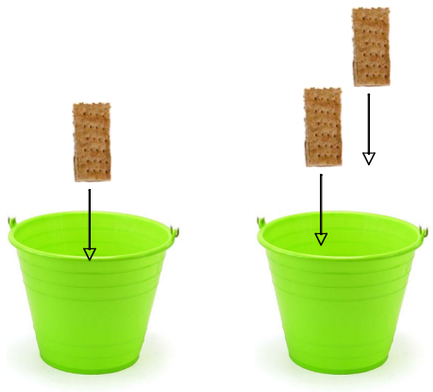
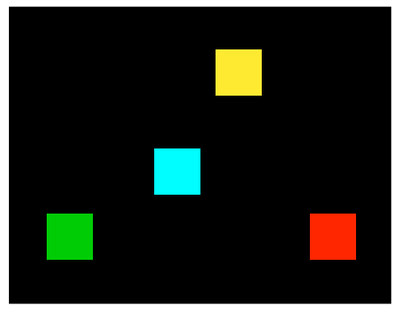
Mariko Moher

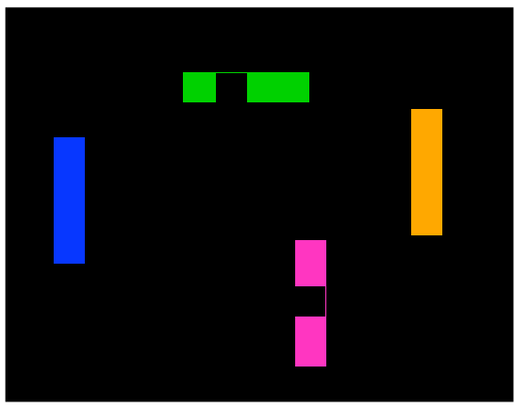
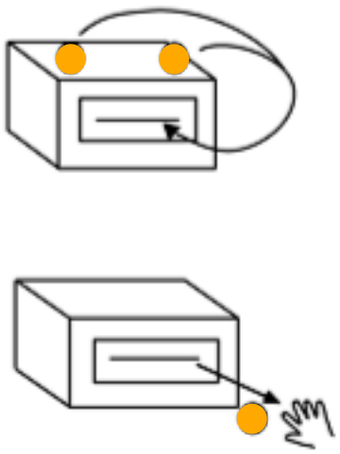
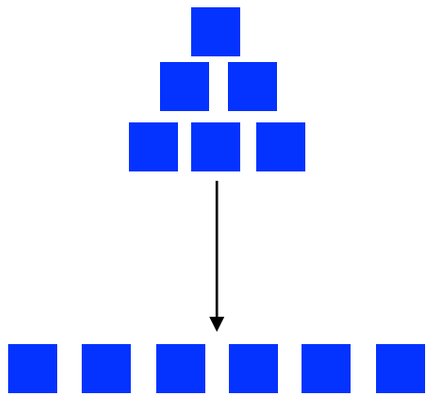
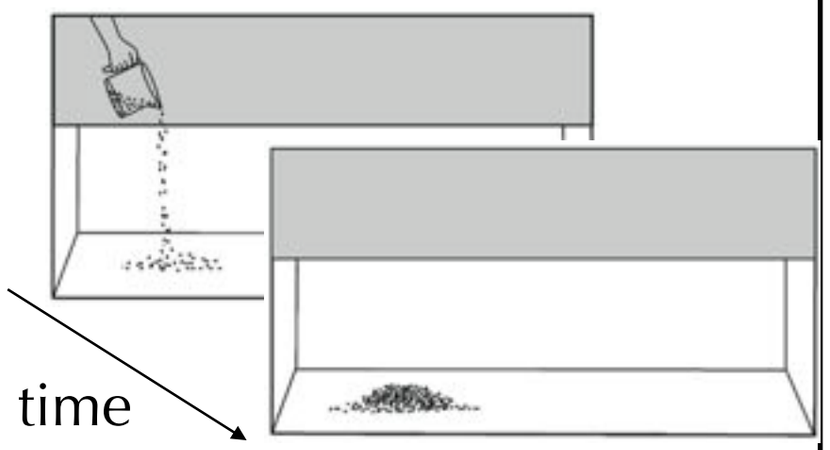
August 5, 2017

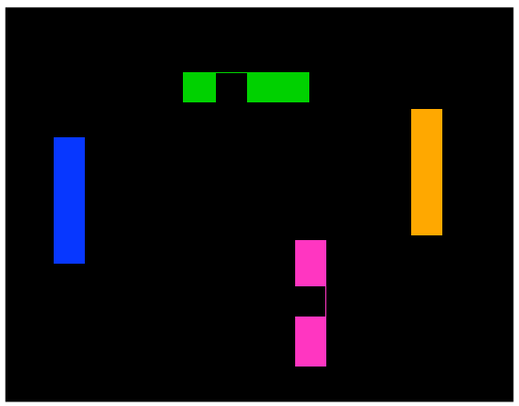
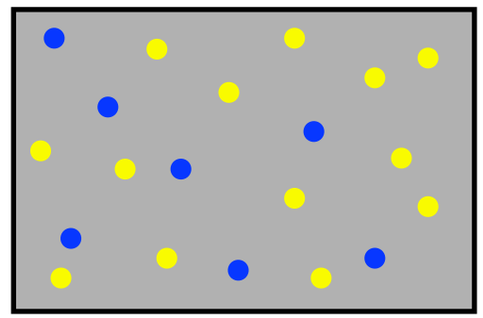
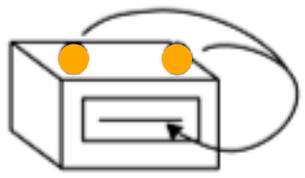
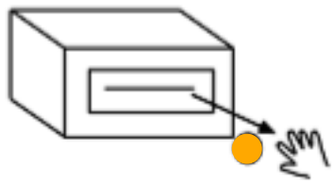
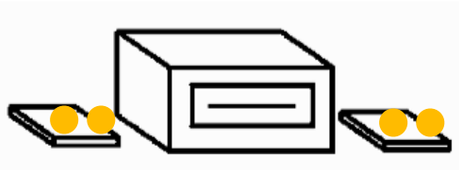
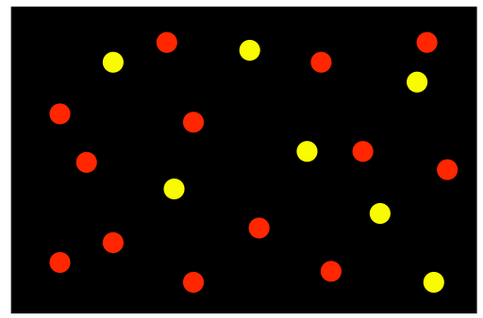

FARM FRESH PRODUCE
KEOWN
ORCHARDS

memory is capacity limited...

...how do we overcome that limit?

	objects		
adults	 Luck & Vogel, 1997	 Jevons, 1871	 Awh et al., 2007
infants	 Feigenson & Carey, 2003	 Feigenson et al., 2002	 Ross-Sheehy et al., 2003

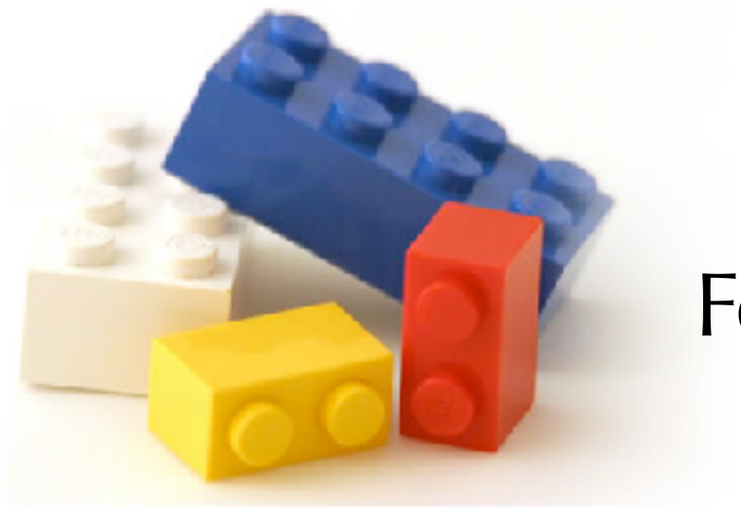
	objects	non-object entities
adults	 Luck & Vogel, 1997	
infants	 Feigenson & Carey, 2003	 Chiang & Wynn, 2000
		 Rosenberg & Carey, 2009

	objects	chunks	ensembles
adults	 Luck & Vogel, 1997	3,4,9,2 ↓ "near-record mile time" Ericsson et al., 1980	 Halberda et al., 2006
infants	  Feigenson & Carey, 2003	 Feigenson & Halberda, 2004	 Zosh et al., 2011

chunking

ensemble

representations



Foundations?

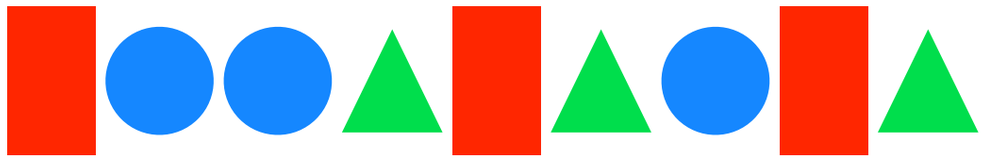
Chunking

apples
broccoli
chicken
eggs
milk
oranges
yogurt

5305206800

530-520-6800

spatially chunked



apples
broccoli
oranges

eggs
milk
yogurt

chicken

conceptually chunked

featurally chunked

Does chunking depend on rich linguistic or conceptual knowledge?

7 month-olds

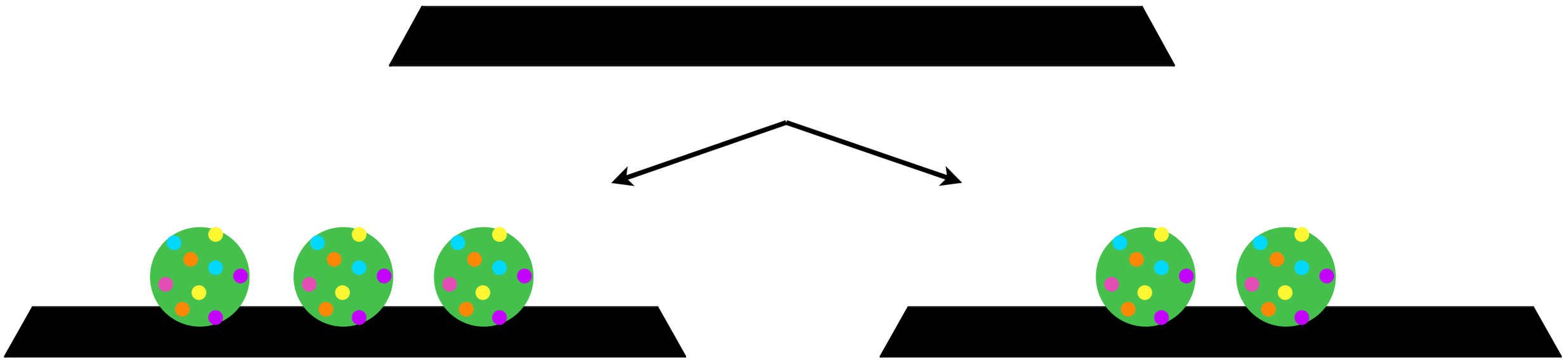
- WM capacity not yet fully developed
- cusp of linguistic comprehension

Violation of expectation looking time paradigm

Moher et al., 2012

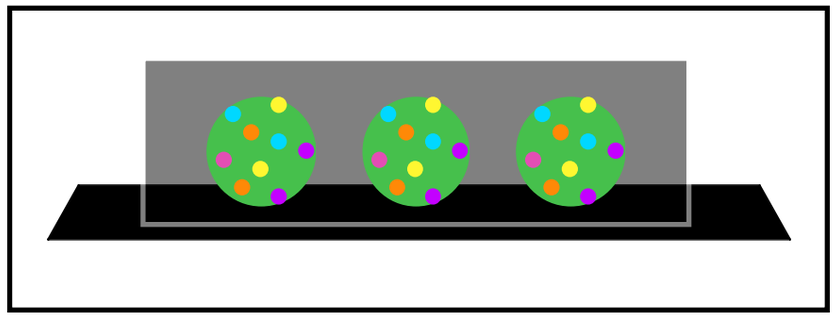
What is beyond the capacity limit at this age?

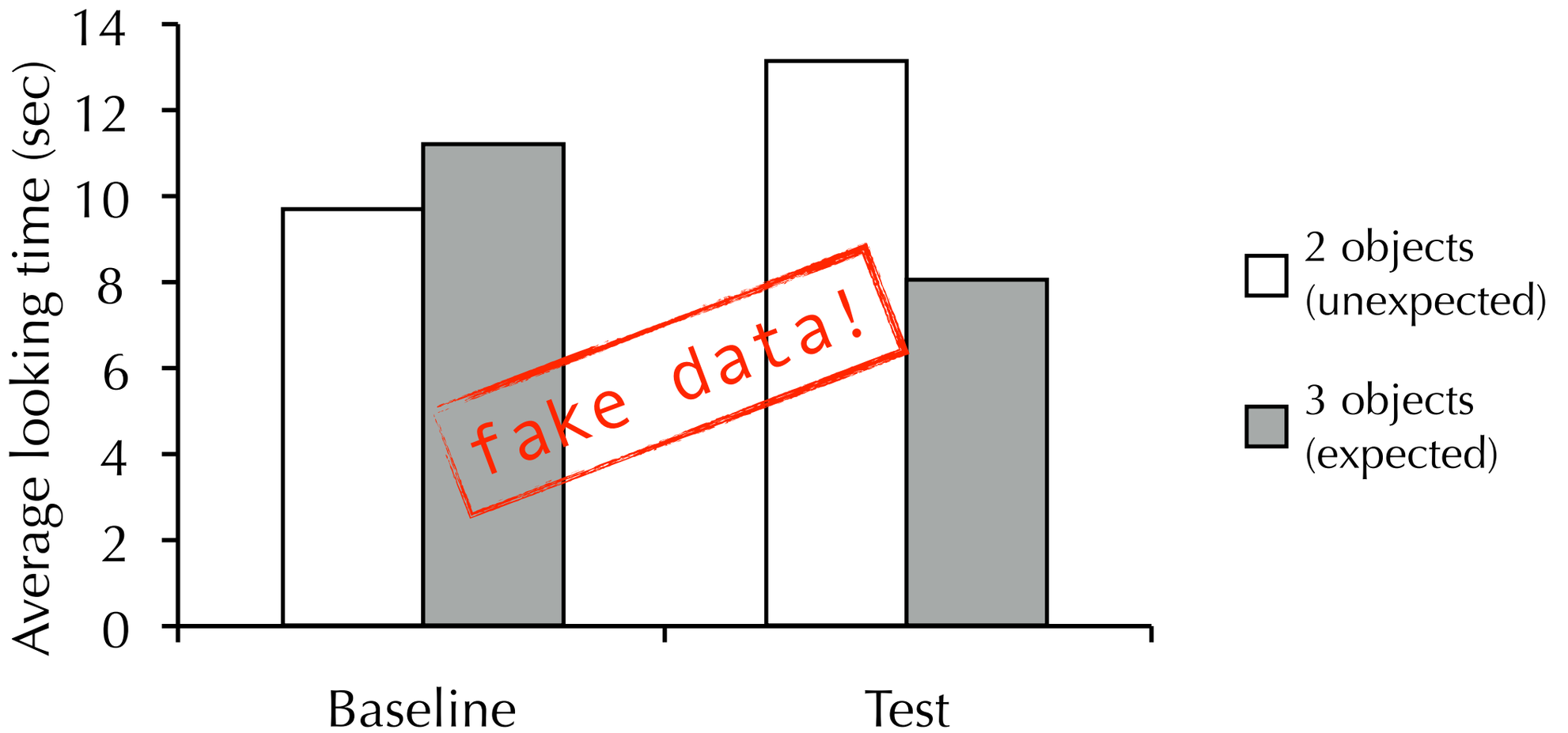
[redacted]

