Every universal is first-orderizable, but only *each* is first-orderized

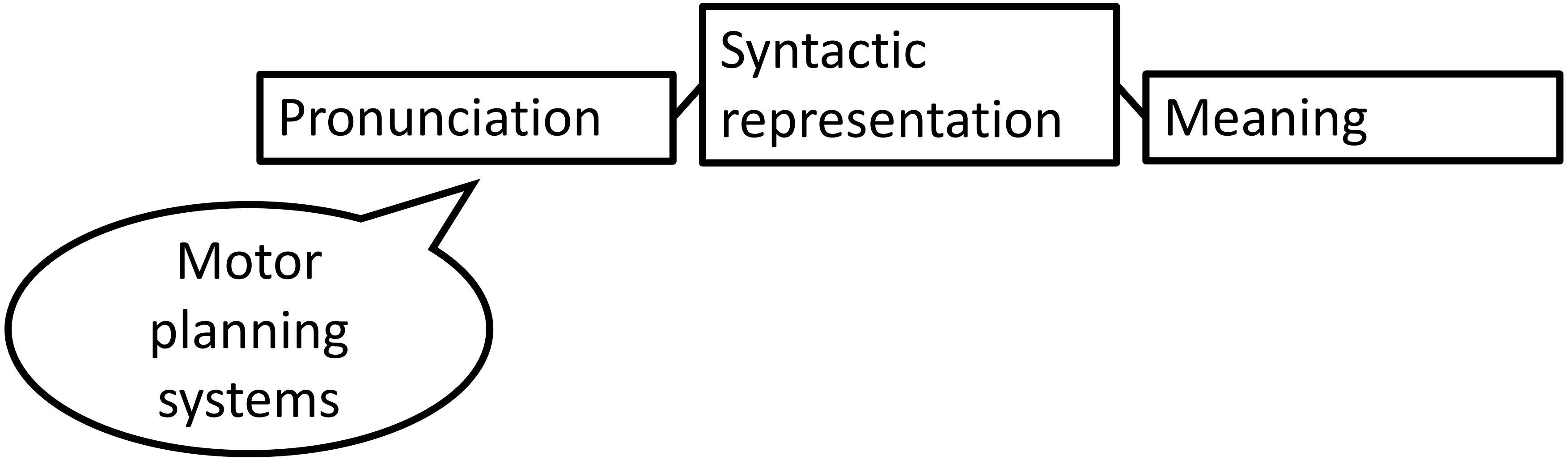
Tyler Knowlton

University of Pennsylvania

CoSaQ - 5.18.22

Big picture: Linguistic meaning in the mind

Big picture: Linguistic meaning in the mind



e.g., Halle 2003; Liberman & Mattingly 1985; Poeppel, Idsardi & van Wassenhove 2008

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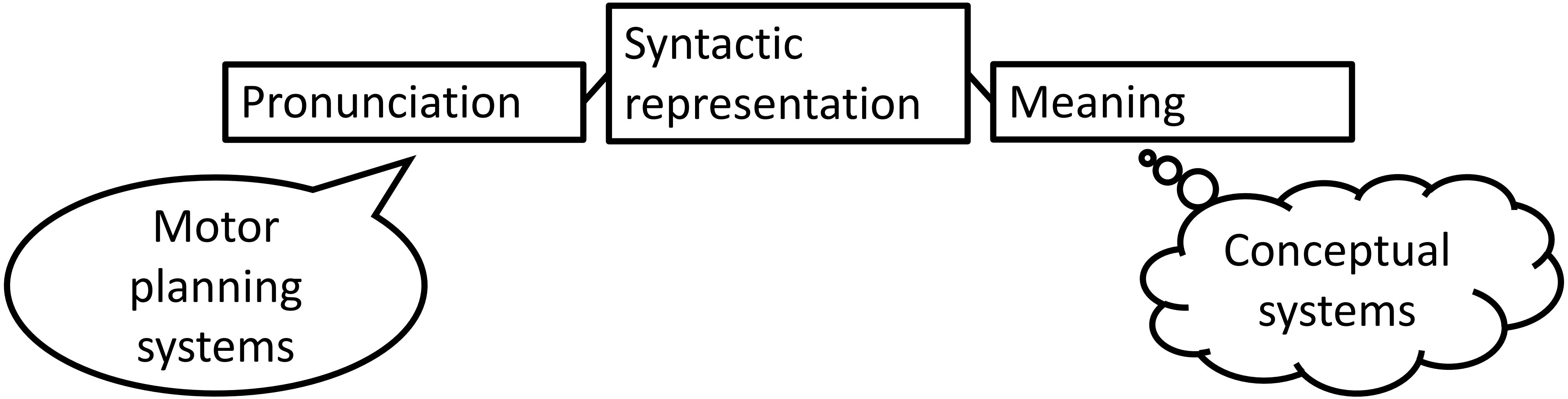

