The psycho-logic of universal quantifiers

Tyler Knowlton

Dissertation defense

6.28.21

Slides available at:
tylerknowlton.com/talks/defense.pdf

Big picture: Linguistic meaning in the mind

What sorts of instructions do meanings provide to cognition?

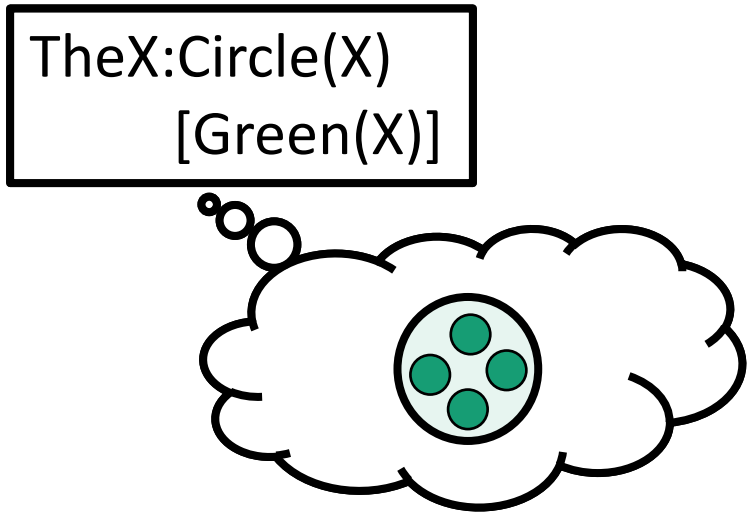
➥ To what extent do they constrain thought?

➥ At what grain-size are they shared by speakers?

Why *each* and *every*?

➥ Can state precise hypotheses about their meaning representations

“Every circle is green”



➥ Can leverage an understanding of supporting cognitive systems

(e.g., those for representing number, groups, individuals)

Roadmap: How are *each* & *every* mentally represented?

Three hypotheses

➥ Two (psycho)logical distinctions

Relational Second-order	**Restricted Second-order**	**Restricted First-order**

Relational vs. Restricted

➥ Number cognition as a probe into which arguments are represented

➥ The “conservativity” universal

First-order vs. Second-order (individual- vs. group- implicating)

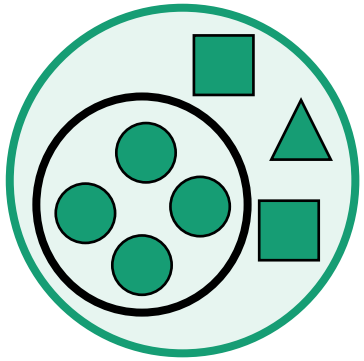
➥ Object-files vs. Ensembles as a probe into how arguments are represented

➥ Consequences for language acquisition

Each/Every circle is green – possible representations

The circles$_X$ are among the green-things$_Y$

TheX:Circle(X) ⊆ TheY:Green(Y)

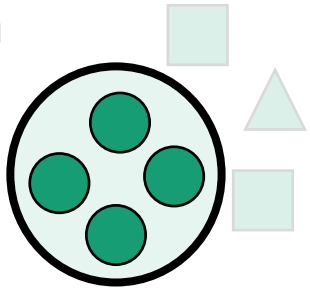


Relational Second-order

The circles$_X$ are such that all of them$_X$ are green

TheX:Circle(X)[Green(X)]

every

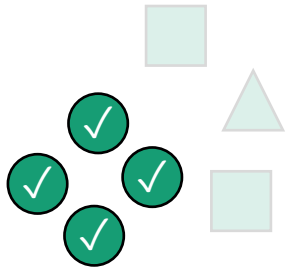


Restricted Second-order

Any individual circle$_x$ is such that it$_x$ is green

∀x:Circle(x)[Green(x)]

each



Restricted First-order

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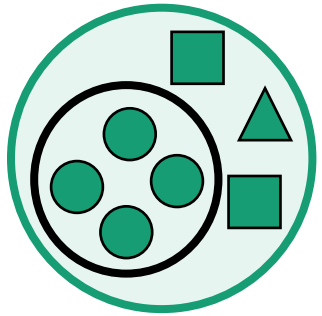

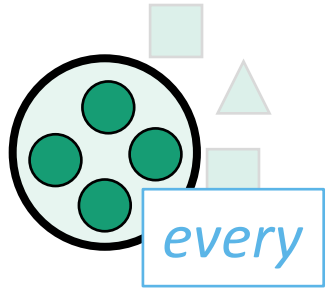

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➥ Consequences for language acquisition

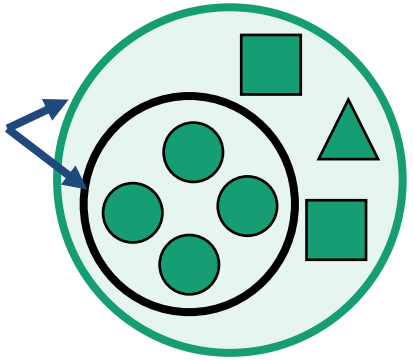
Different representations & behavioral predictions

Linking hypothesis (Interface Transparency): In evaluating a sentence, people are biased toward strategies that directly compute the relations & operations expressed by the semantic representation under evaluation

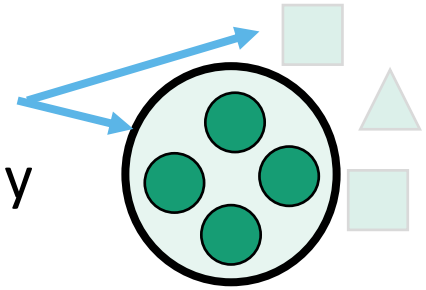
Relational
TheX:Circle(X) ⊆ TheY:Green(Y)
≈The circles$_X$ are among the green-things$_Y$

Restricted
TheX:Circle(X)[Green(X)]
≈The circles$_X$ are such that all of them$_X$ are green

Represent & compare both arguments



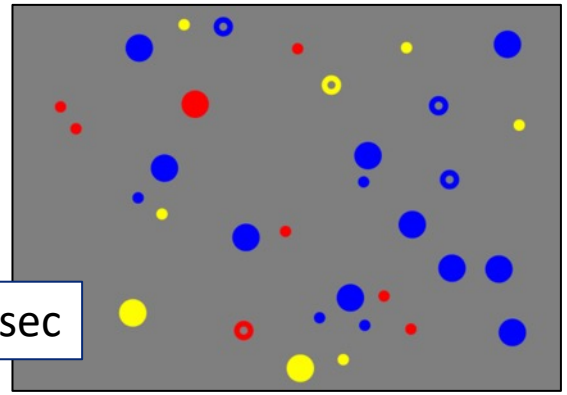
Treat arguments asymmetrically



(Linking hypothesis from Lidz et al. 2011)