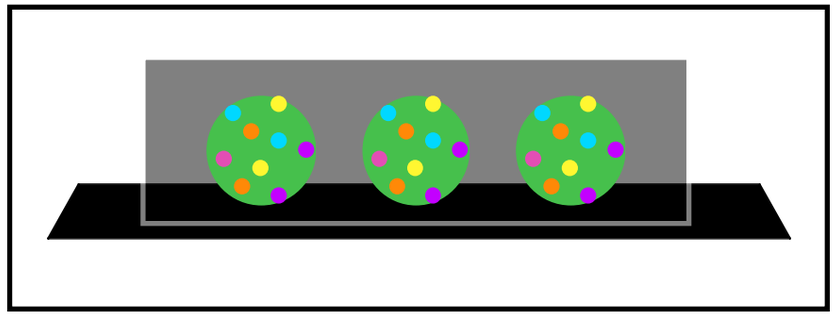


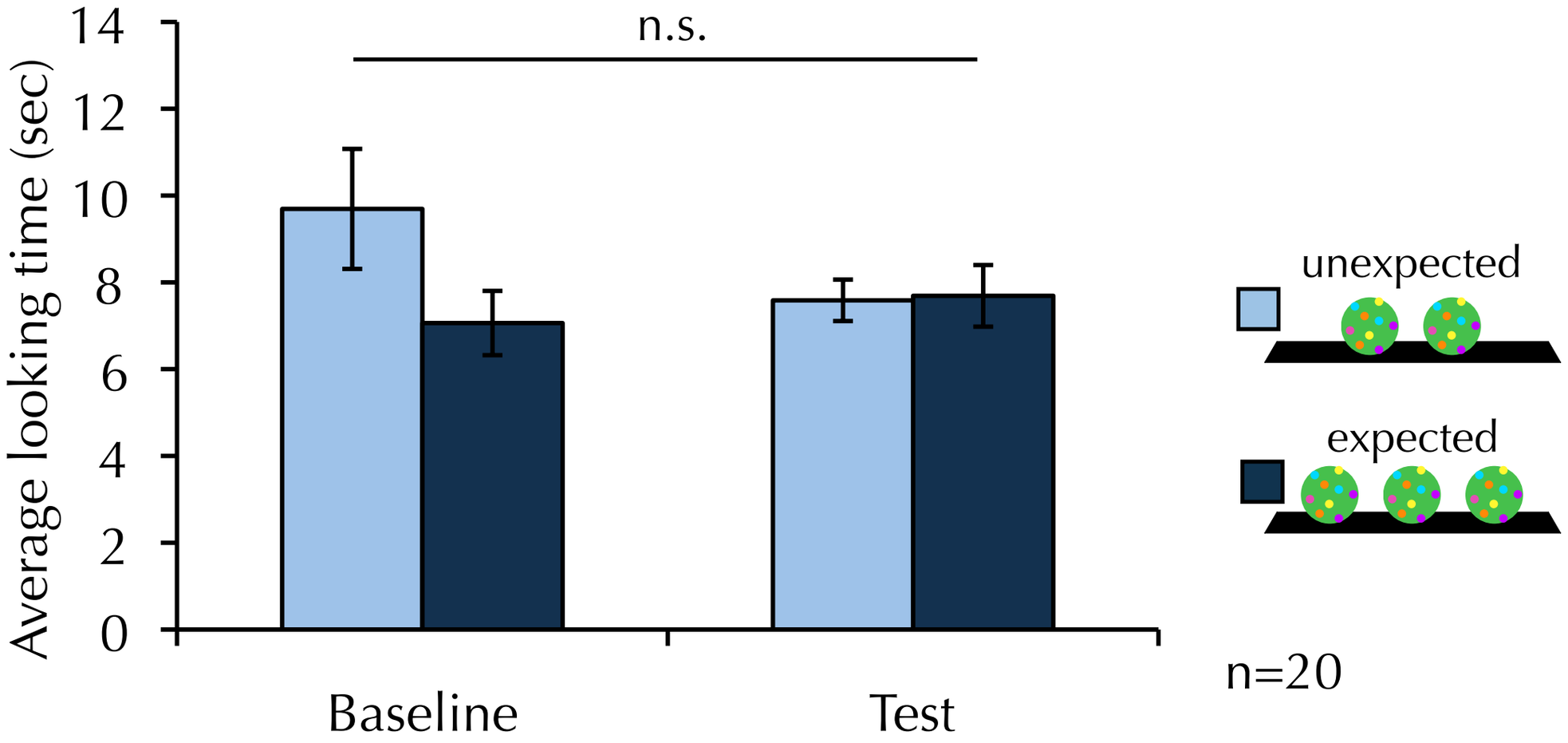
expected

unexpected



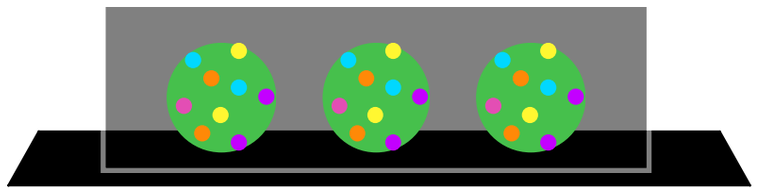

Average looking time (sec)
0
2
4
6
8
10
12
14
Baseline
Test
fake data!
2 objects (unexpected)
3 objects (expected)





7 month-olds' memory capacity < 3 objects

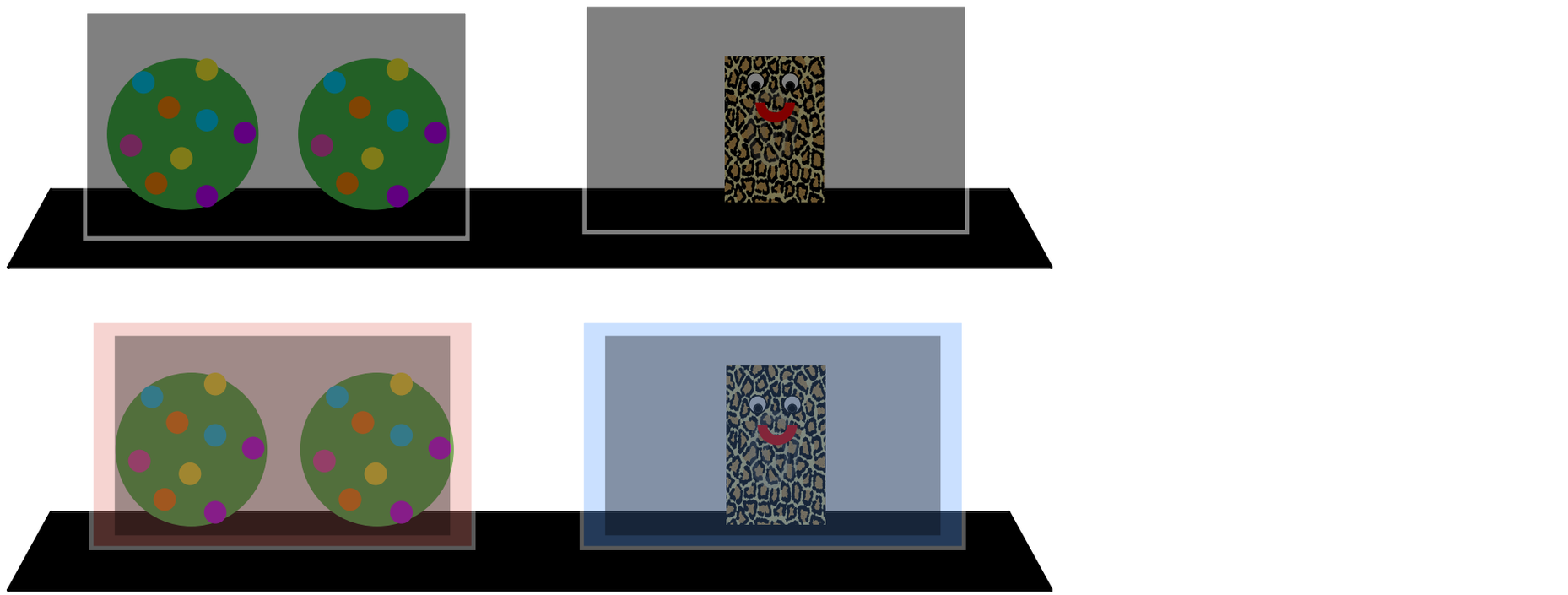
Moher et al., 2012

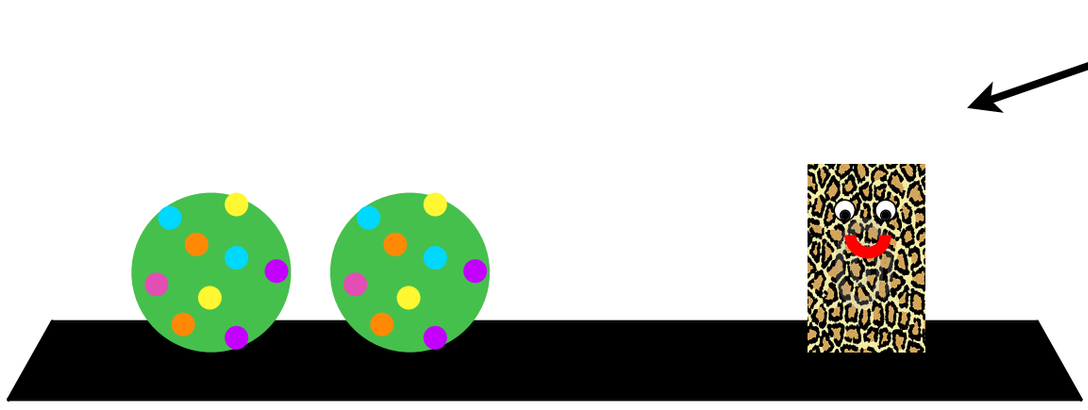
cues	display	success?
none		✗

Moher et al., 2012

REDUNDANCY

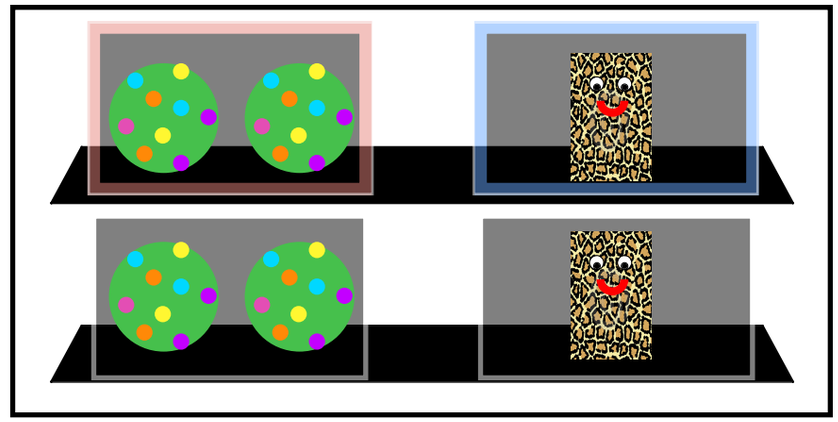
Just in case you're totally oblivious.

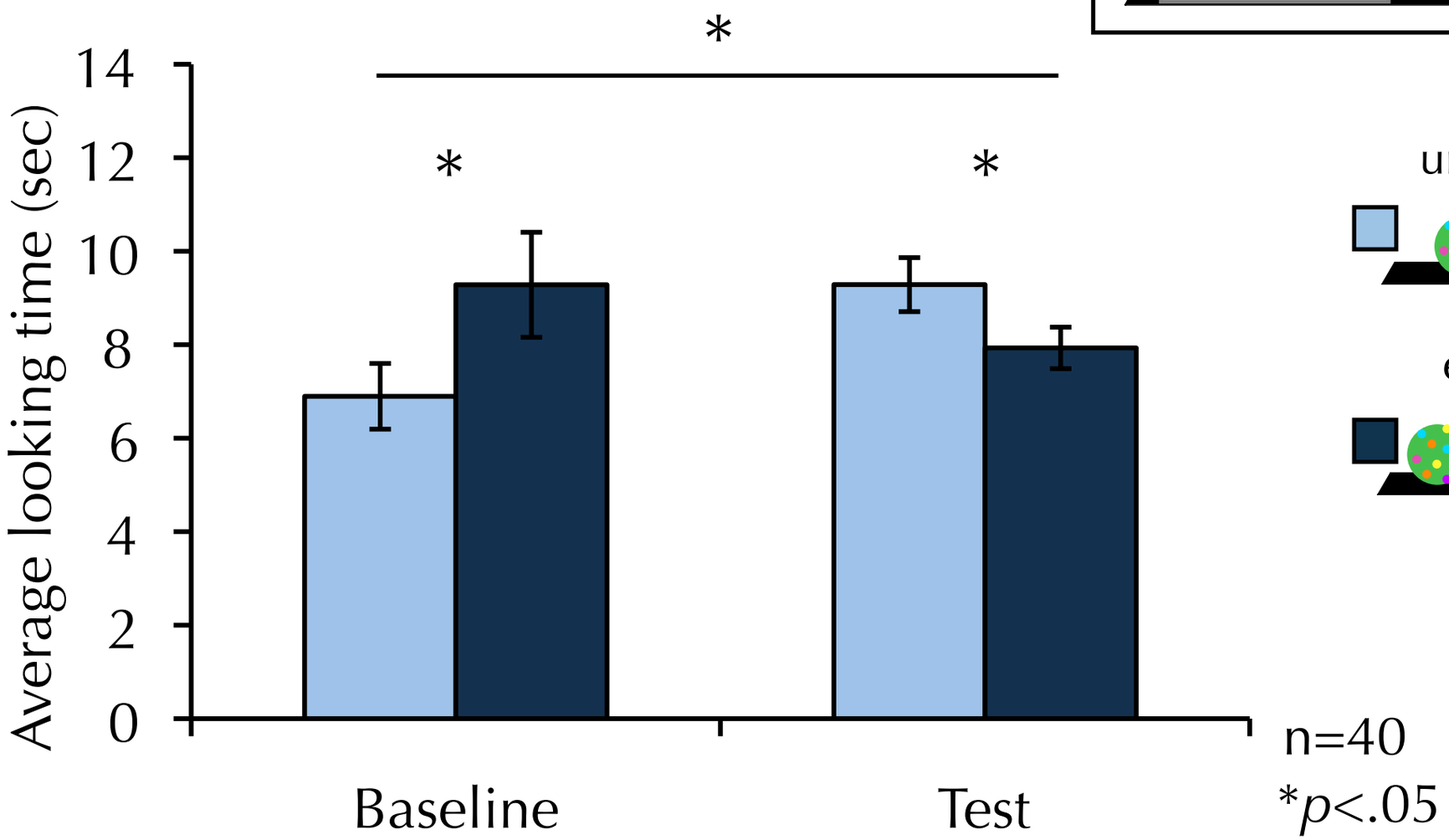




expected

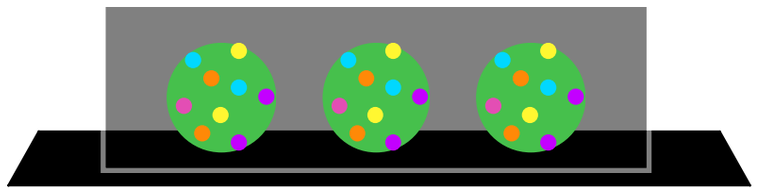
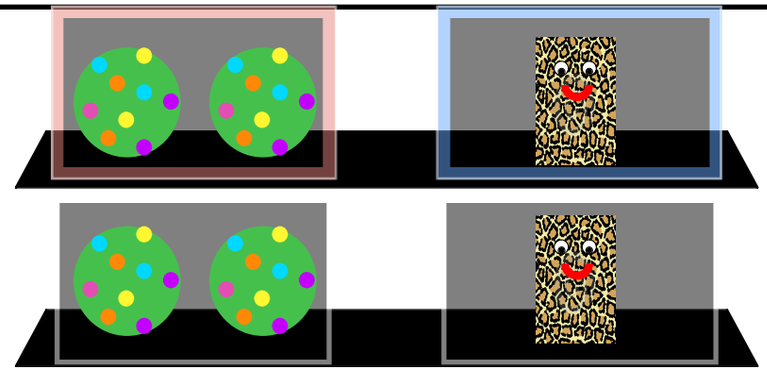
unexpected