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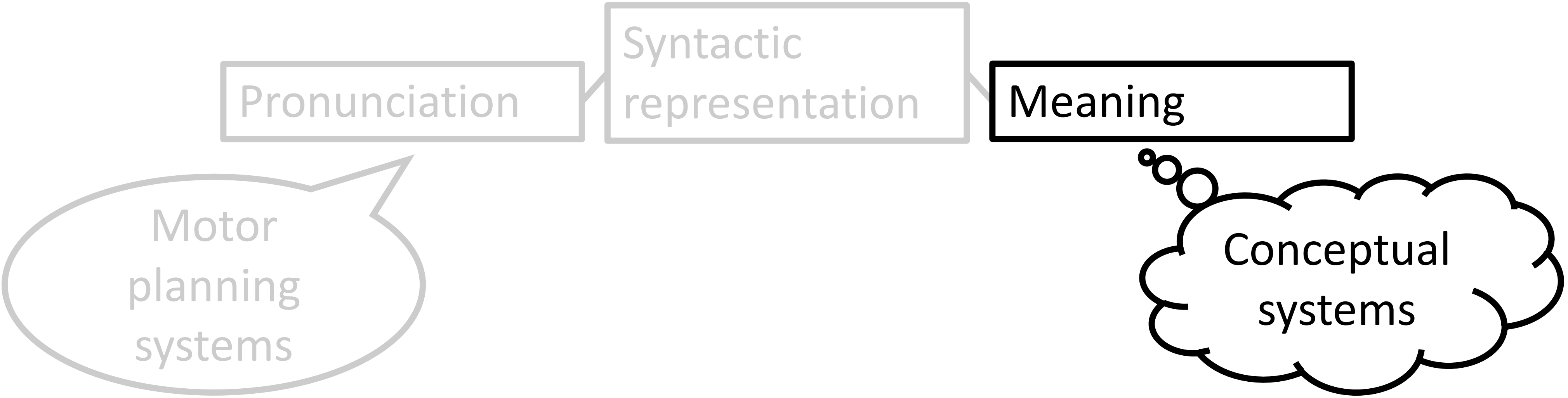
Why *each* and *every*?



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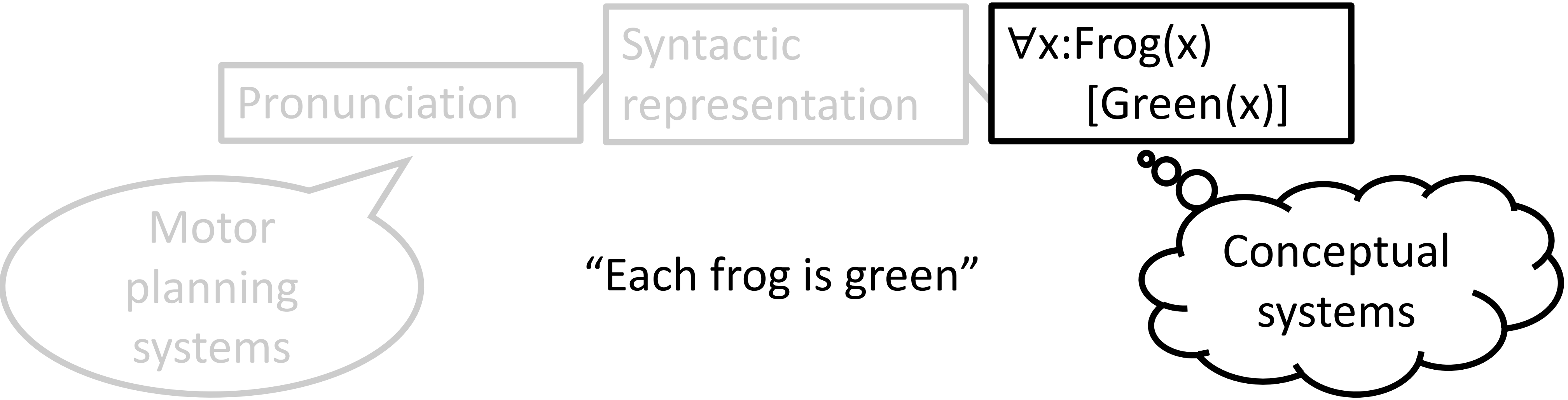