Every big circle is blue

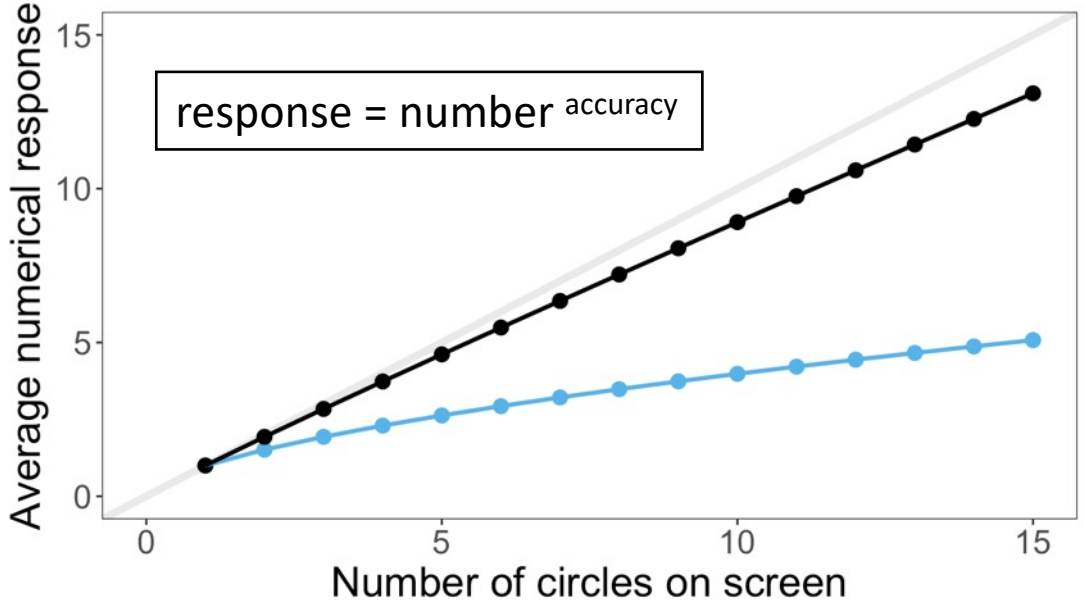
TRUE FALSE



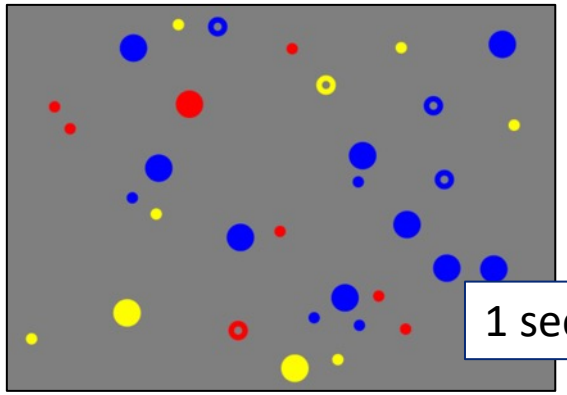
1 sec

How many big circles were there?

Accuracy on "how many" question



How many big circles are there?



1 sec

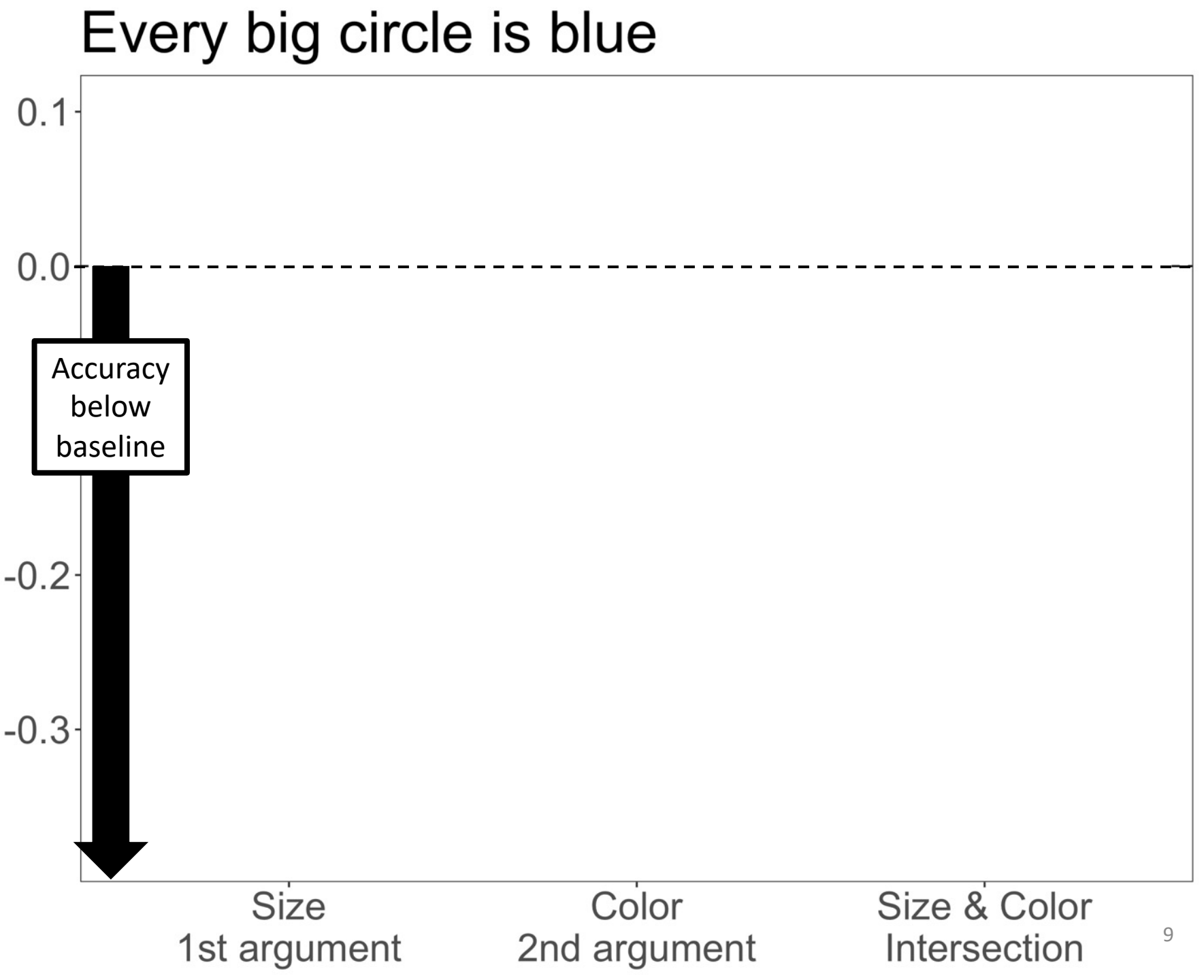
How many big circles were there?

#-knowledge following ***every***

vs.