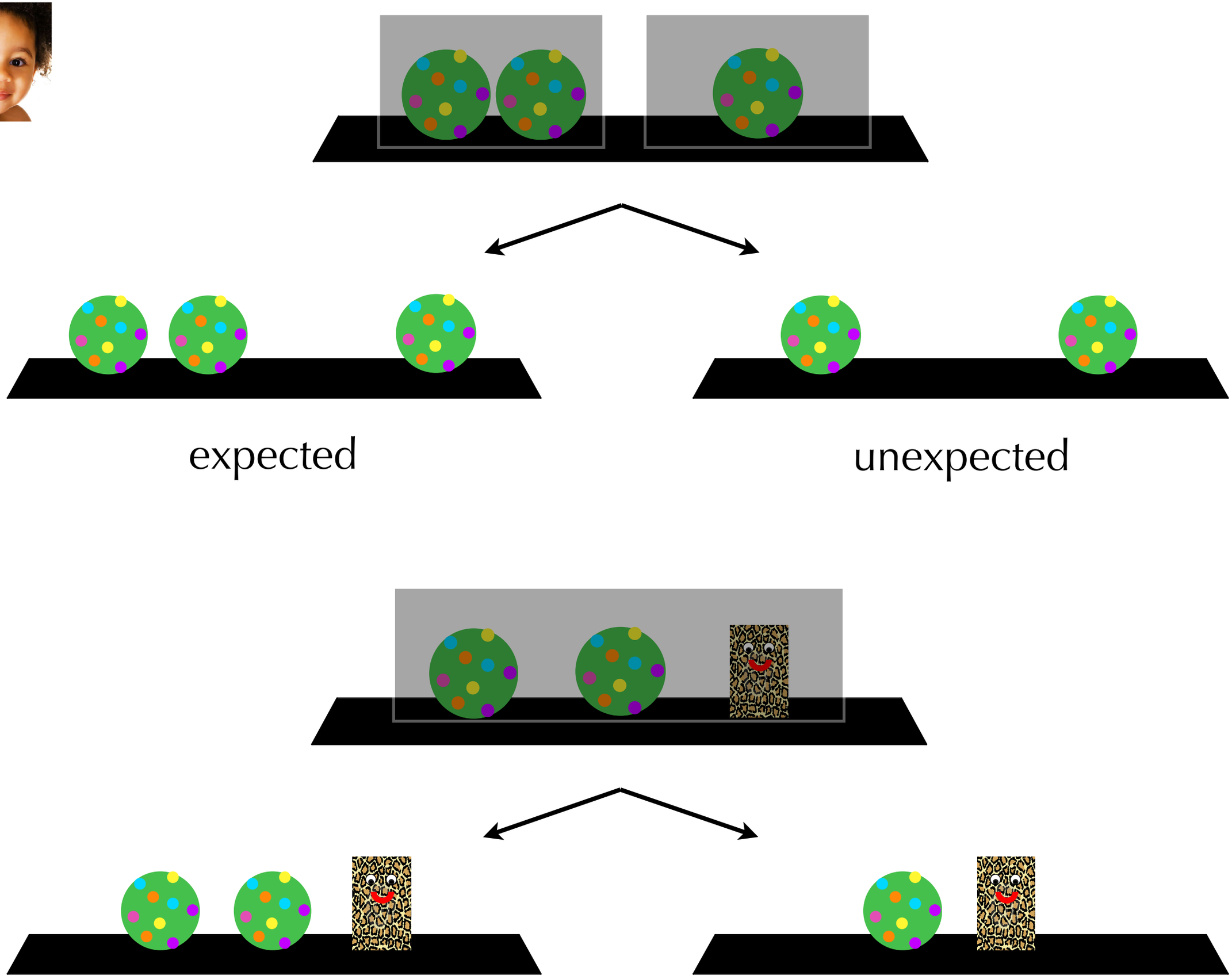


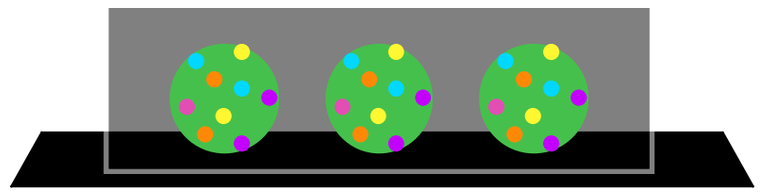
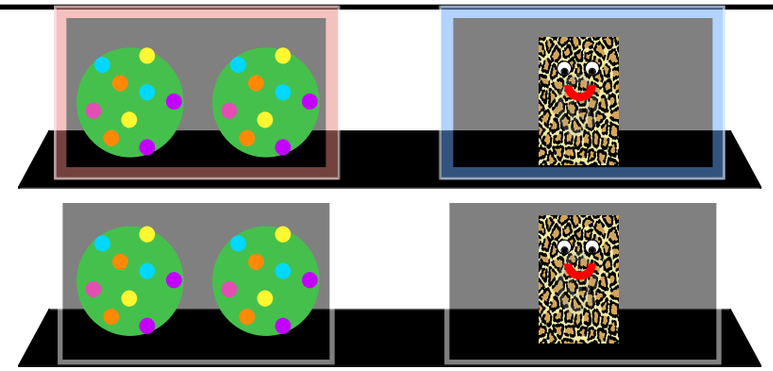
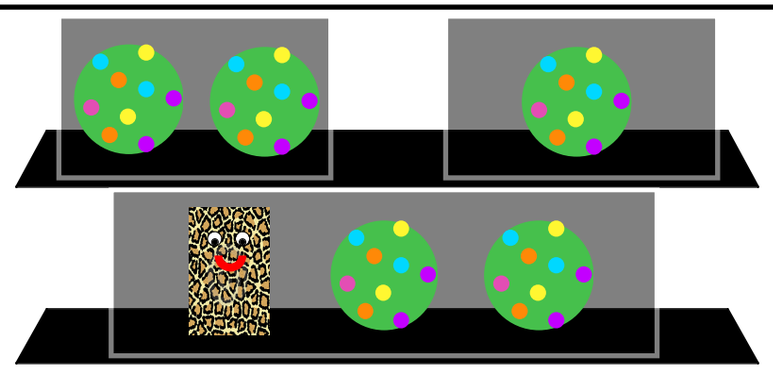
Infants can **chunk** using spatial and featural cues

Moher et al., 2012

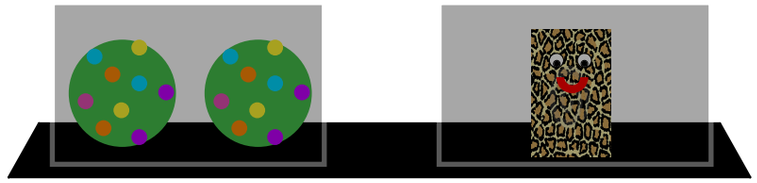
cues	display	success?
none		✗
spatial and featural		✓

Moher et al., 2012


expected
unexpected
expected
unexpected

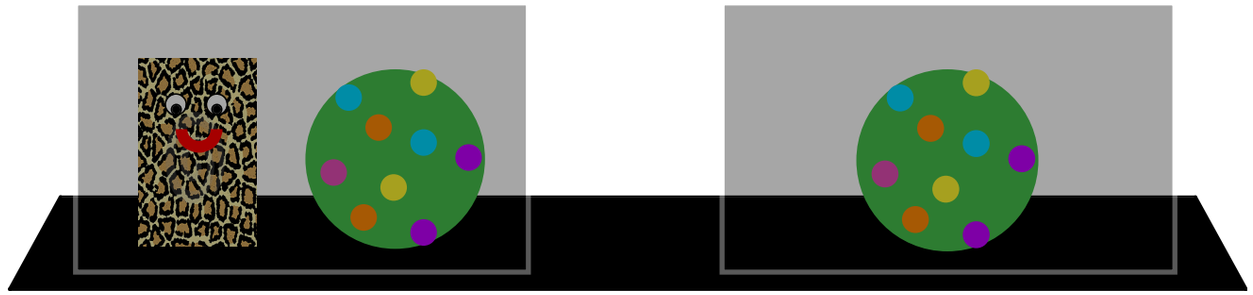
cues	display	success?
none		✗
spatial and featural		✓
spatial or featural		✗

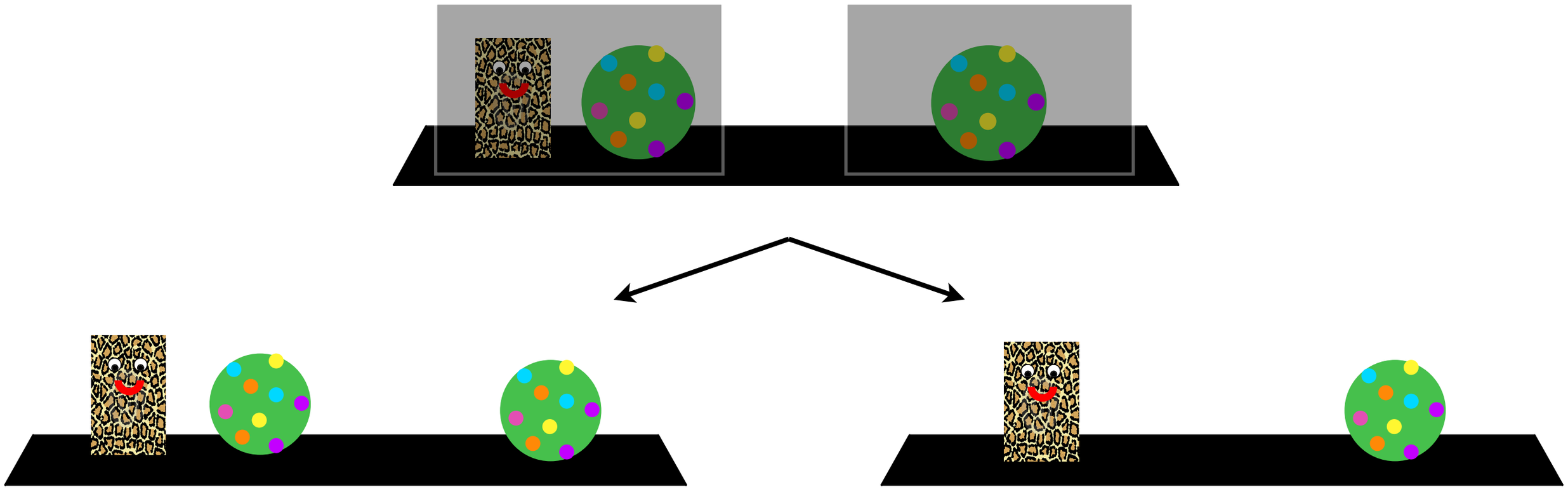
Moher et al., 2012



redundant cues

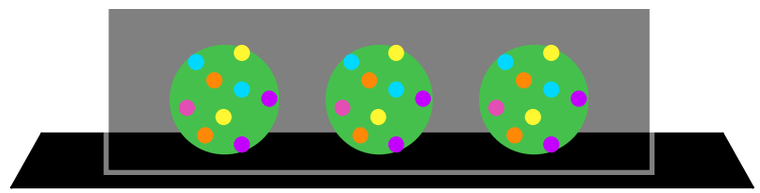
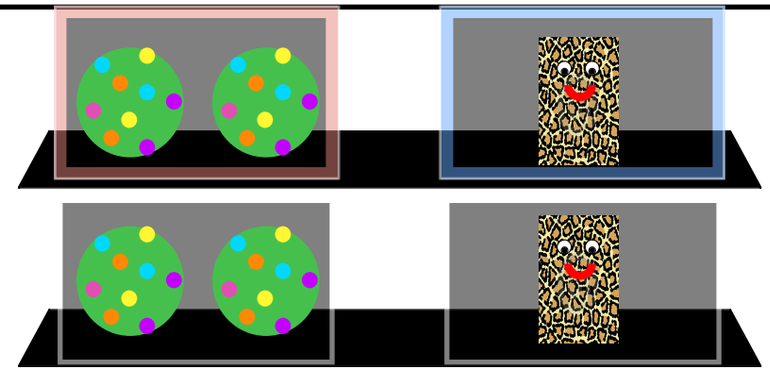
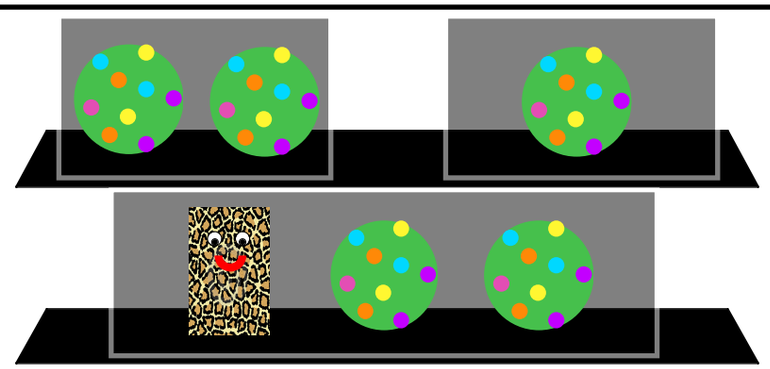
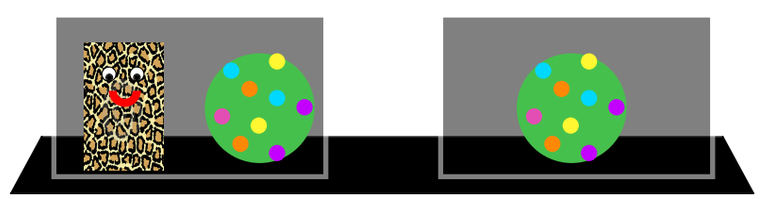
conflicting cues





expected

unexpected

cues	display	success?
none		✗
spatial and featural		✓
spatial or featural		✗
conflicting		✗

Moher et al., 2012

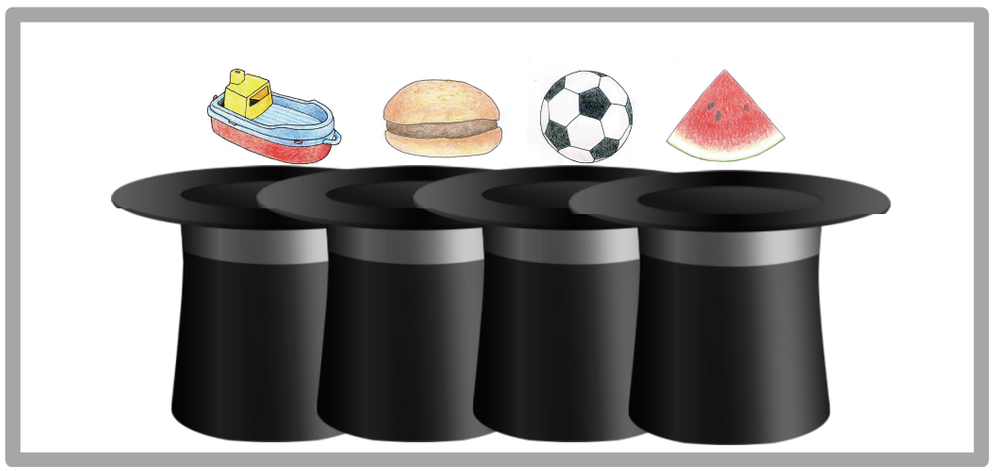
- Chunking does not depend on:
  - linguistic / conceptual knowledge
  - a fully developed working memory capacity
- Younger infants need multiple, redundant cues

Are children able to chunk using conceptual & spatial cues?