➥ Can state precise hypotheses about their meanings

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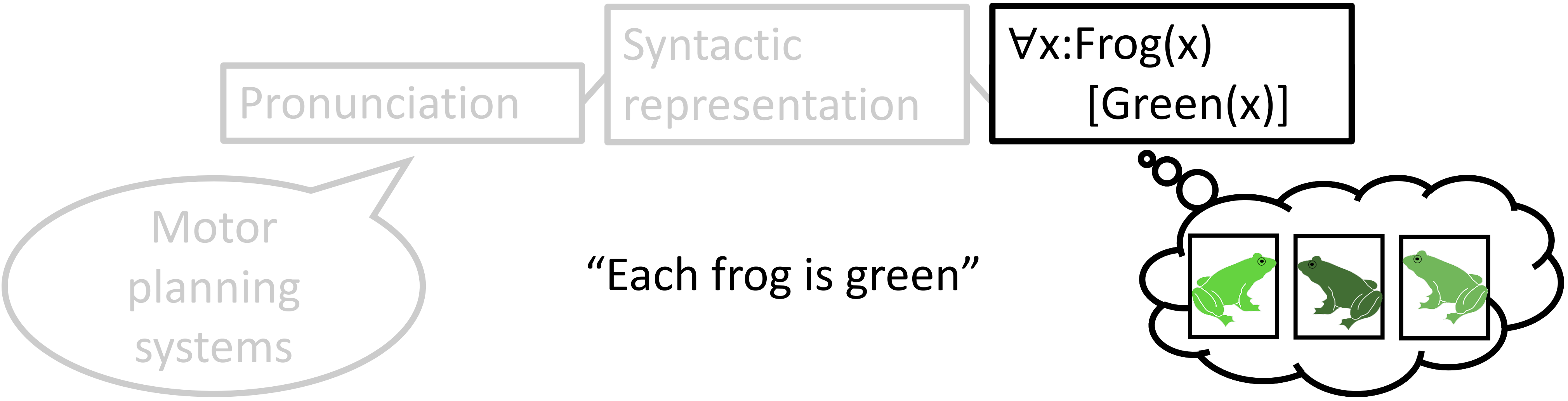

➥ Can state precise hypotheses about their meanings

➥ Can leverage an understanding of supporting cognitive systems
e.g., those for representing individuals & groups

Roadmap

✓ **Big picture**

✓ Linguistic meaning in the mind

Psychosemantic proposal

➥ First-order *each*; Second-order *every*

Evidence

➥ Sentence verification: Encoding & recalling individual properties vs. summary statistics

➥ Pragmatic use: Quantifying over small & local vs. large & global domains

➥ Language acquisition: Object-files vs. ensembles as evidence for learners

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How are *each* and *every* mentally represented?

"Each/Every frog is green"

TheX:Frog(X) ⊆ TheY:Green(Y)

≈The frogs$_X$ are among the green-things$_Y$

(Barwise & Cooper 1981)

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➡ Evidence that *each* is somehow more individualistic than *every*

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(1) a. # In this talk, I combine **each** theory of quantification.

b. ✓In this talk, I combine **every** theory of quantification.