#-knowledge **baseline**

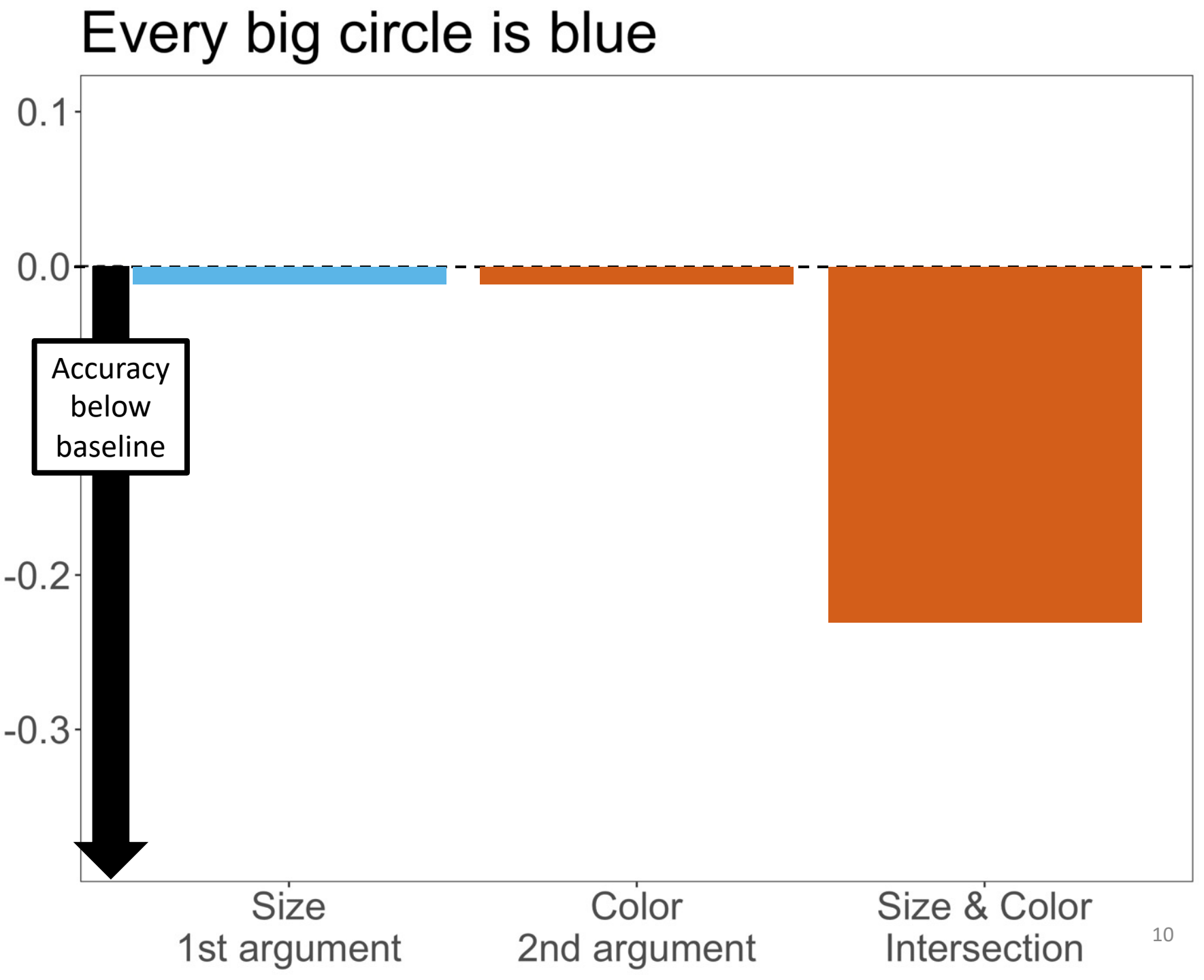
(e.g., Stevens 1964; Krueger 1984; Halberda, Sires & Feigenson 2006; Odic et al. 2016)


Every big circle is blue
0.1
0.0
-0.2
-0.3
Accuracy below baseline
Size
1st argument
Color
2nd argument
Size & Color
Intersection

Relational

The big-circles$_X$ are among the blue-circles$_Y$

Represent both arguments



Relational

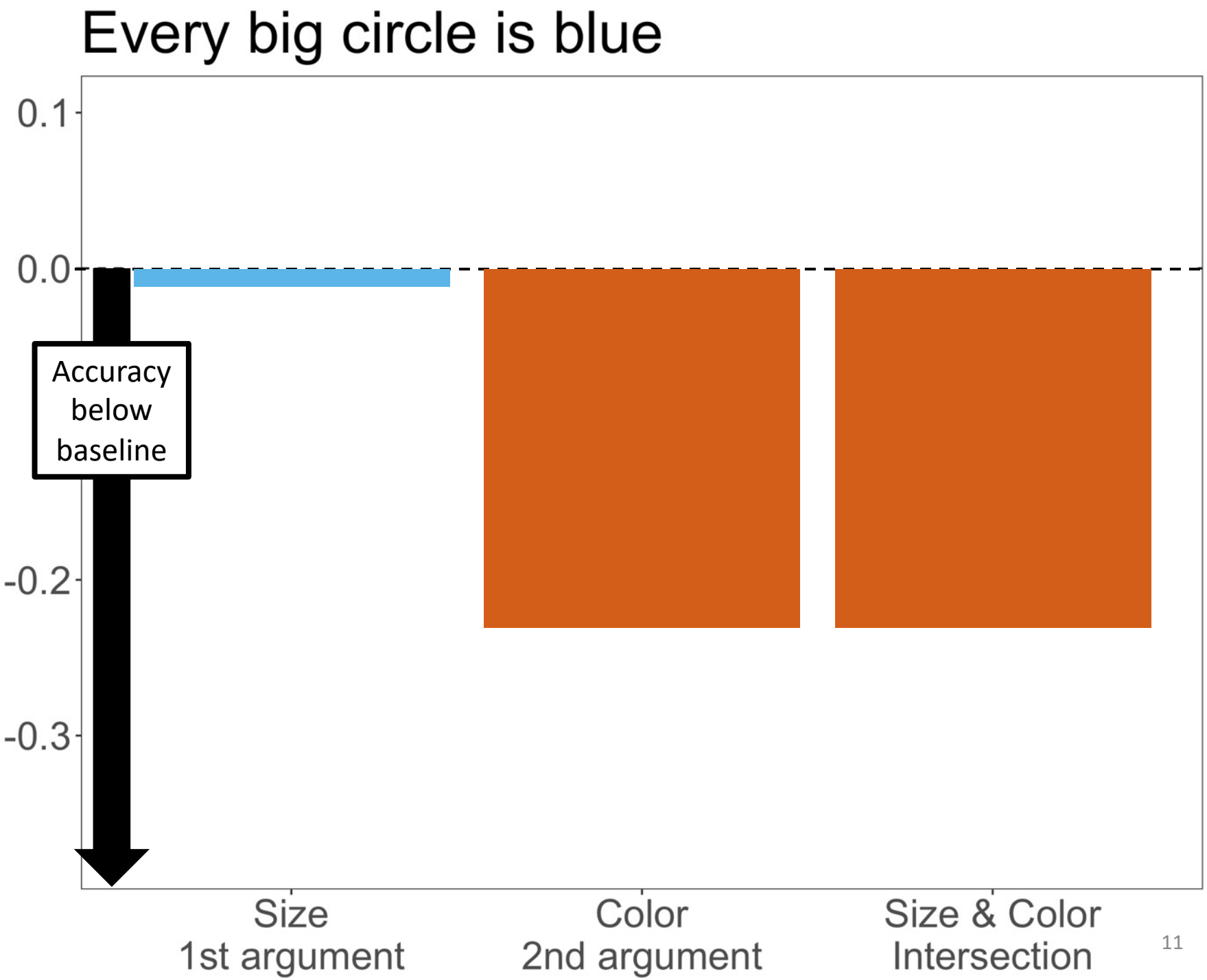
The big-circles$_X$ are among the blue-circles$_Y$