- younger children: 5-year-olds
- older children: 6- to 10-year-olds

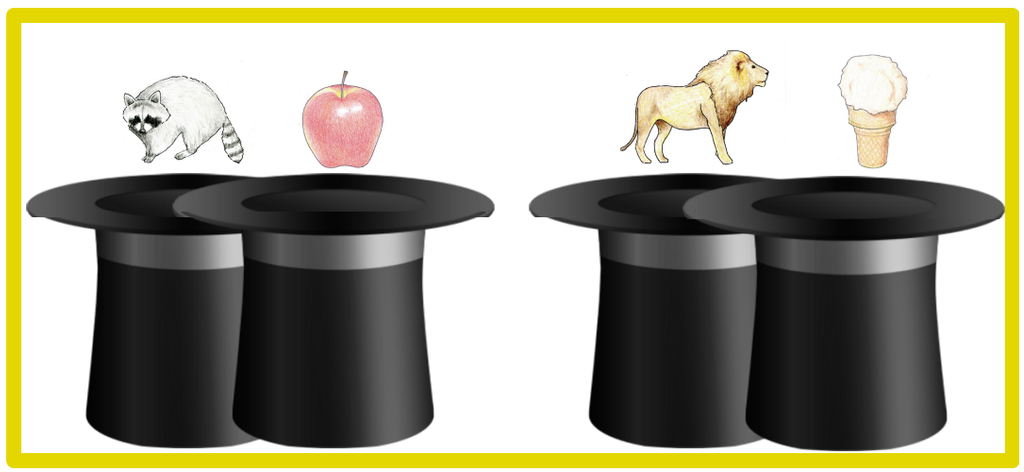
Tablet game
36 test trials

Alida Davis ’13 senior thesis
Davis & Moher (2015) CDS poster

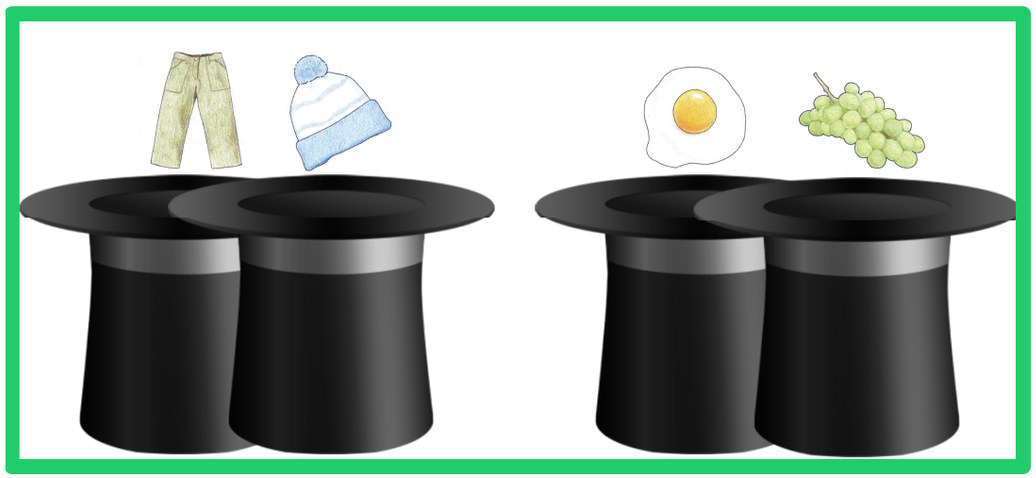


no organization (N)
0 cues

conceptual (C)
1 cue

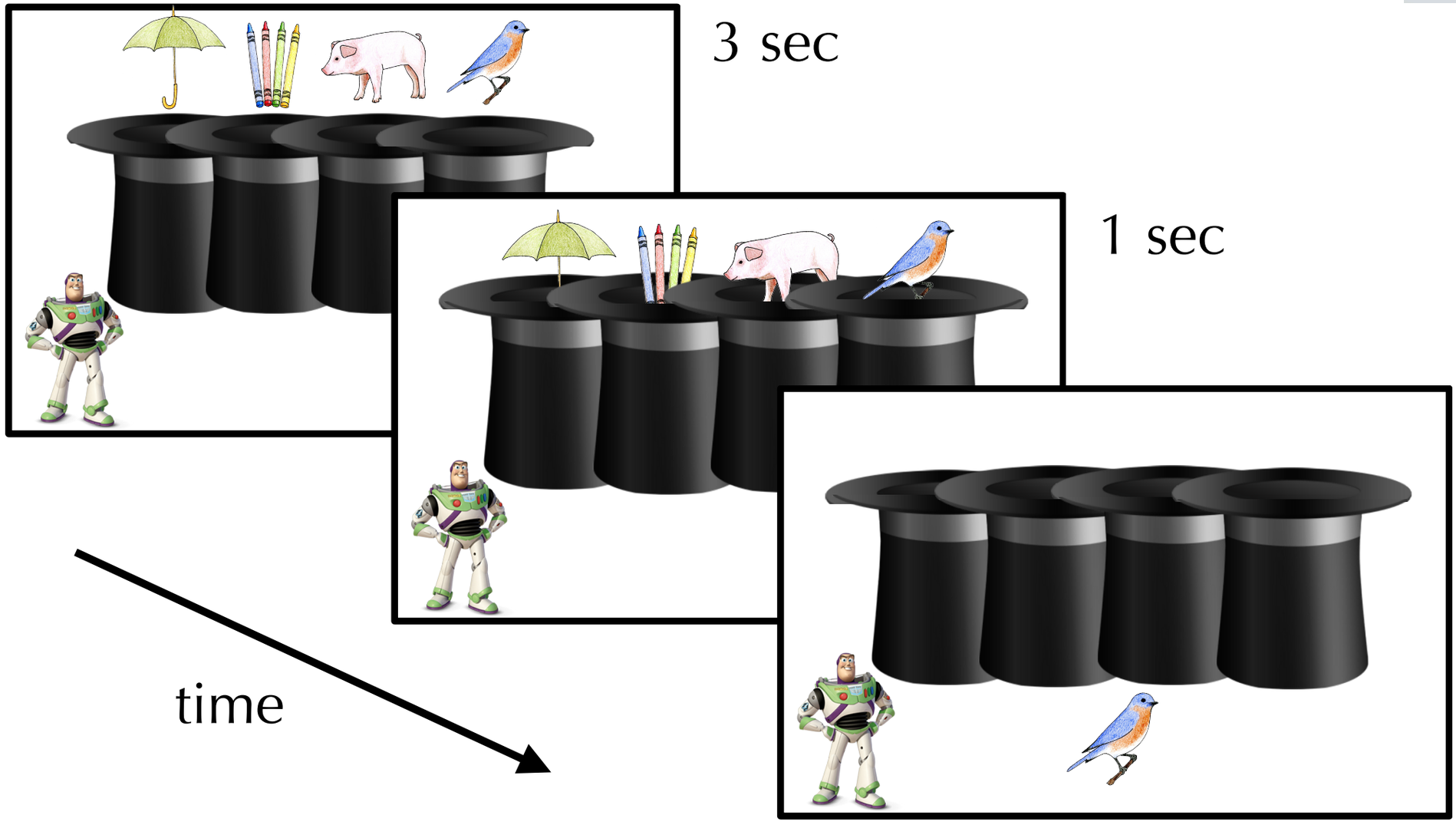


spatial (S)
1 cue



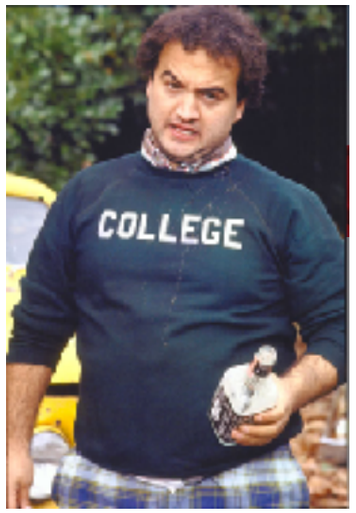
conceptual & spatial (CS)
2 cues

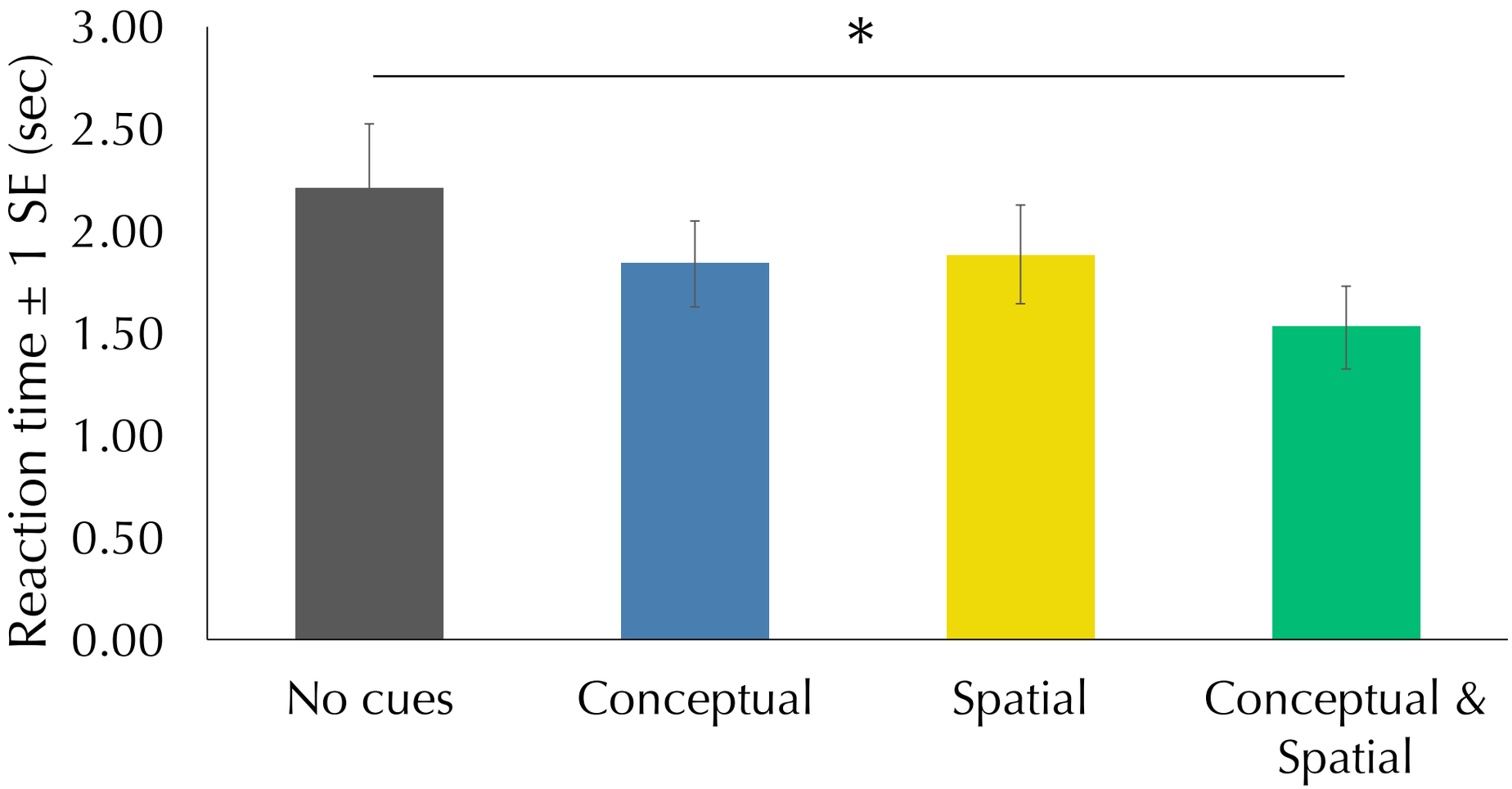
Alida Davis ’13 senior thesis
Davis & Moher (2015) CDS poster



"Where did the bird go?"

Alida Davis '13 senior thesis
Davis & Moher (2015) CDS poster



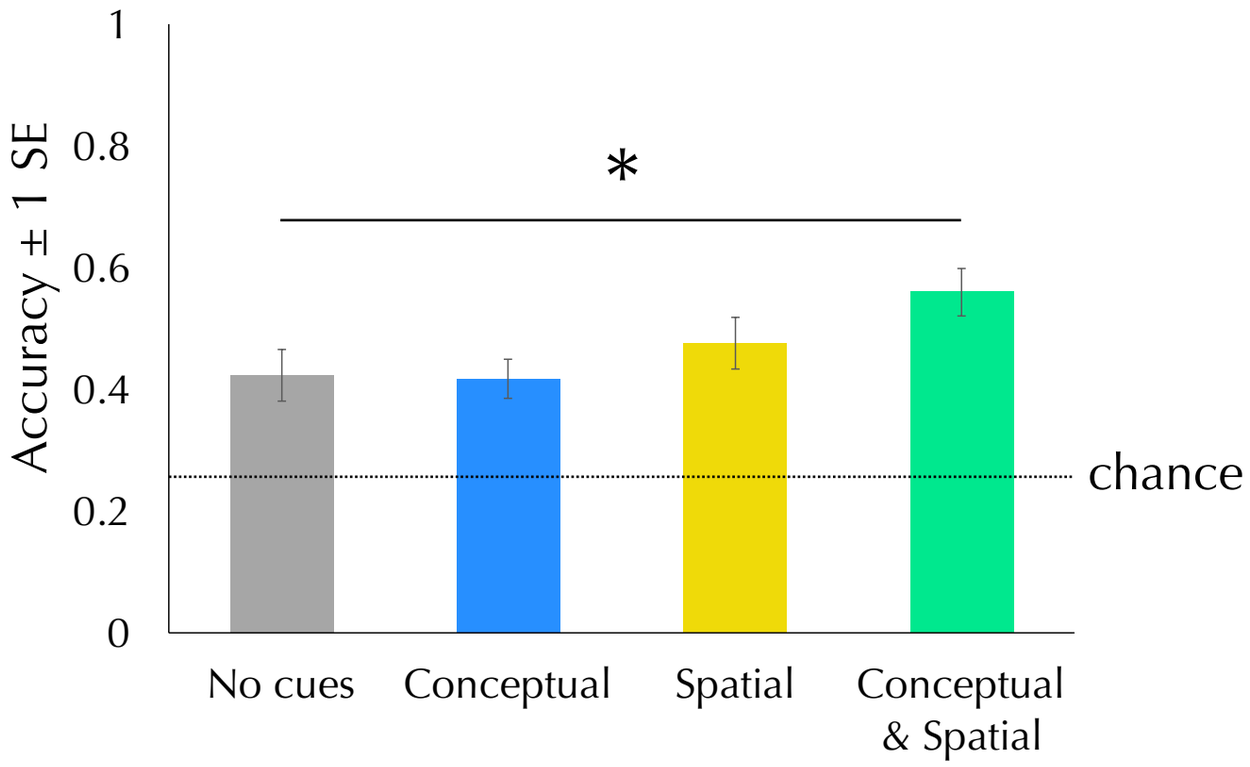


6 pictures / trial
n=8

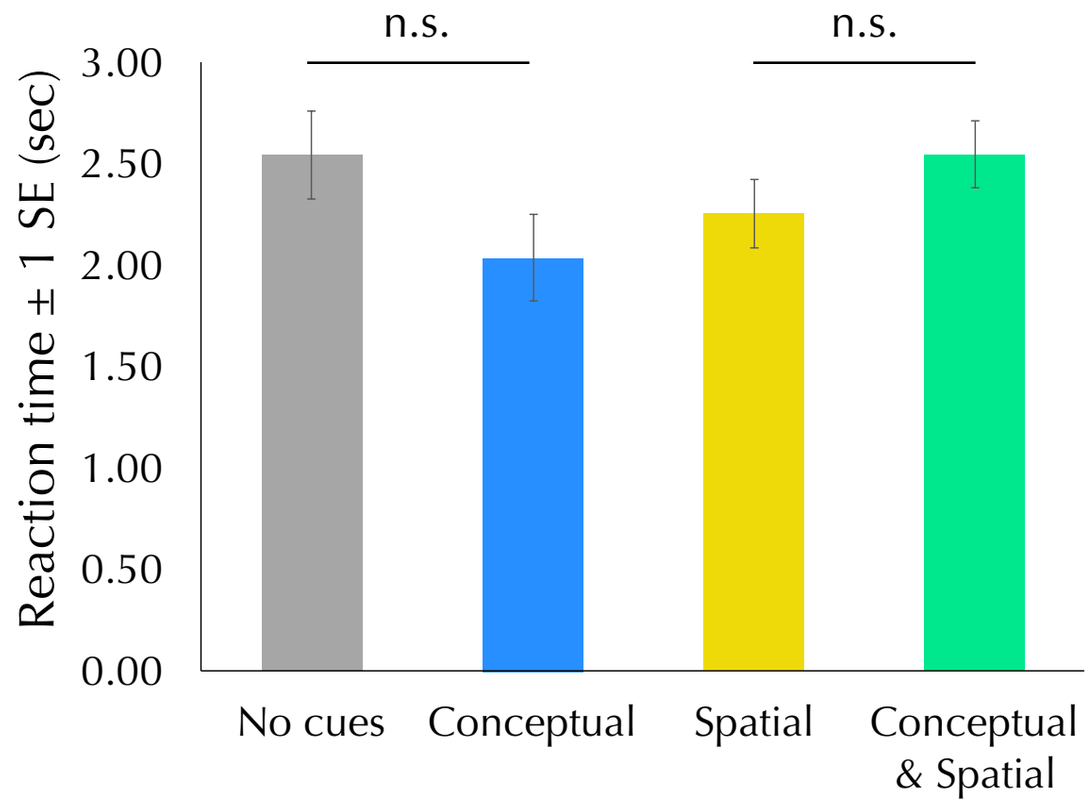
Chunking cues improve adults' performance