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Frankenstein to Frank, *Persuasion* to Paula, and *Dune* to Dani

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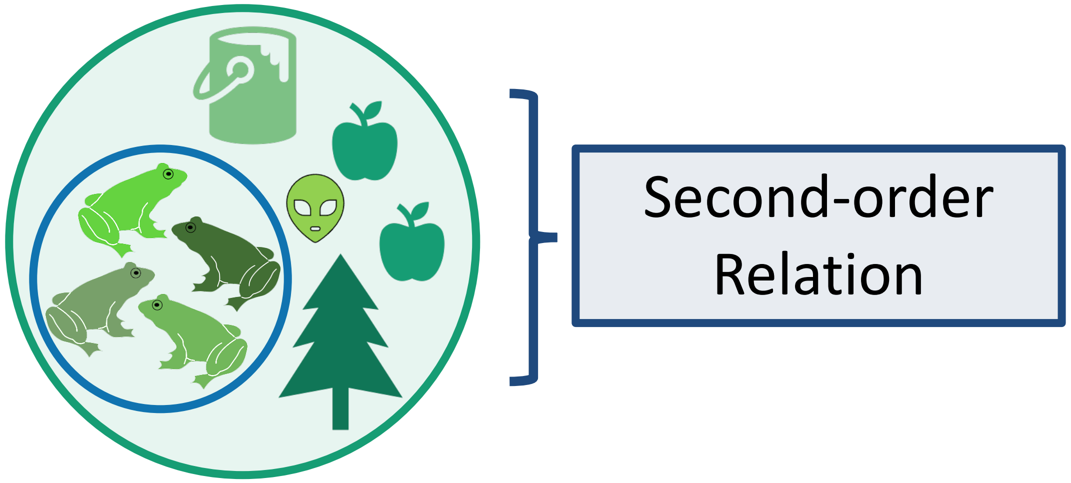

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(3) Which book did you loan to **every** student?

There's no one book I loaned to every student

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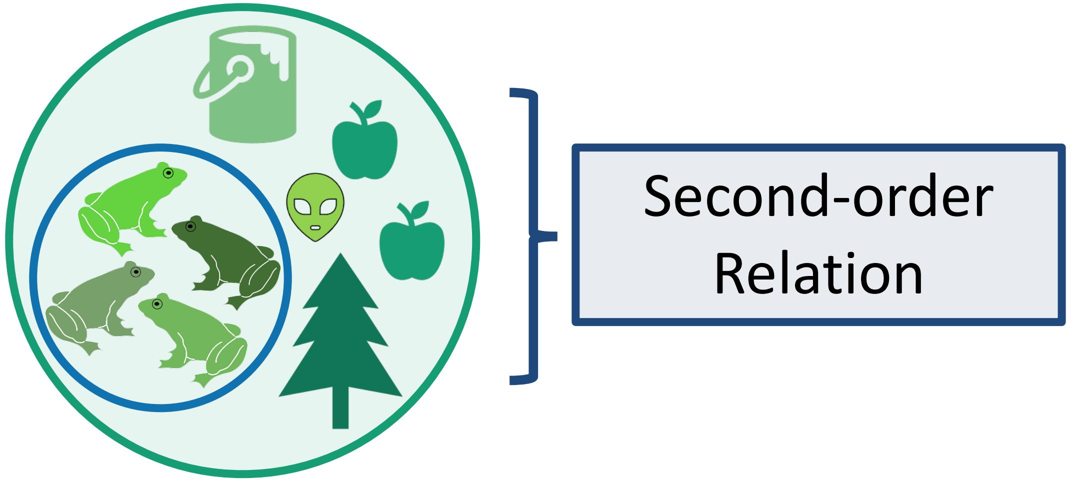

➥ Evidence that *each* is somehow more individualistic than *every*

(e.g., Vendler 1962; Beghelli & Stowell 1997; Beghelli 1997; Tunstall 1998; Landman 2003; Surányi 2003)

➥ Evidence that universal quantifiers are computationally simpler than e.g., *most*

(e.g., van Benthem 1986; McMillan et al. 2005; Clark & Grossman 2007; Szymanik 2007 2009; Szymanik & Zajenkowskib 2010; 2011; Zajenkowski, Styła & Szymanik 2011; Isaac, Szymanik & Verbrugge 2014; Olm et al. 2014)

Psychosemantic proposal

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(First-order representation)