Represent both arguments

Restricted

The big-circles$_X$ are such that all of them$_X$ are blue

Treat arguments asymmetrically



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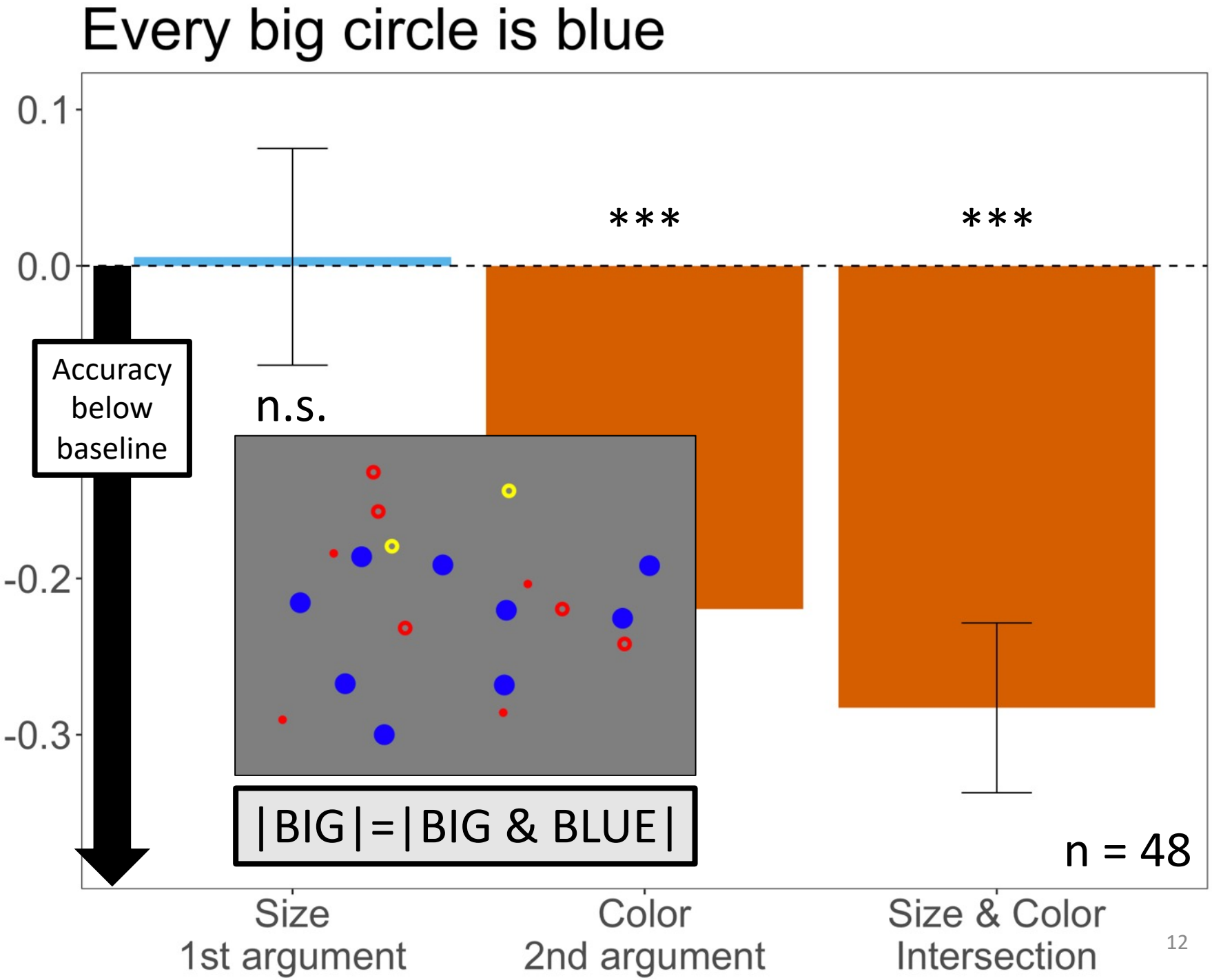

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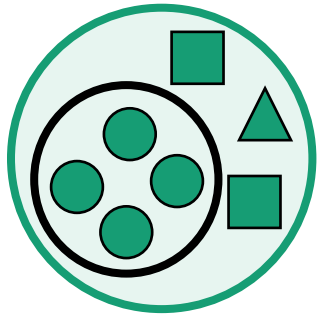

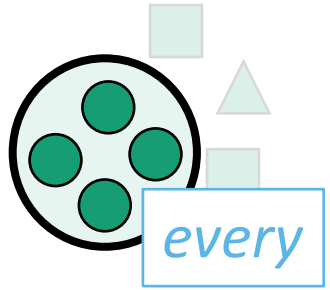

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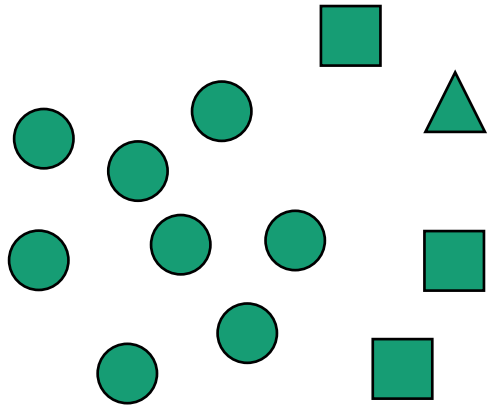
Natural language determiners are “conservative”

A determiner **DET** is conservative iff

(1) [[**DET** NP] PRED] =

(2) [[**DET** NP] [be NP that PRED]]



every *circle is green* (TRUE) =

every *circle is a circle that is green* (TRUE)

(e.g., Barwise & Cooper 1981; Higginbotham & May 1981; Keenan & Stavi 1986)

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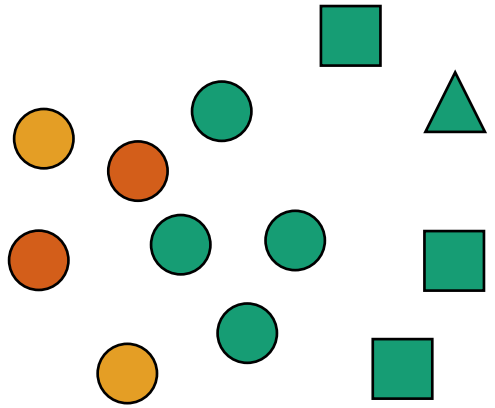


every *circle is green* (FALSE) =

every *circle is a circle that is green* (FALSE)

(e.g., Barwise & Cooper 1981; Higginbotham & May 1981; Keenan & Stavi 1986)

Natural language determiners are “conservative”

A determiner **DET** is conservative iff

(1) [[**DET** NP] PRED] =

(2) [[**DET** NP] [be NP that PRED]]

➥ Cross-linguistically, all determiners are conservative

➥ 5year-olds can learn novel conservative determiners **but not** novel non-conservative ones!