Alida Davis '13 senior thesis
Davis & Moher (2015) CDS poster

younger children
age: 66 mo
n=21



Accuracy affected by cue type



RT not affected by cue type

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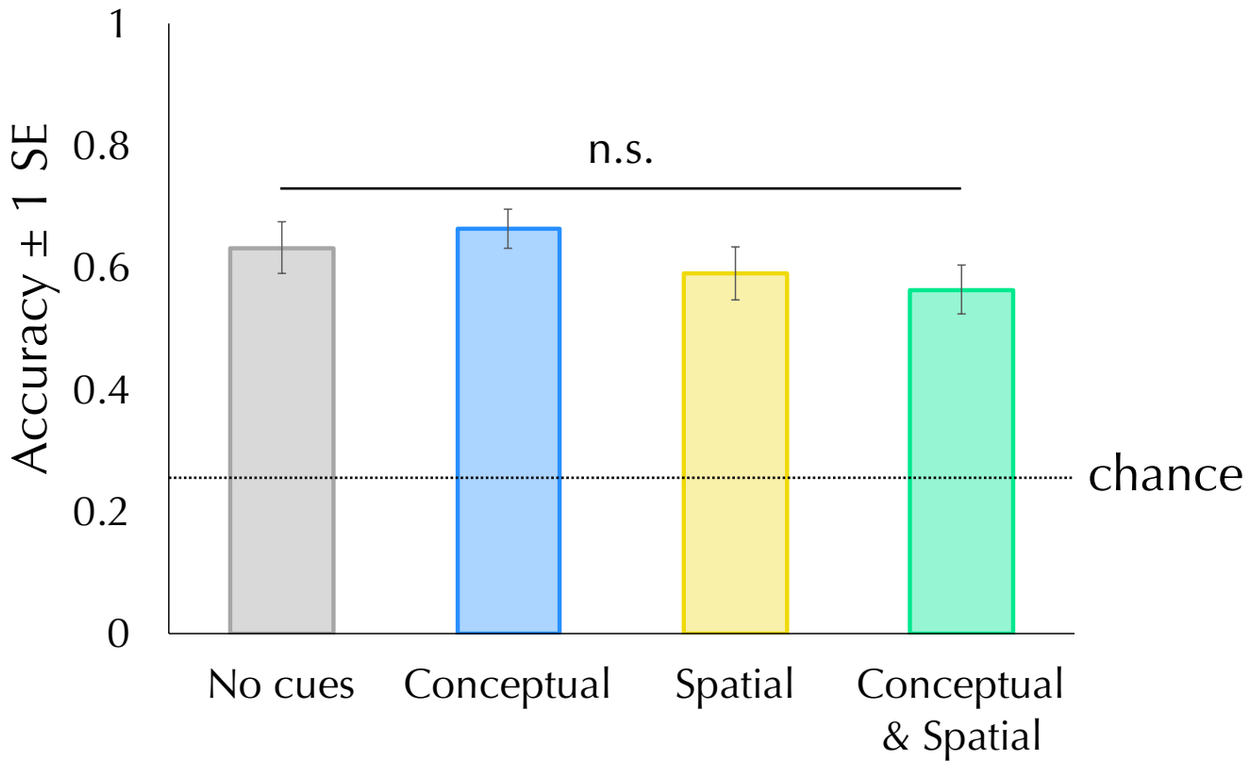
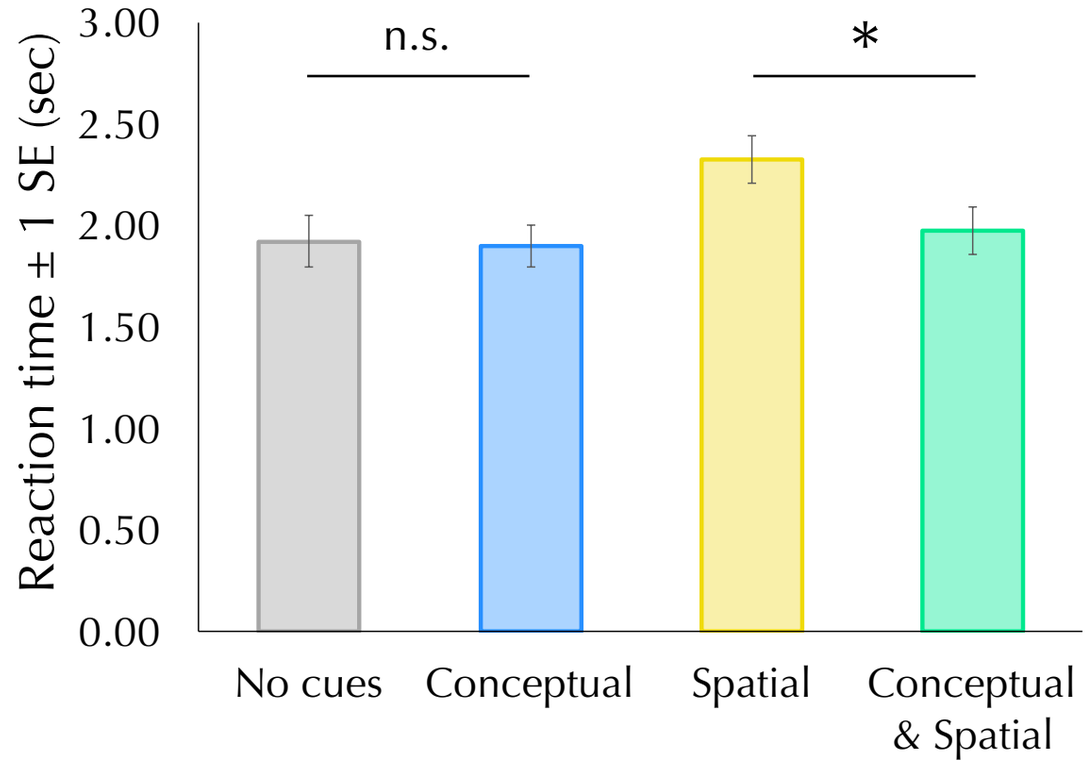
Davis & Moher (2015) CDS poster

older children
age: 90.3 mo
n=29

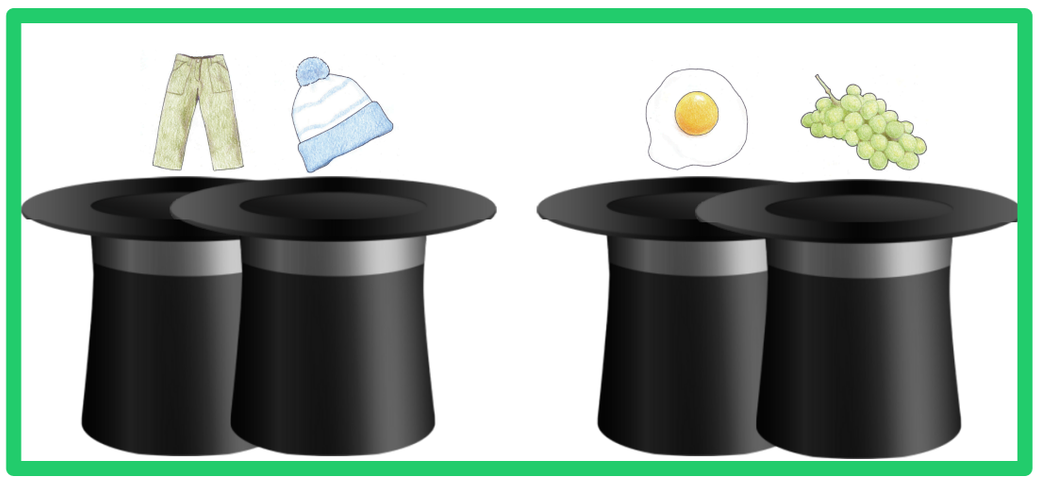


Accuracy not affected by cue type



RTs affected by cue type;
redundant cues needed

Alida Davis ’13 senior thesis
Davis & Moher (2015) CDS poster

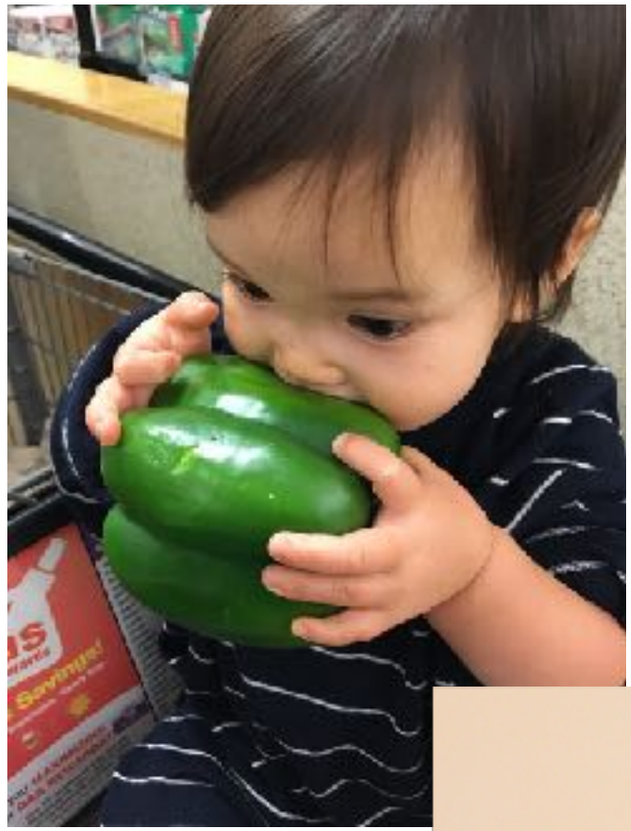


- Children can take advantage of chunking cues
  - redundancy needed / helpful
- Divergence between implicit and explicit chunking

- average size, orientation, direction
- approximate numerosity

single ensemble

multiple ensembles
individuated using features



How do we process arrays with overlapping ensembles?

Can infants represent multiple overlapping ensembles?

9 month-olds

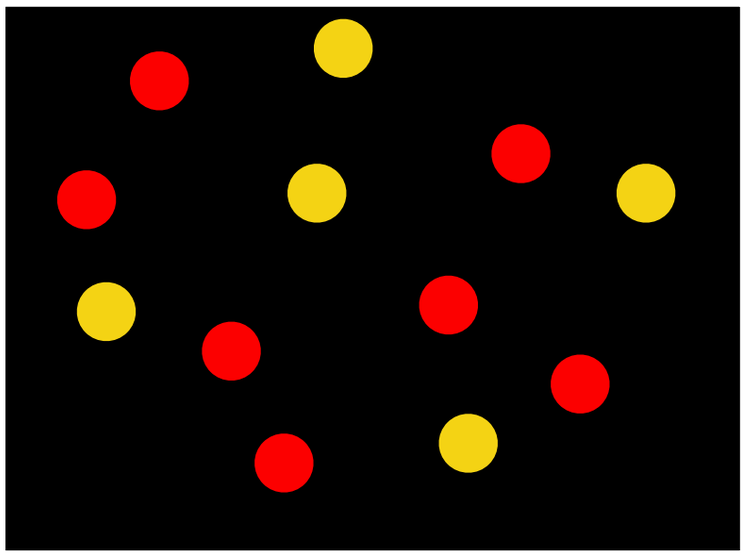
- can discriminate arrays at a 1:2 ratio