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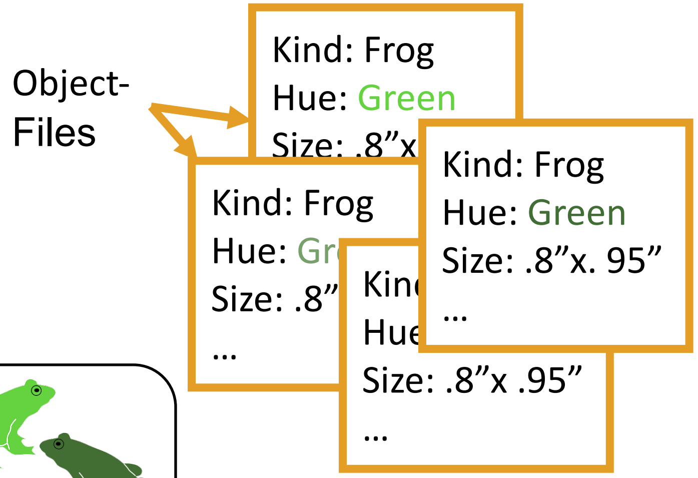

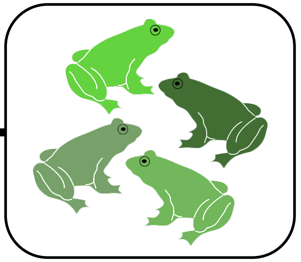

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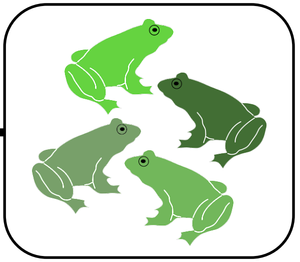

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Kind: Frogs
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Ensemble

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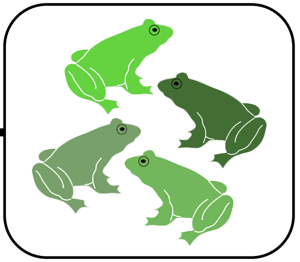

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What about second-order **relations** (i.e., two groups)?

Theoretical & empirical reasons to reject:

Knowlton, Pietroski, Williams, Halberda & Lidz (2021) *Semantics & linguistic theory*

Knowlton (2021) *UMD dissertation*

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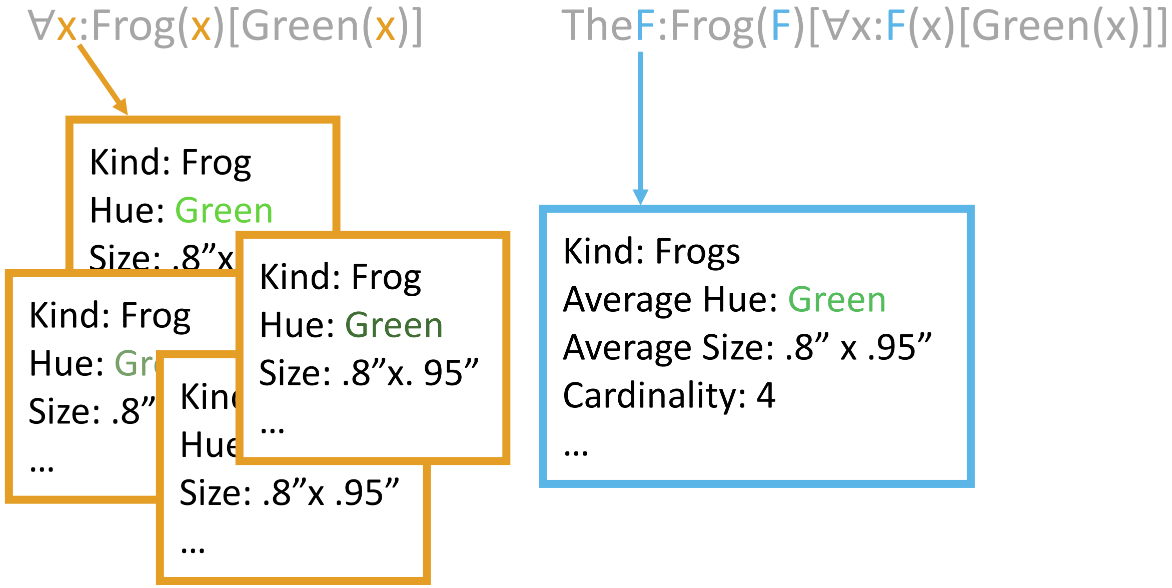