(e.g., Barwise & Cooper 1981; Higginbotham & May 1981; Keenan & Stavi 1986; Hunter & Lidz 2013; *cf*. Spenader & de Villiers 2019)

“Conservativity” is puzzling on the relational view

What rules out all the non-conservative relations?

|CIRCLES ∩ GREEN| > |CIRCLES - GREEN|

≈*most circles are green*

CIRCLES ⊆ GREEN

≈*every circle is green*

|CIRCLES| = |GREEN|

CIRCLES ⊇ GREEN

(For relationality-preserving proposals, see: Keenan & Stavi 1986; Romoli 2015; Chierchia 1995; Fox 2002; Sportiche 2005)

“Conservativity” is entailed on the restricted view

Relative to the circles, *is green* applies to

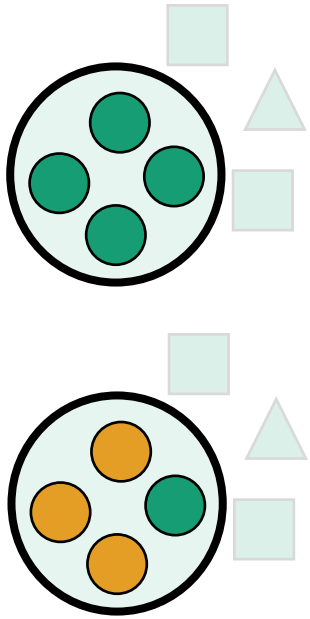
…all things

…most things

…at least 2 & at most 4 things

…??? things

(intended: |CIRCLES| = |GREEN|)



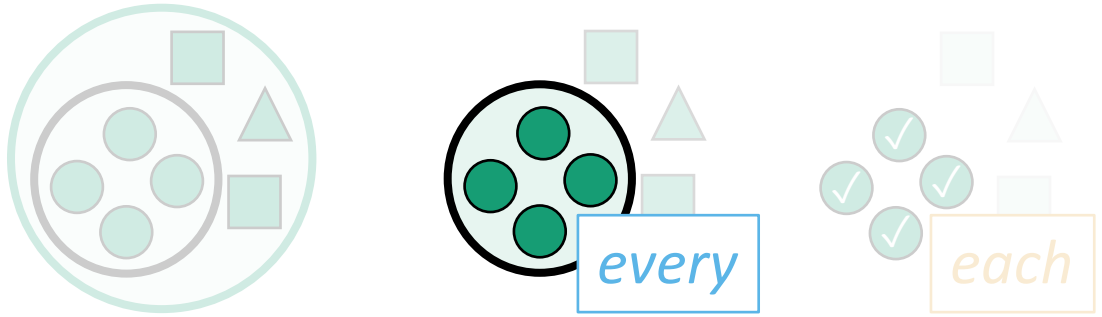
➥ Non-conservative meanings are not stateable if the first argument restricts the domain of quantification

(Pietroski 2005, 2018; Westerståhl 2019; Lasersohn 2021)

Roadmap: How are *each* & *every* mentally represented?

Three hypotheses

✓ Two (psycho)logical distinctions



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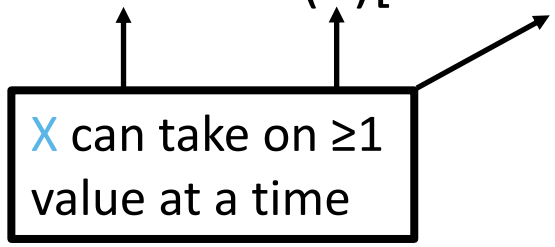
➥ Consequences for language acquisition

Different representations

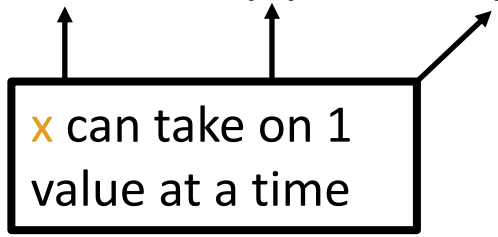
Second-order representation (*every circle is green*)

TheX:Circle(X)[Green(X)] ≈The circles are such that they are green



First-order representation (*each circle is green*)

∀x:Circle(x)[Green(x)] ≈Any individual circle is such that it is green



(Boolos 1984, 1985, 1998; Schein 1993; Pietroski 2018)

Different representations & cognitive systems

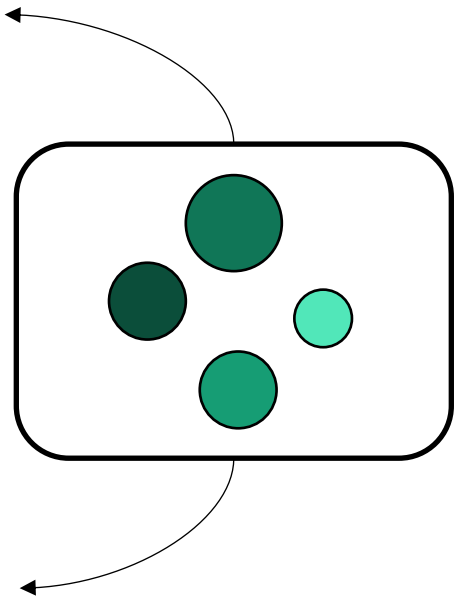
Second-order representation (*every circle is green*)

TheX:Circle(X)[Green(X)] ≈The circles are such that they are green

X can take on ≥1 value at a time

Ensemble representation
Objects abstracted away from summary statistics encoded

Center: (0,0)
Avg. Hue:
Avg. Size:



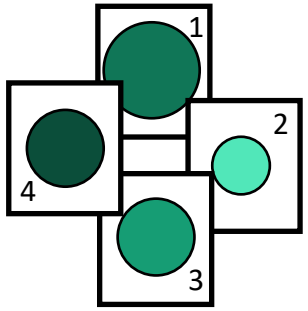
(e.g., Ariely 2001; Feigenson, Dehaene & Spelke 2004; Alvarez 2011; Haberman, Brady & Alvarez 2015; Ward, Bear & Scholl 2016; Whitney & Leib 2018)

First-order representation (*each circle is green*)