Habituation looking time paradigm

Moher & Feigenson, under review

1 feature	colour only	
	shape only	

Individuate by colour

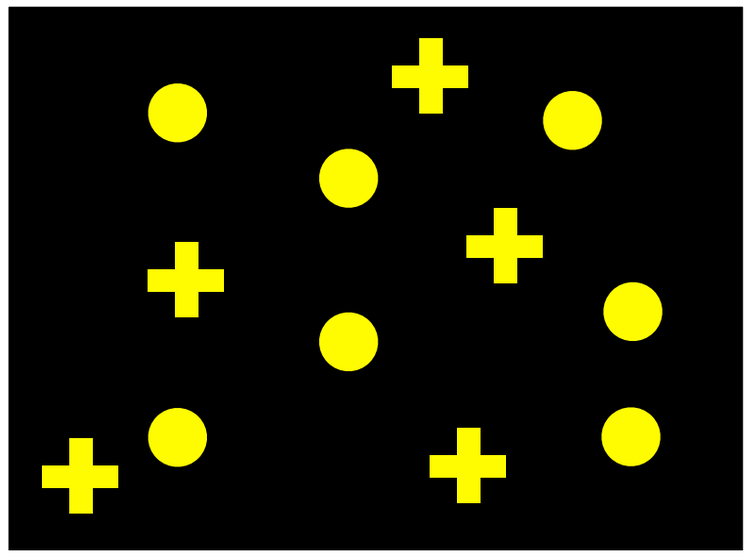


Zosh et al., 2011

Yellow circles: 5

Red circles: 7

Individuate by shape

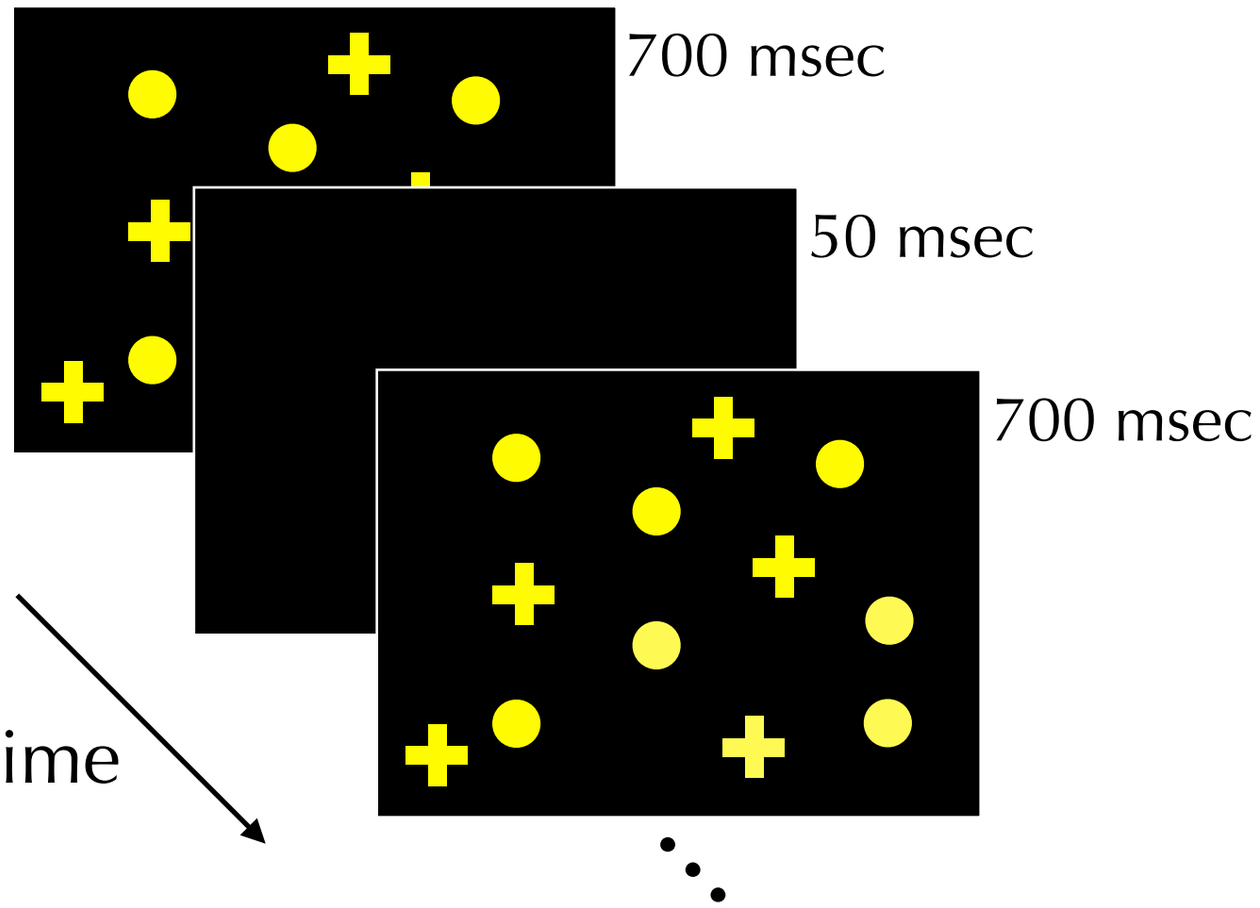


Crosses: 5

Circles: 7

Habituation

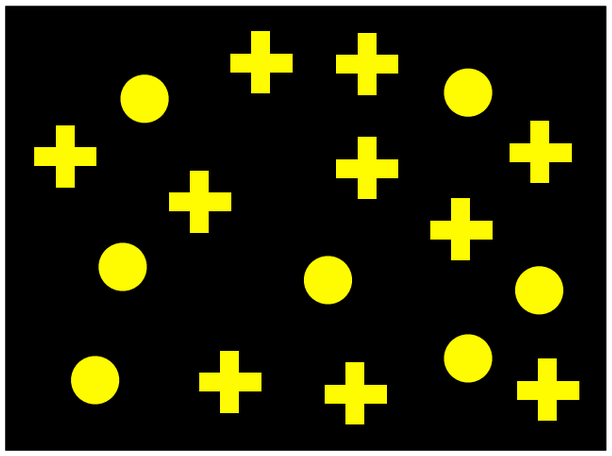
5 crosses



until infant looks away for 2 consecutive seconds

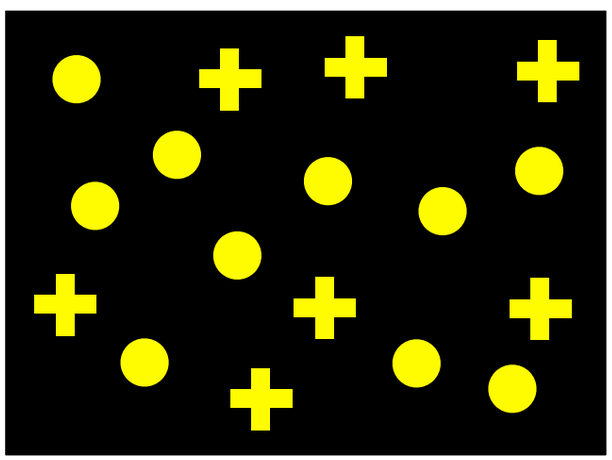
Discriminable

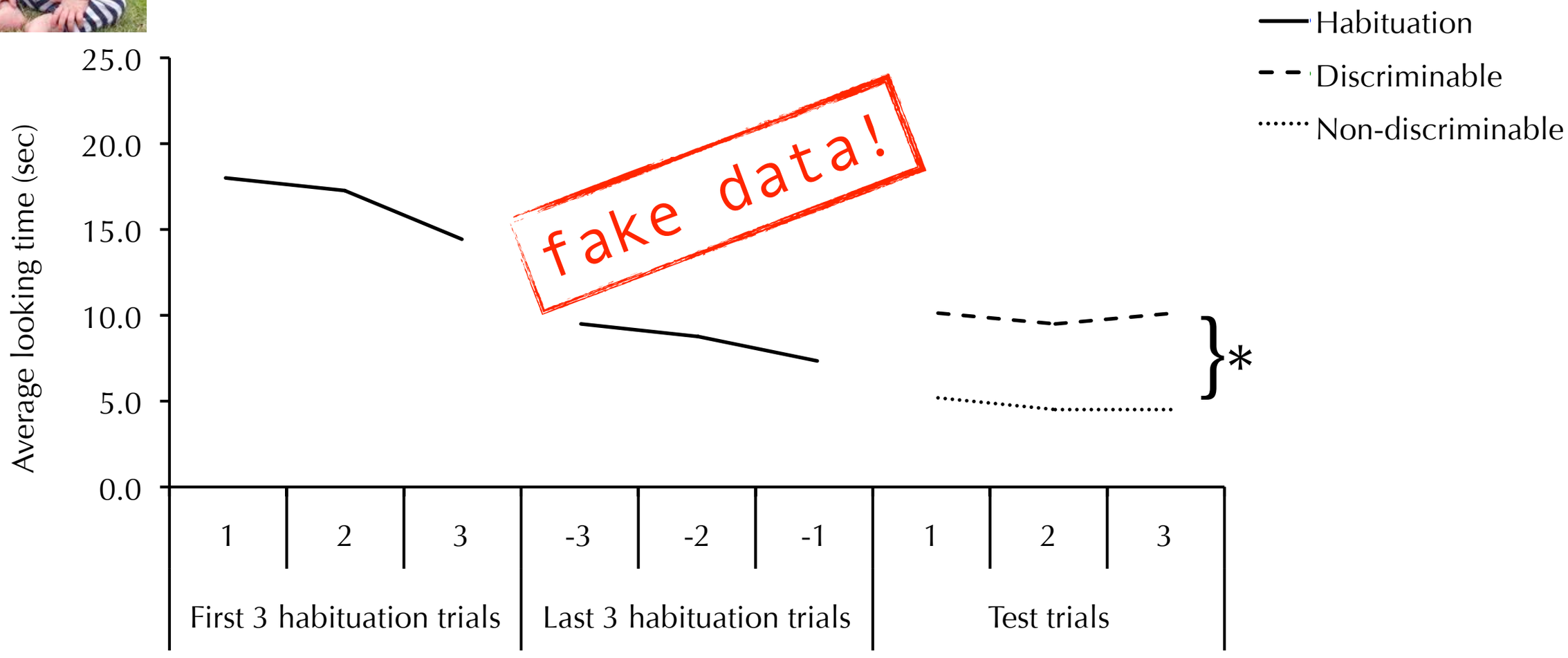
10 crosses

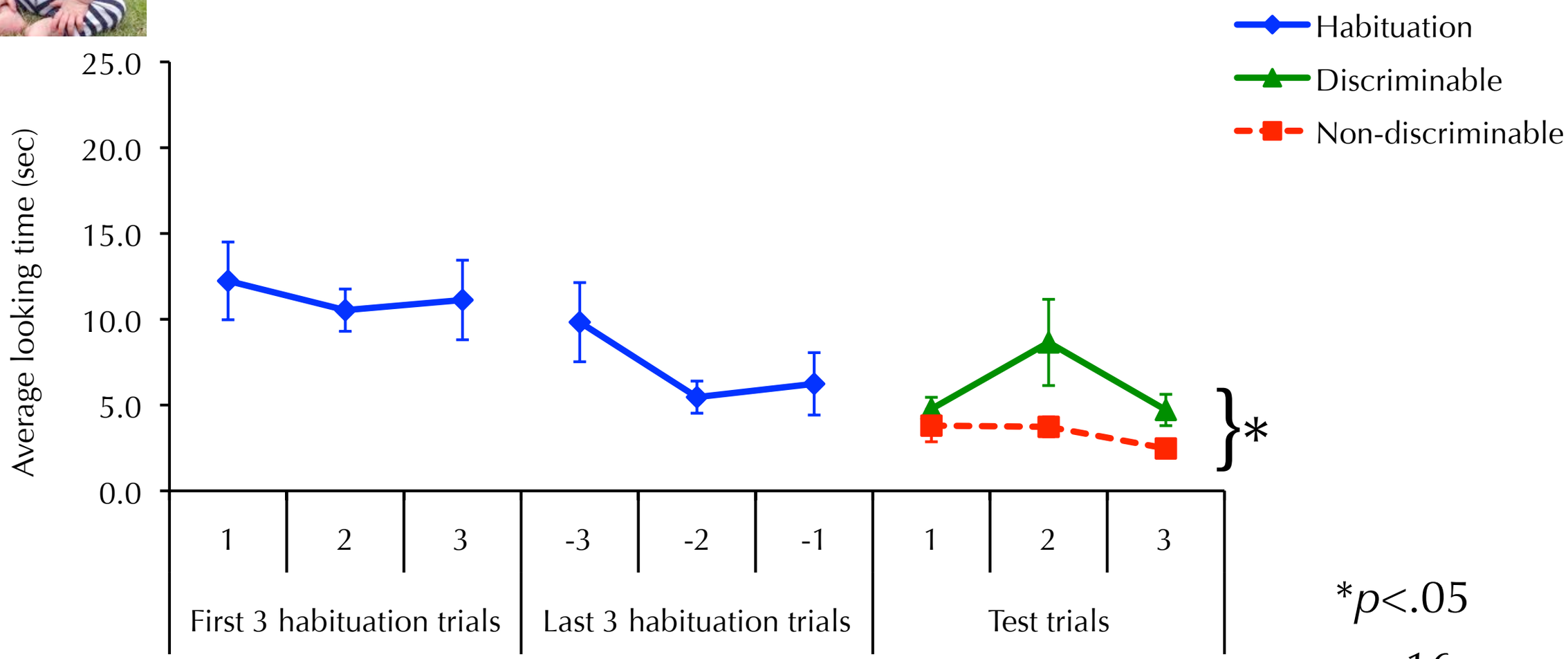


Non-discriminable

7 crosses




Habituation
Discriminable
Non-discriminable
fake data!
*
Average looking time (sec)
25.0
20.0
15.0
10.0
5.0
0.0
1
2
3
-3
-2
-1
1
2
3
First 3 habituation trials
Last 3 habituation trials
Test trials



*p<.05

n=16

Infants can use shape to individuate ensembles and store the numerosity of each set

Moher & Feigenson, under review

only 1 feature	colour only	✓
	shape only	✓

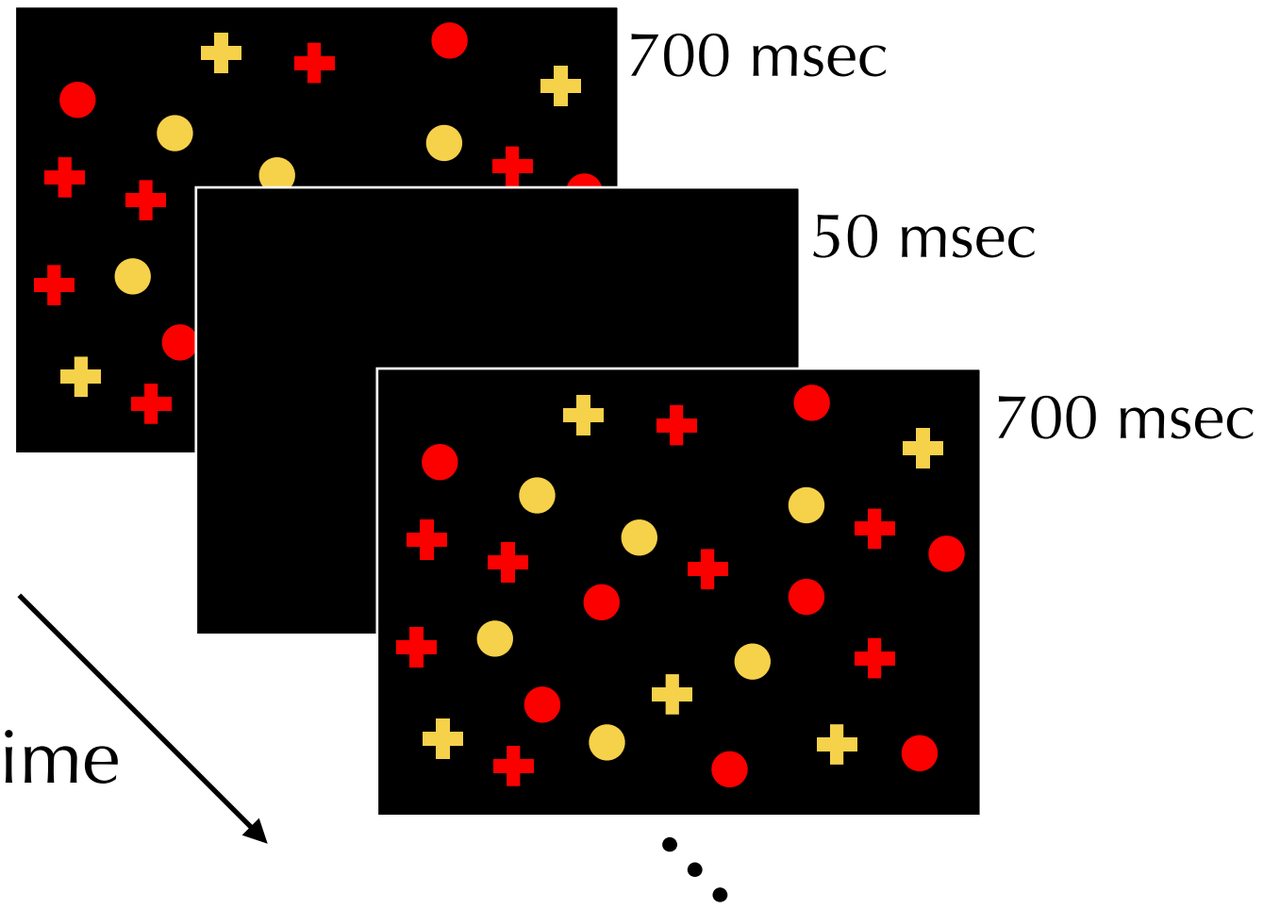
Infants can use multiple types of cues to individuate ensembles

Moher & Feigenson, under review

Can infants individuate overlapping ensembles?