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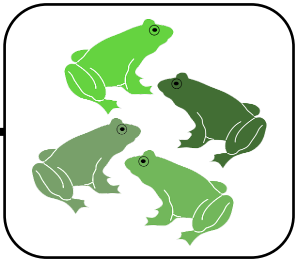

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➥ Individual properties encoded

(e.g., Kahneman & Treisman 1984; Kahneman et al. 1992; Xu & Chen 2009; Carey 2009)

Ensembles

➥ Summary statistics encoded

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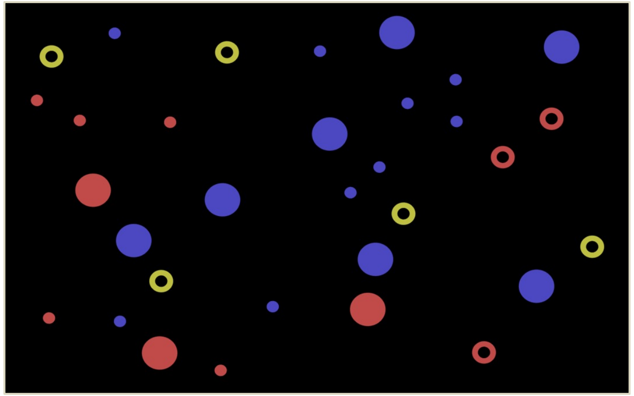
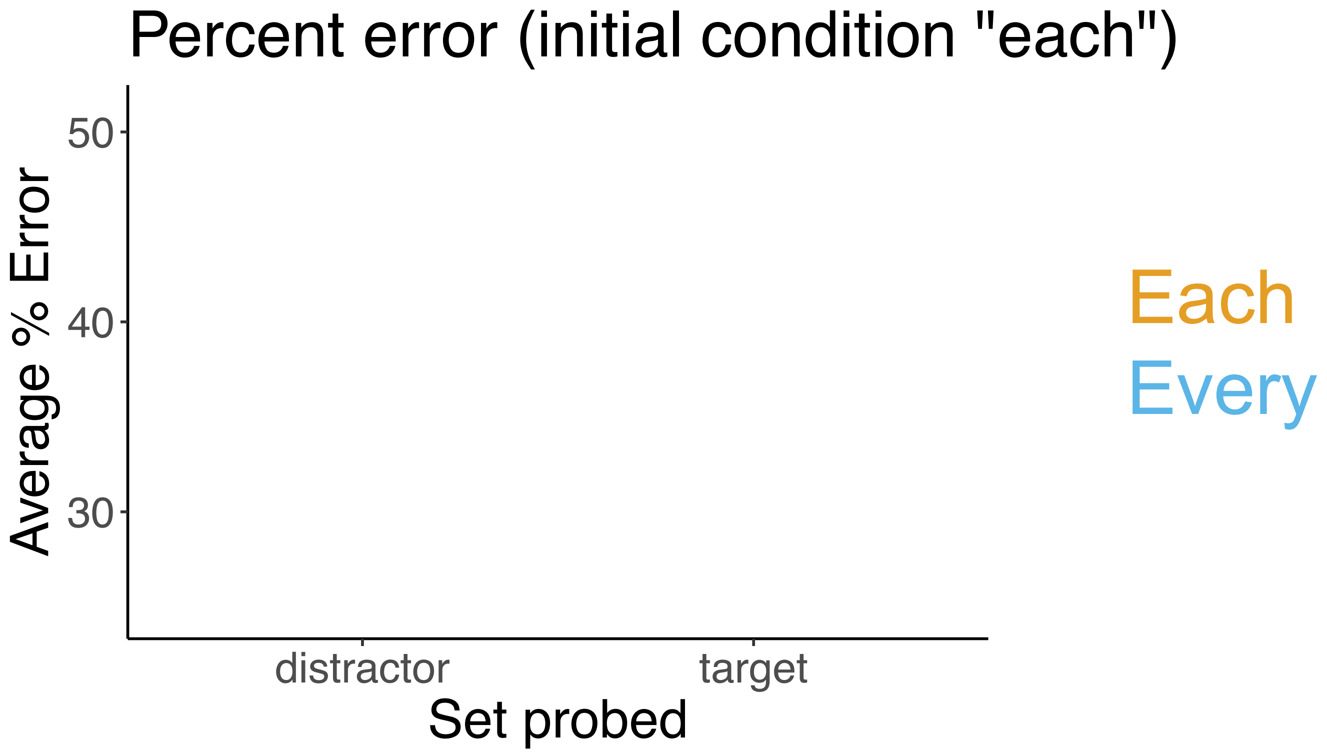
{Each/Every} big circle is blue