∀x:Circle(x)[Green(x)] ≈Any individual circle is such that it is green

x can take on 1 value at a time

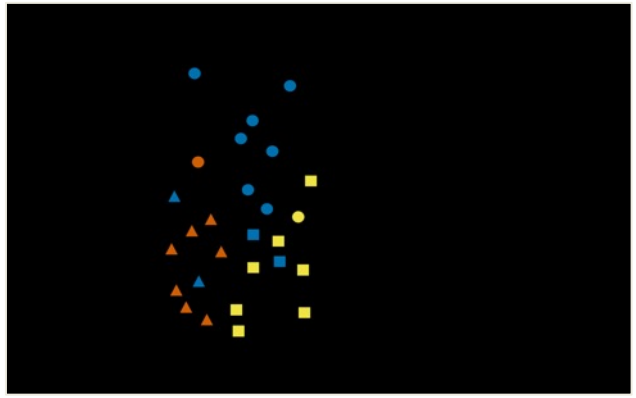
Object-file representations
Objects individuated
individual properties encoded



(e.g., Kahnemann et al. 1992; Pylyshyn & Storm 1998; Scholl, Pylyshyn & Feldman 2001; Scholl 2002; Feigenson, Dehaene & Spelke 2004; Carey 2009)

Is {each/every} circle blue?

“Yes” “No”



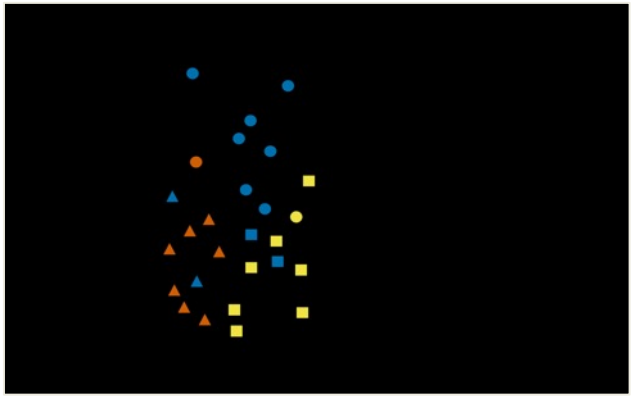
Where was the middle of the circles?

Center of Mass (group property)

(with 3- to 8-year-olds)

Is {each/every} circle blue?

“Yes” “No”



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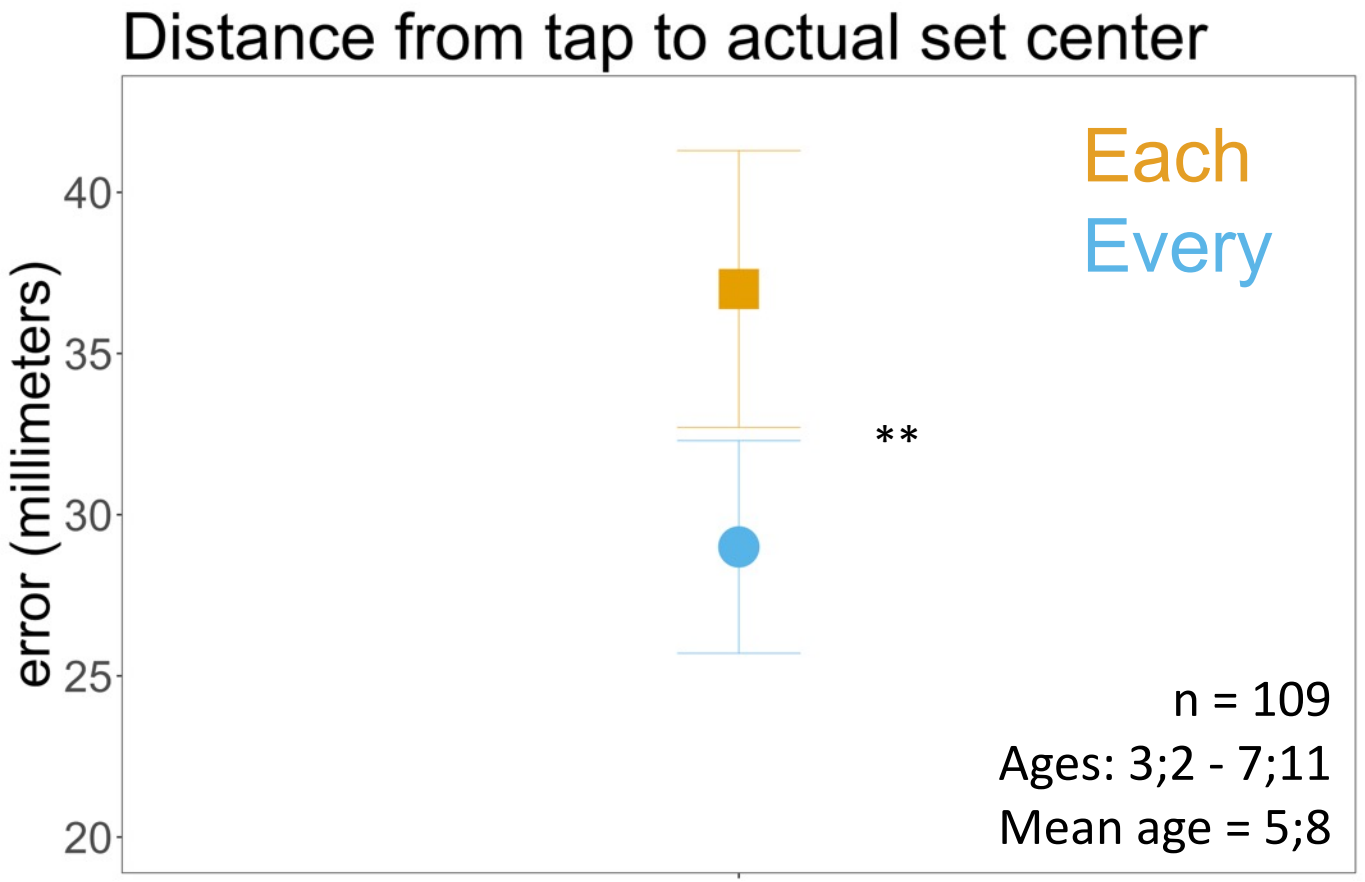