Habituation

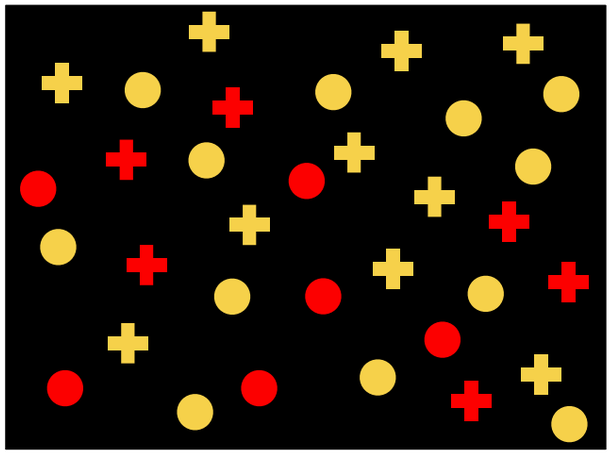
11 yellow items



until infant looks away for 2 consecutive seconds

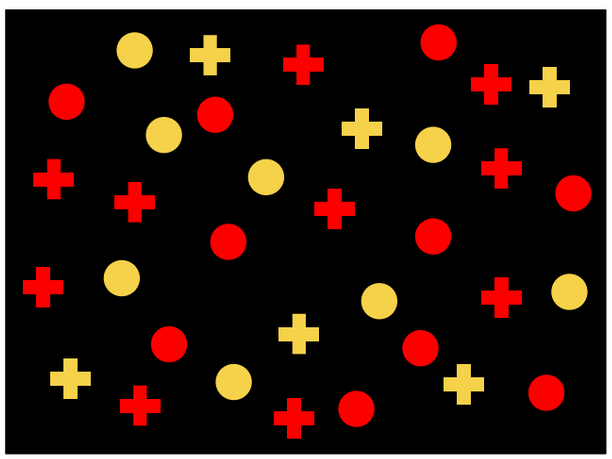
Discriminable

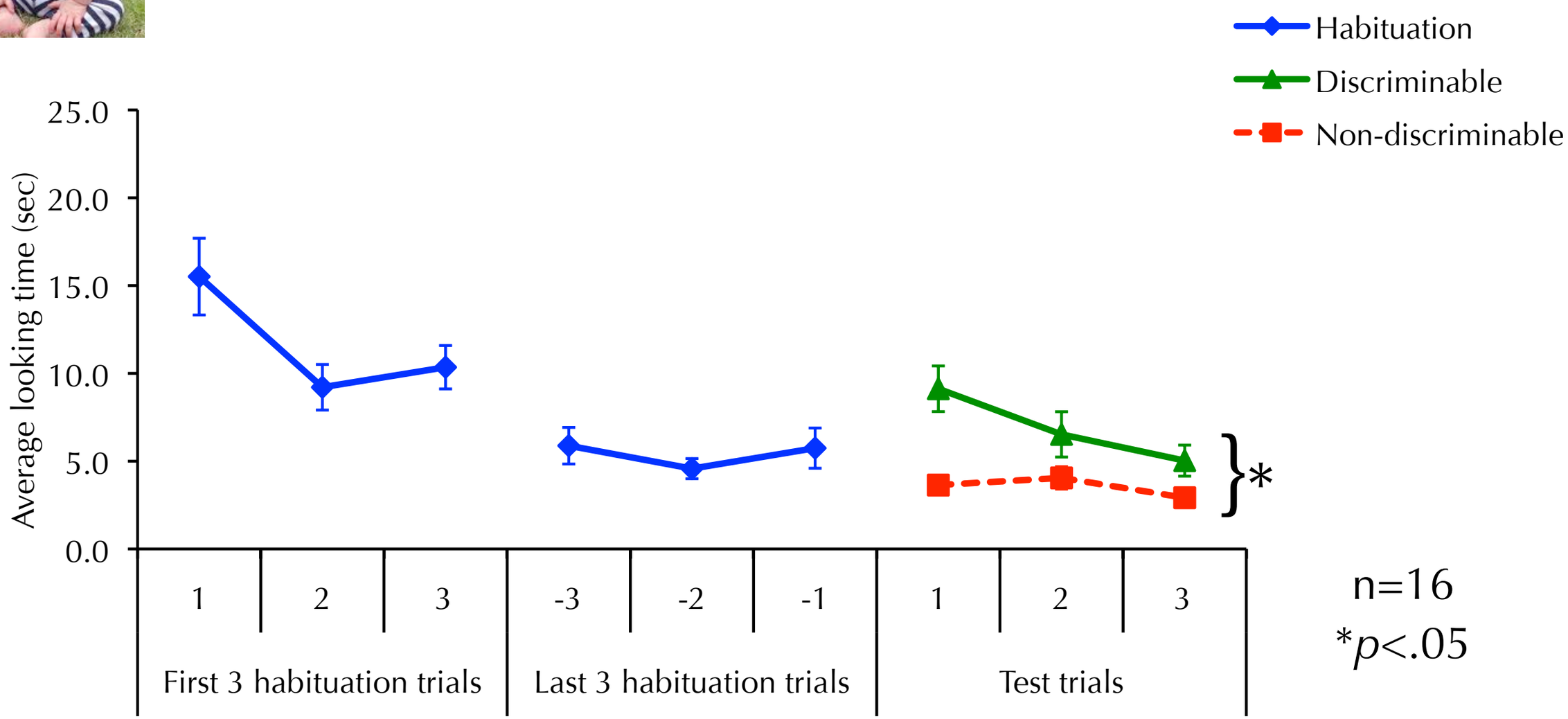
22 yellow items



Non-discriminable

14 yellow items



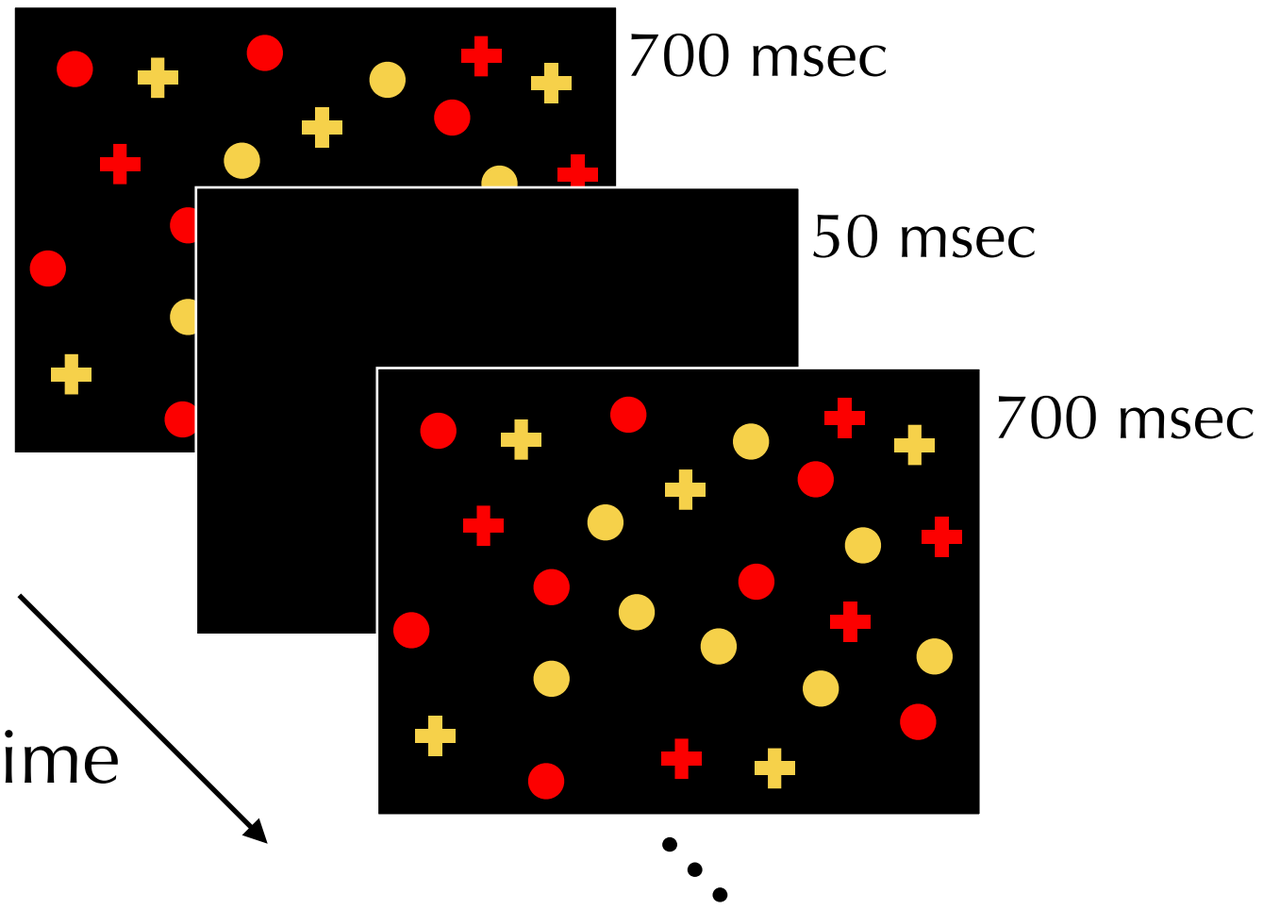


Infants can individuate colour-defined ensembles from an array containing overlapping ensembles

Moher & Feigenson, under review

Habituation

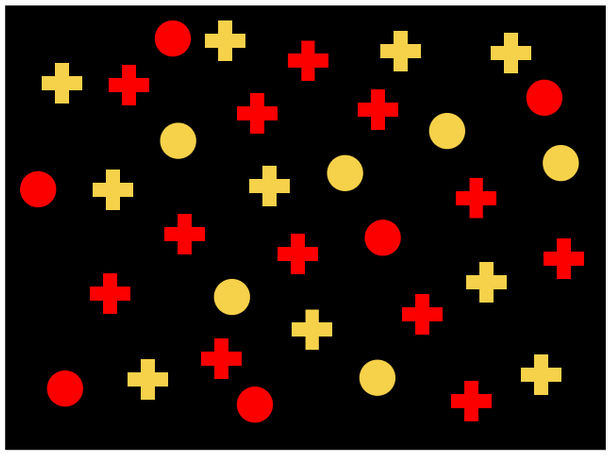
11 crosses



until infant looks away for 2 consecutive seconds

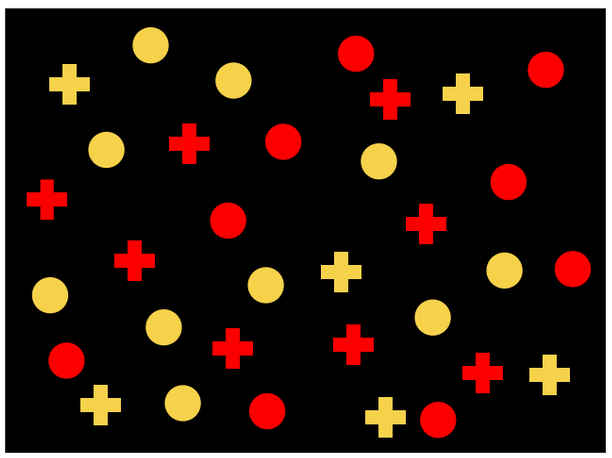
Discriminable

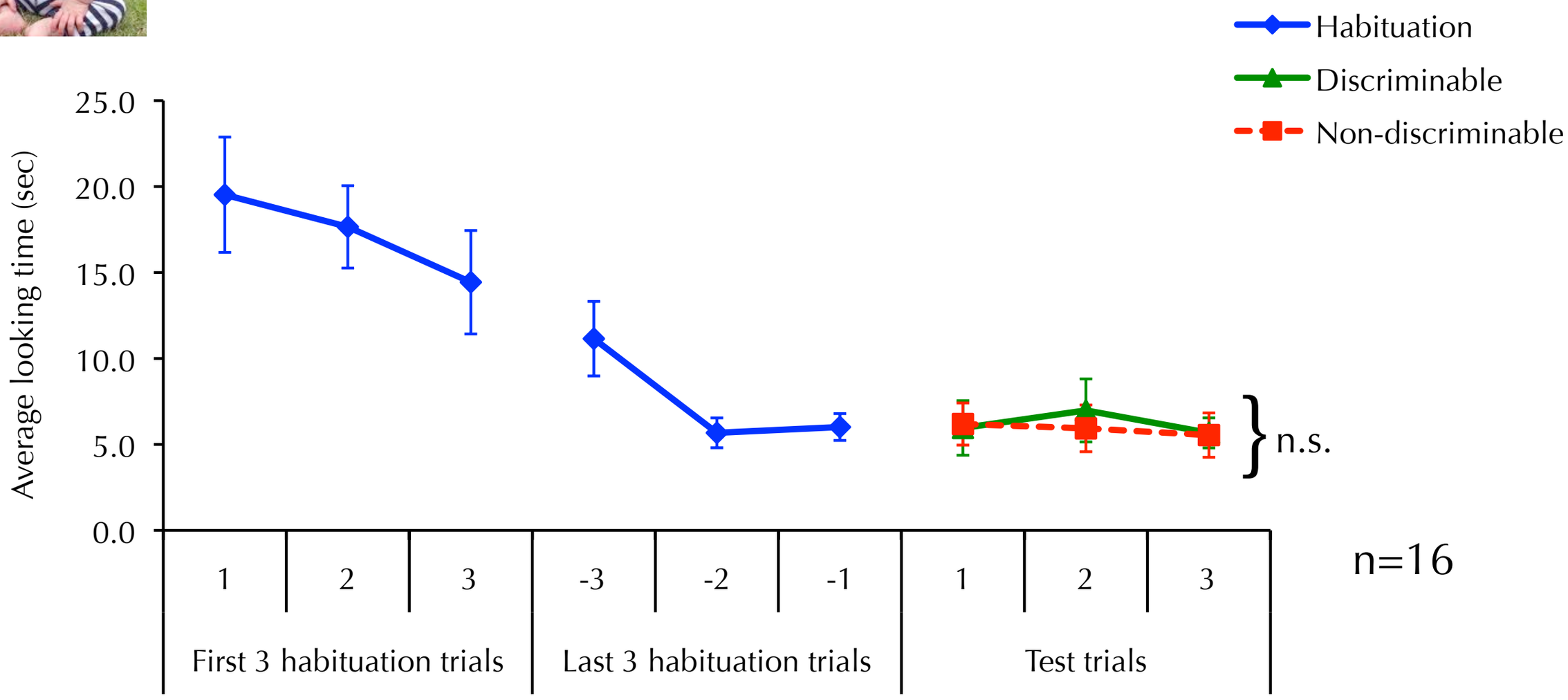
22 crosses



Non-discriminable

14 crosses





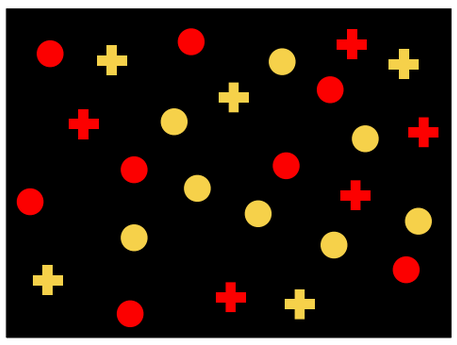
Infants cannot individuate shape-defined ensembles from an array containing overlapping ensembles

Moher & Feigenson, under review

only 1 feature	colour only	✓
	shape only	✓
conflicting features: colour & shape	colour	✓
	shape	✗
	shape: tripling	✗
	shape: feature salience	✗

- Why the failure?
  - infants store the shape-based ensemble but at a coarser resolution
  - the difference in colour is more salient than the difference in shape

Moher & Feigenson, under review



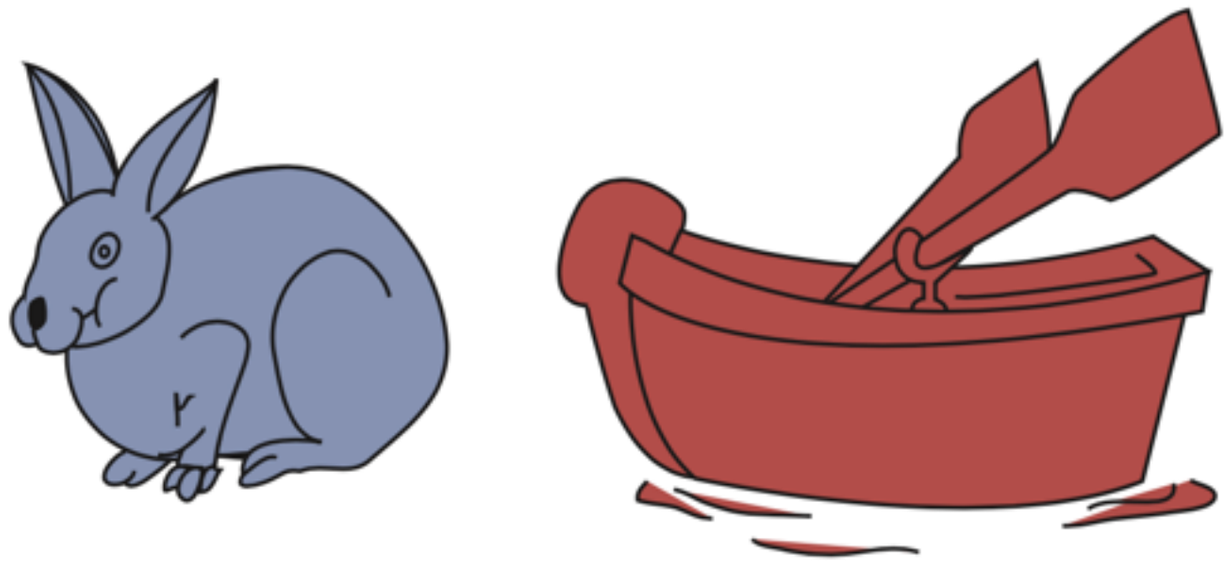
- Infants can individuate colour-defined ensembles in complex arrays
- Different prioritization of dimensions?

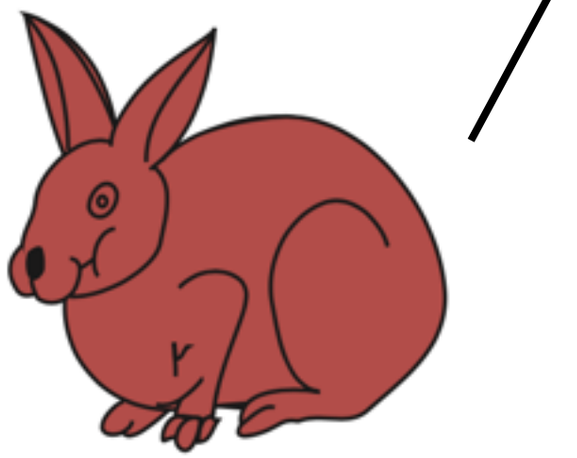
Moher & Feigenson, under review

Are some dimensions easier to categorize by than others?

Jose Rivera-Aparicio ’17 & Ben Lin ’17 senior theses
Rivera-Aparicio, Lin, Cone, & Moher (2017) VSS poster

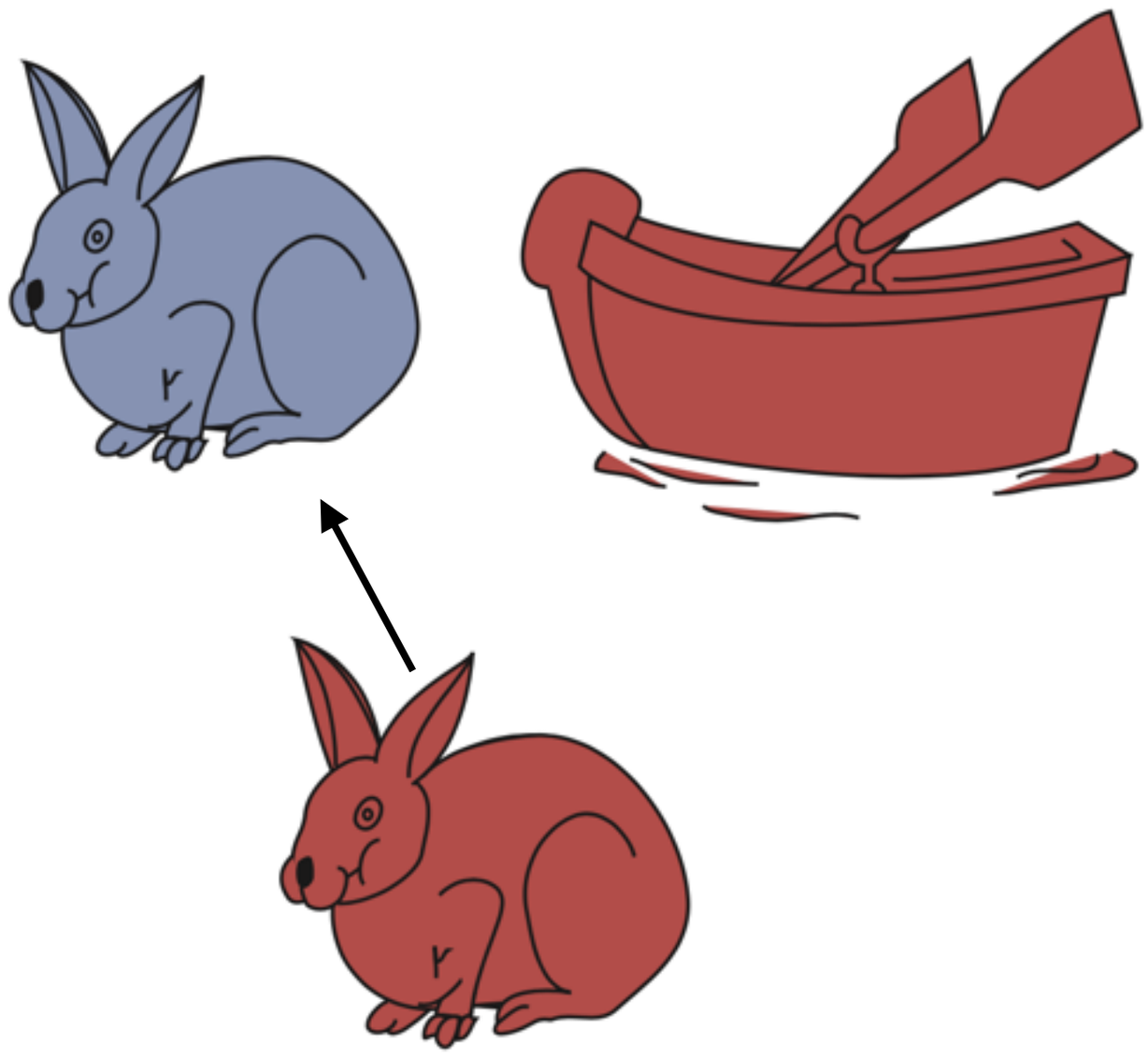
Dimensional Change Card Sort (Zelazo, 2006)