TRUE FALSE



Cardinality (group property)



How many {big/medium/small} circles were there?

n = 12

Knowlton, Pietroski, Halberda & Lidz 2021 *Linguistics & Philosophy*

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{Each/Every} big circle is blue

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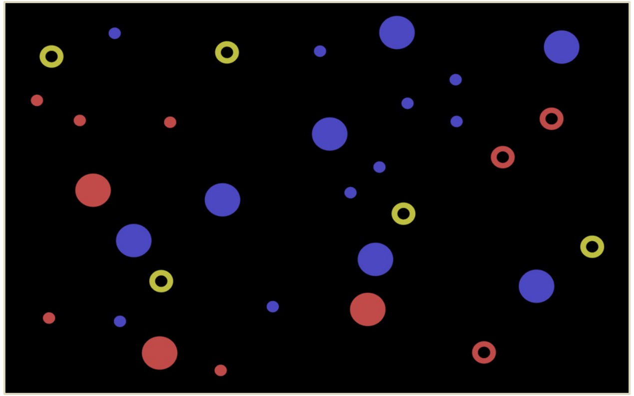

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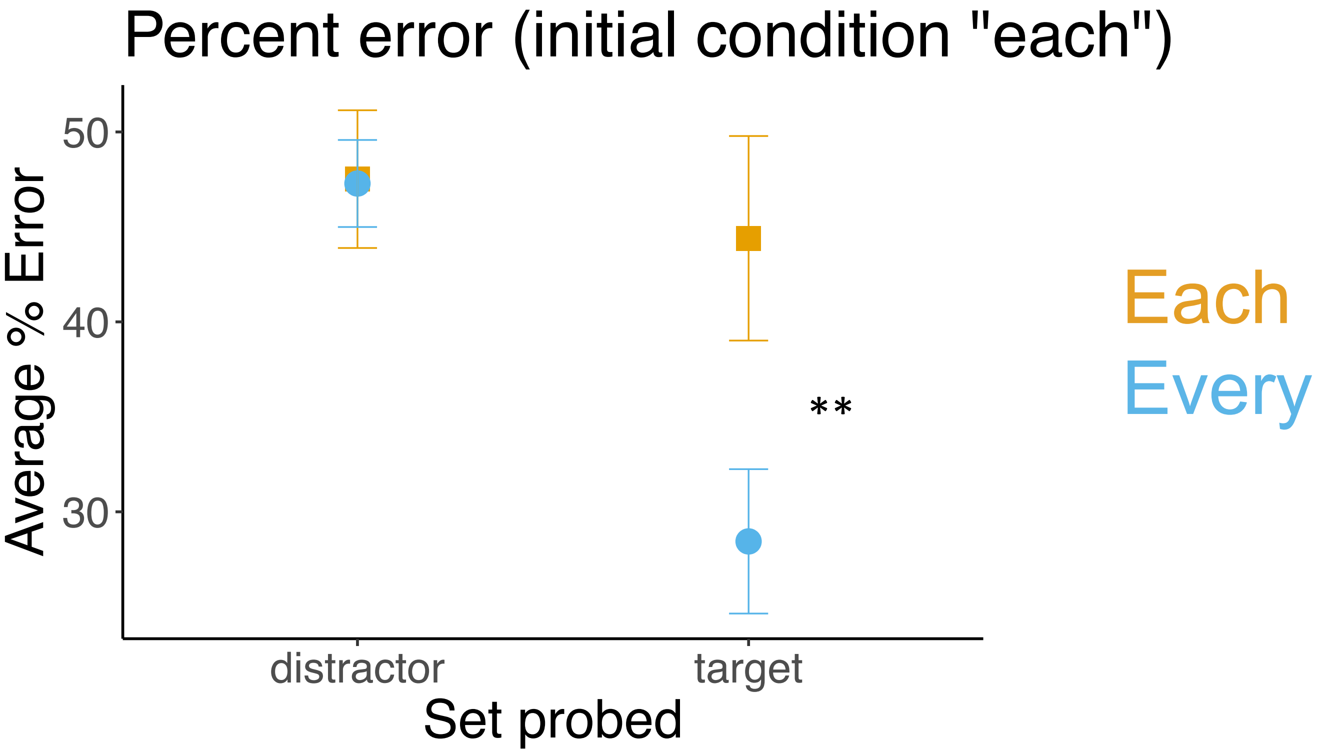