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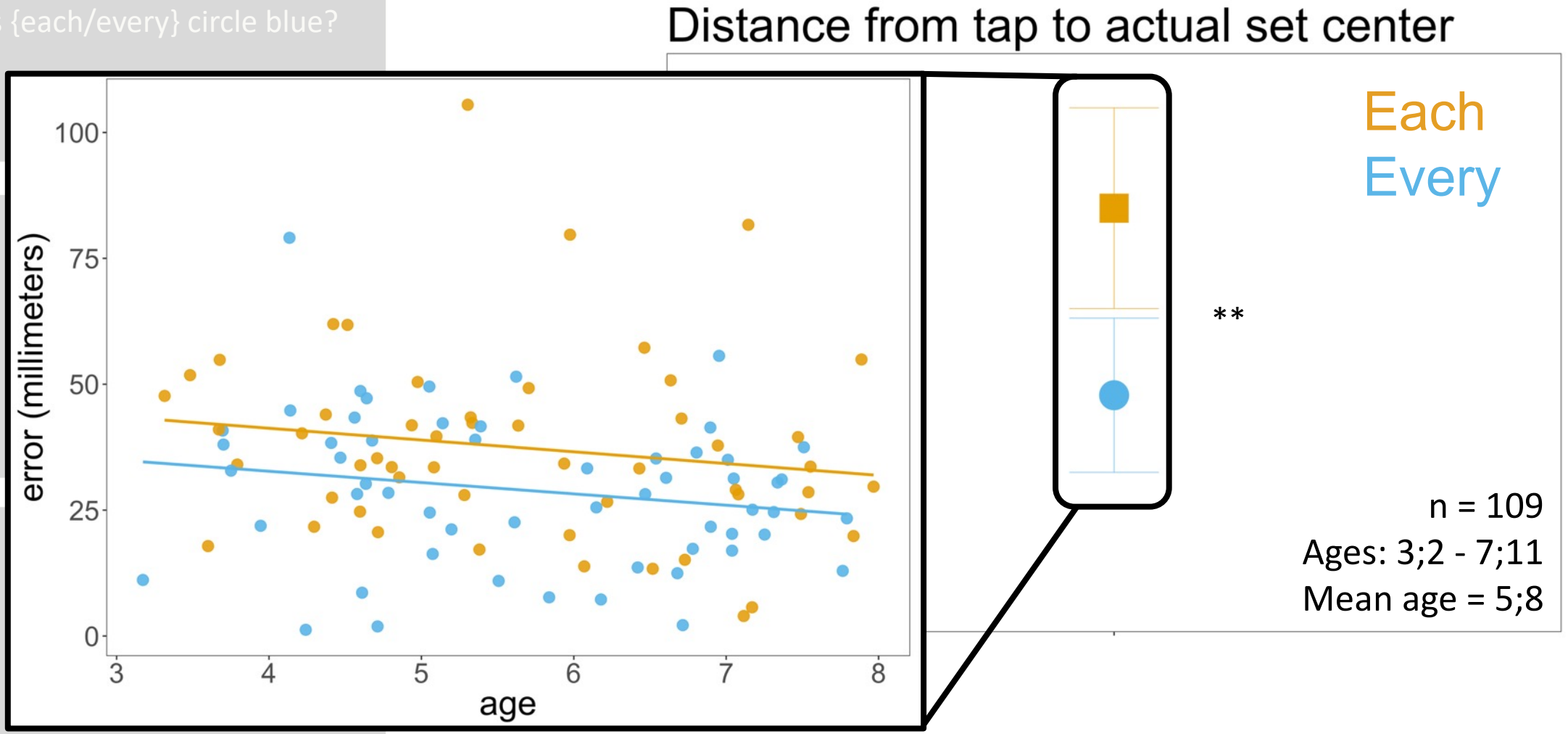
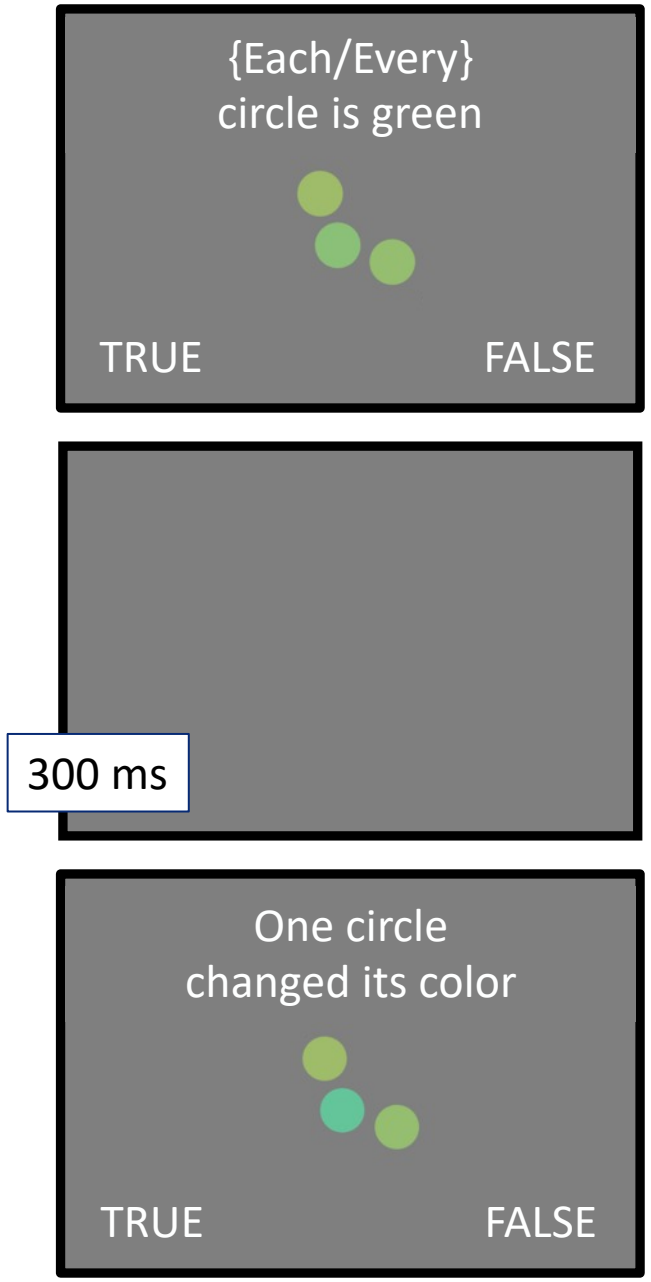
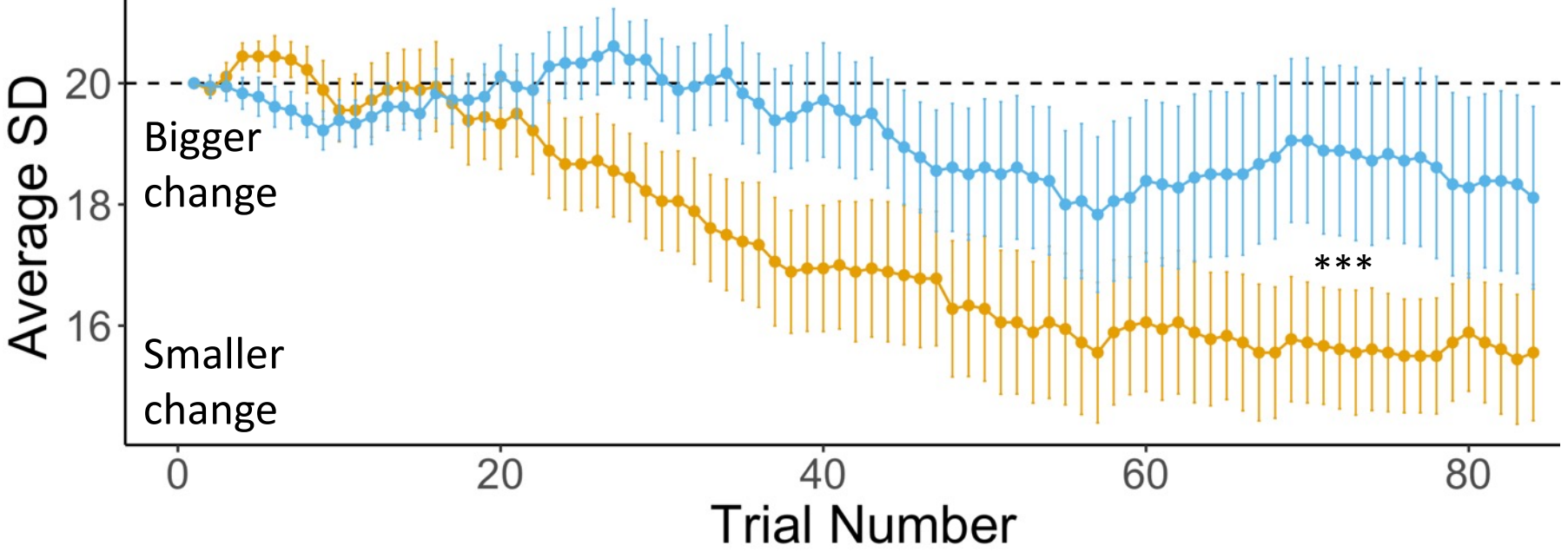