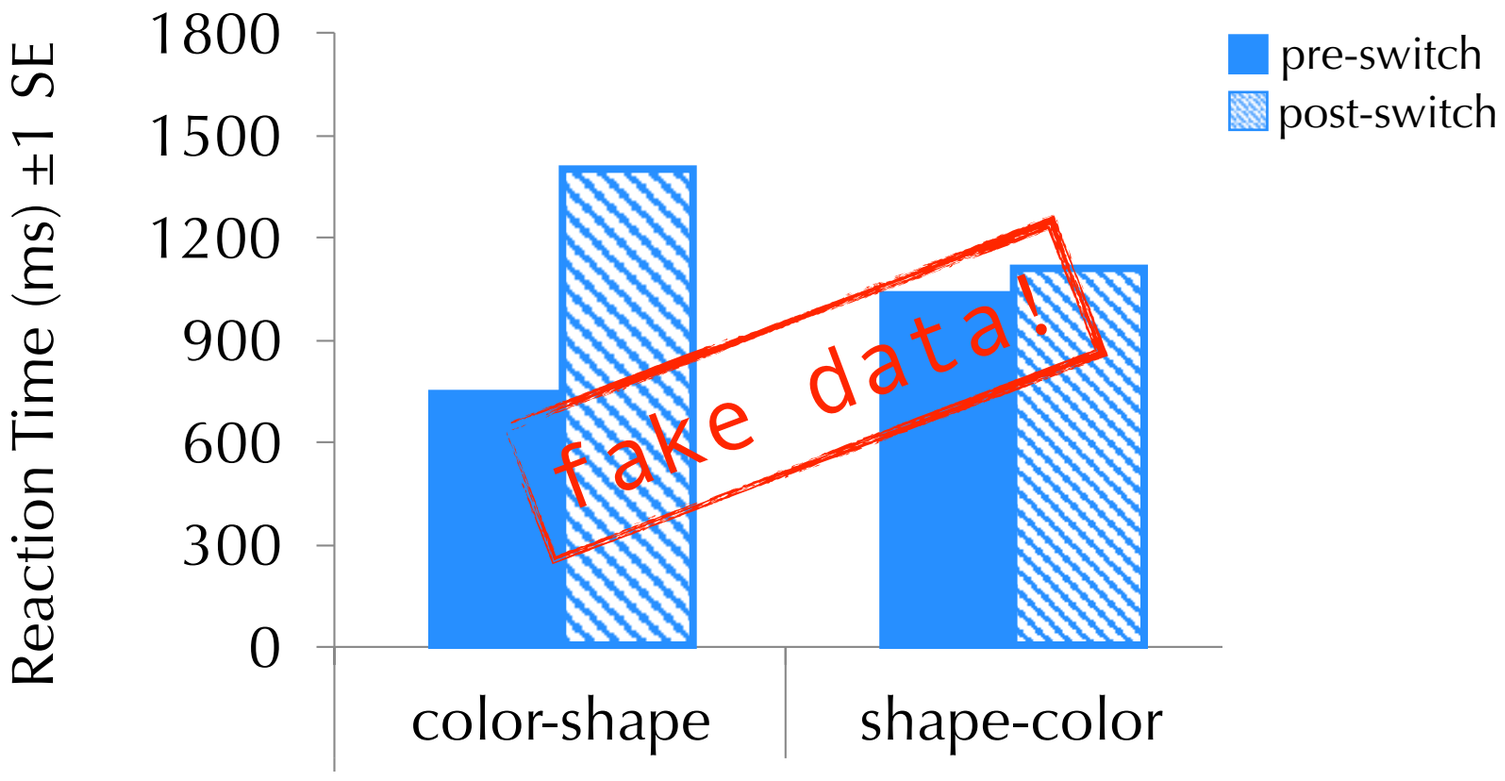
colour

Dimensional Change Card Sort (Zelazo, 2006)

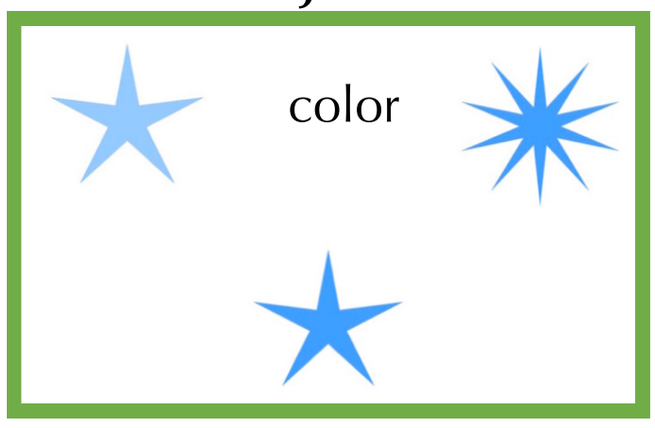


shape

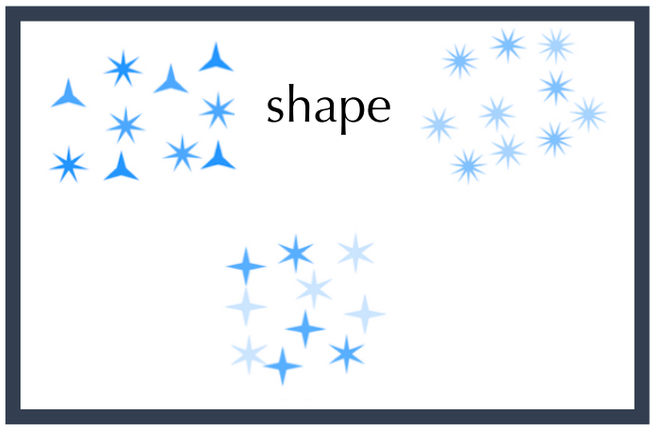
Dimensional Change Card Sort (Zelazo, 2006)



objects



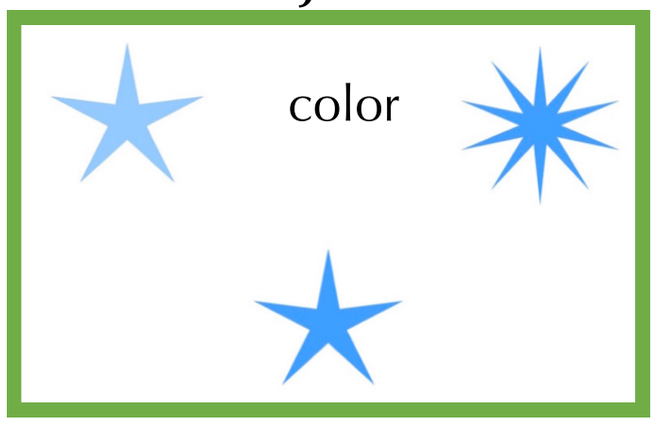
heterogeneous ensembles



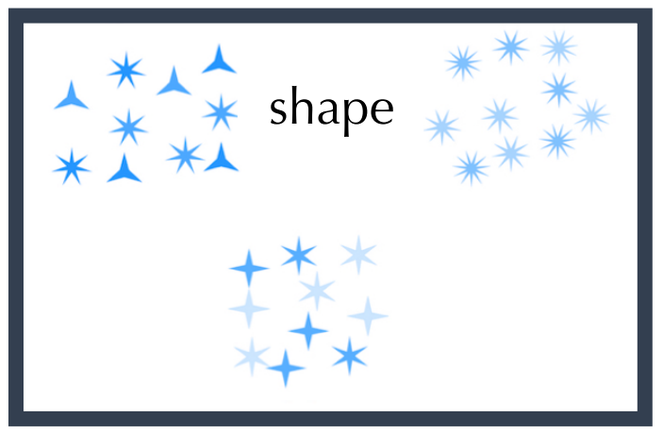
are some dimensions easier to sort by,
or switch into, than others?

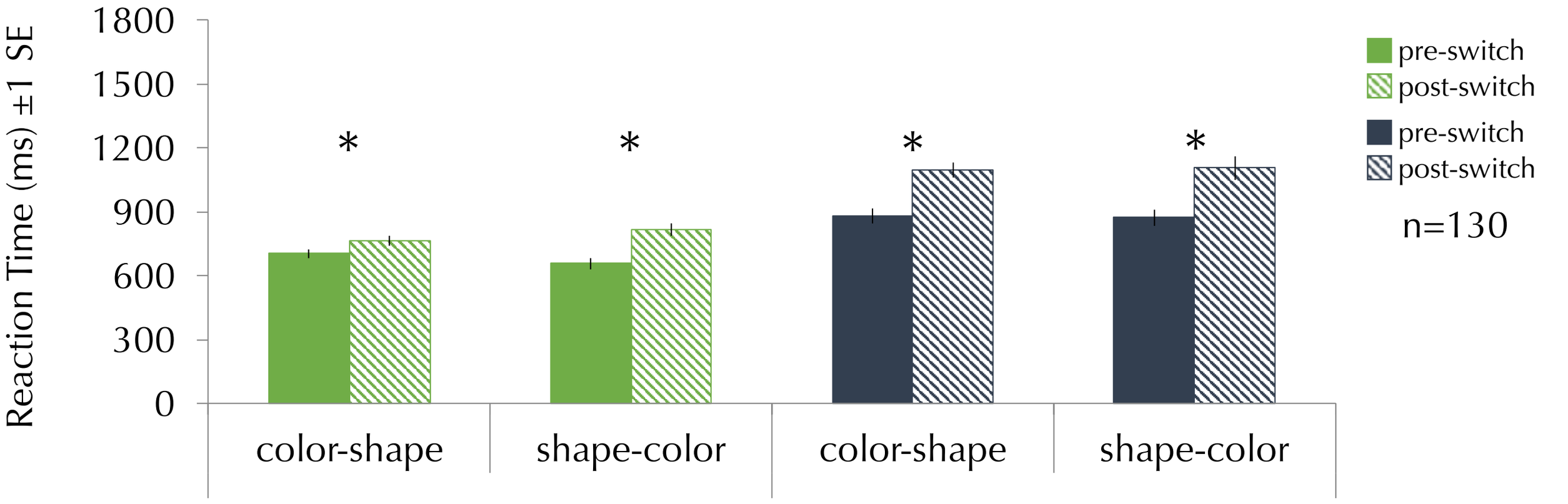
Jose Rivera-Aparicio ’17 senior thesis
Rivera-Aparicio, Lin, Cone, & Moher (2017) VSS poster

objects



heterogeneous ensembles





neither colour nor shape prioritized

Rivera-Aparicio, Lin, Cone, & Moher (2017) VSS poster

Ben Lin ’17 senior thesis

Rivera-Aparicio, Lin, Cone, & Moher (2017) VSS poster

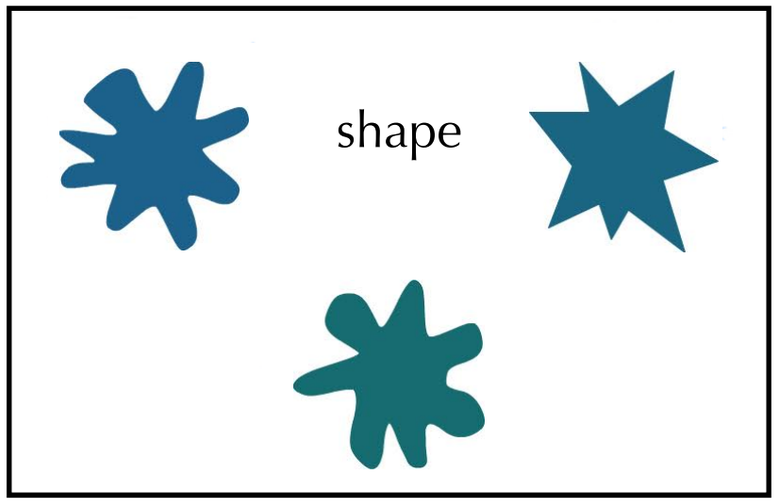
colour
flexible

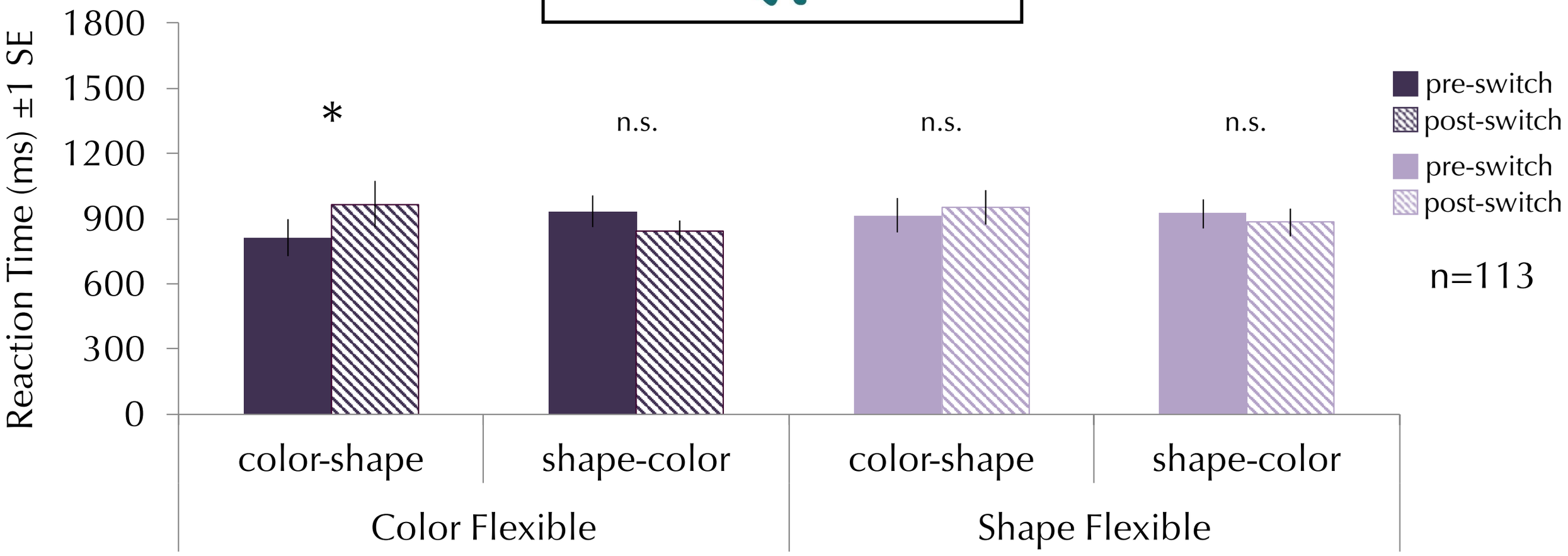
shape
flexible

are some dimensions easier to sort by,
or switch into, than others?

is this malleable?

Ben Lin ’17 senior thesis
Rivera-Aparicio, Lin, Cone, & Moher (2017) VSS poster



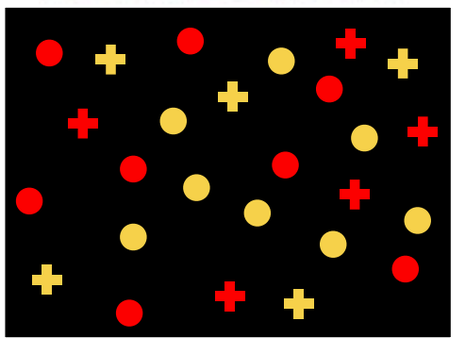


Contextual information can affect switch costs

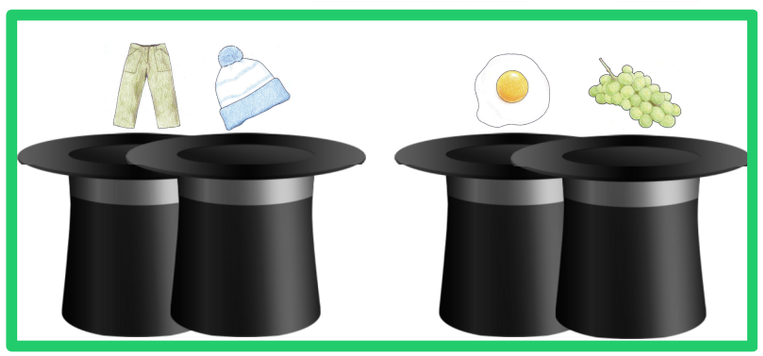
Rivera-Aparicio, Lin, Cone, & Moher (2017) VSS poster

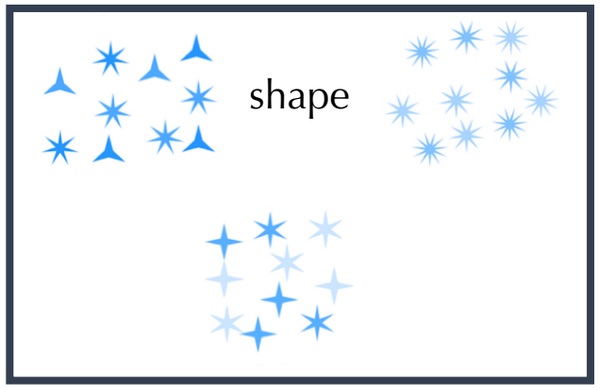
- ways to overcome capacity limits in memory:

ensembles



chunks





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