Color (individual property)

Color change detection: difficulty required for 70% accuracy following *each* or *every*



n = 36

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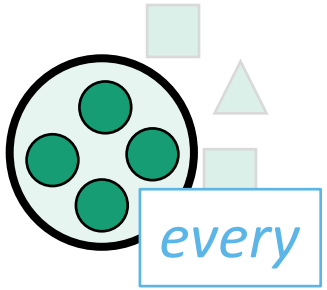

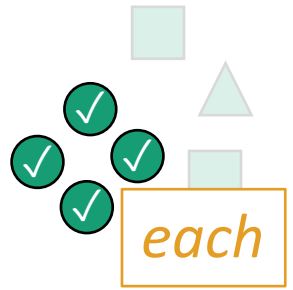

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How are *each* & *every* acquired?

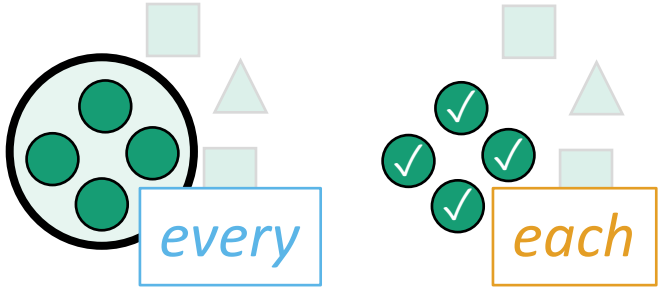
"You have to ring up each thing"
"Could you put a flower on each plate?"
"Put sugar in each coffee"
"We'll put one finger on each thing we count"
"We each have three"

Generalize over local domain

"Every time I ask a question,
you say you don't know"
"You turn into a wild man every time we get out"
"Your birthday's at the same time every year"
"She watches every movie they make"

Project beyond local domain

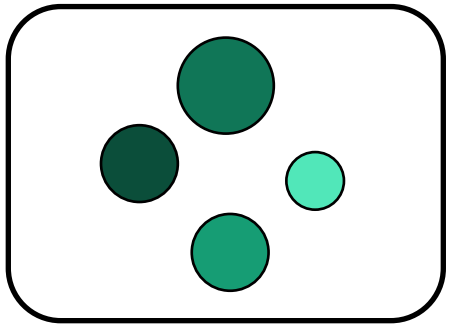
Child ambient speech (CHILDES)



What leads learners to pair "each" and "every" with the right representations?

(CHILDES: MacWhinney 2000)

Ensembles – but not object-files – support projecting beyond local domain



Every circle is green (second-order)

TheX:Circle(X)[Green(X)] ≈The circles are s.t. they are green

X can take on ≥1 value at a time

Ensemble representation
Objects abstracted away from summary statistics encoded

Predicts that new object will preserve homogeneity

Diversity: low
Avg. Hue:
Avg. Size:

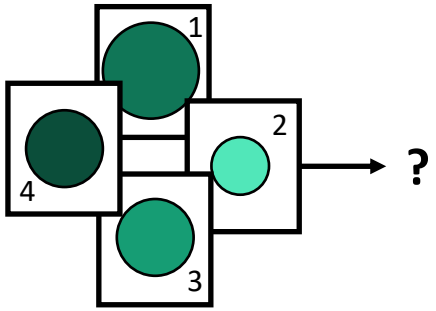
Each circle is green (first-order)

∀x:Circle(x)[Green(x)] ≈Any individual circle is s.t. it is green

x can take on 1 value at a time

Object-file representations
Objects individuated
individual properties encoded

Predicts nothing in particular about new object



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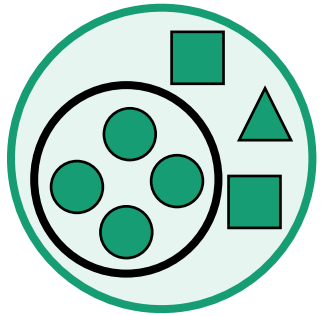

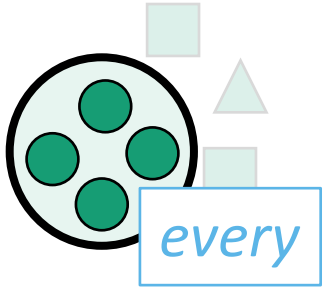

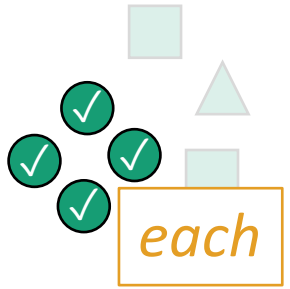

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✓ The “conservativity” universal

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✓ Object-files vs. Ensembles as a probe

✓ Consequences for language acquisition

Thanks!

To my committee:

Jeff Lidz
Paul Pietroski
Alexander Williams
Valentine Hacquard
Justin Halberda
Yi Ting Huang

To my cohort:

Sigwan Thivierge
Mina Hirzel
Anouk Dieuleveut
Aaron Doliana
Rodrigo Ranero

To others who've offered feedback/help/support:

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Adam Liter
Yu'an Yang
Laurel Perkins
Tara M Mease
Victor Gomes
Nicolò Cesana-Arlotti
Darko Odic
Alexis Wellwood
Simon Chervenak
Meagan Griffith
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The members of the UMD Acquisition & CNL labs

And to each and every one of you!

Language at Maryland

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Painting courtesy of Alex Oppenheimer (1;6)