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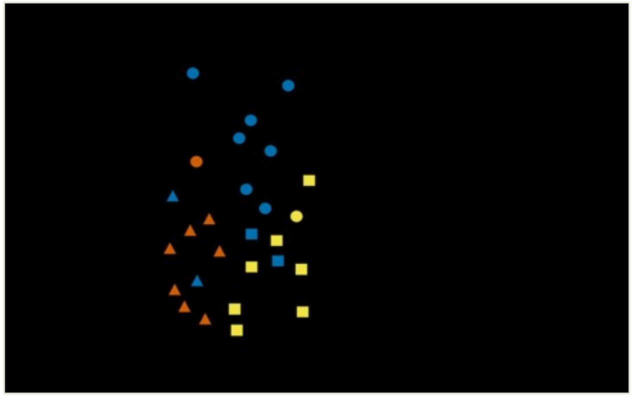
Center of Mass (group property)

(with 3- to 8-year-olds)

Is {each/every} circle blue?

"Yes" "No"



Where was the middle of the circles?

Knowlton 2021 *UMD dissertation*

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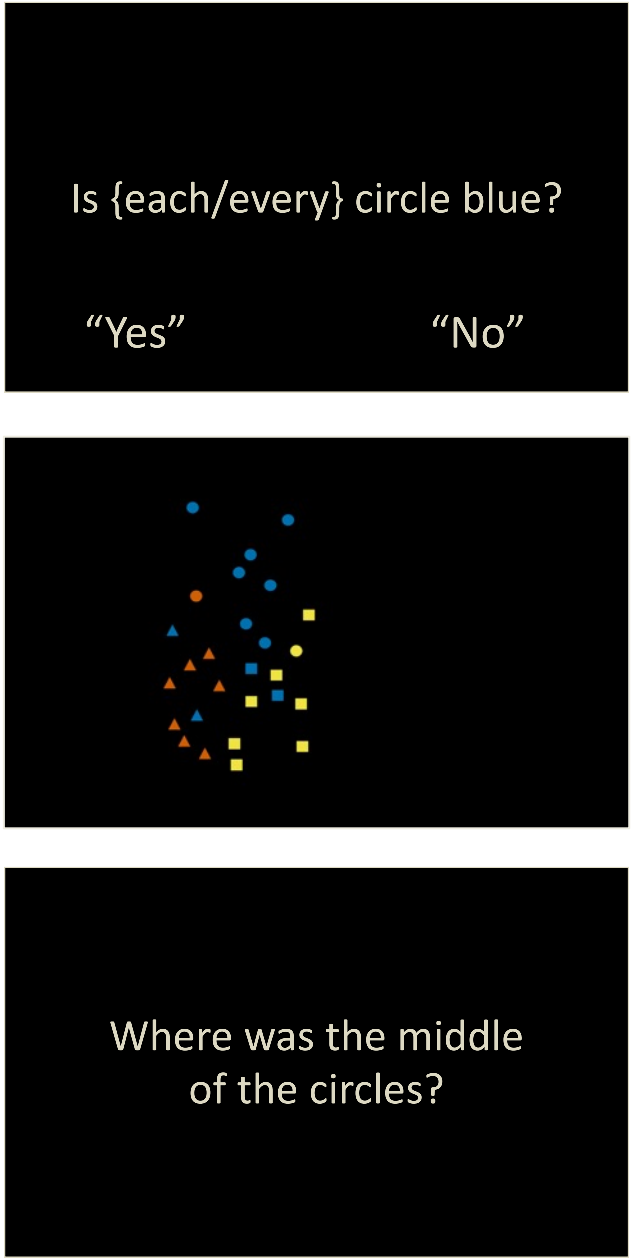
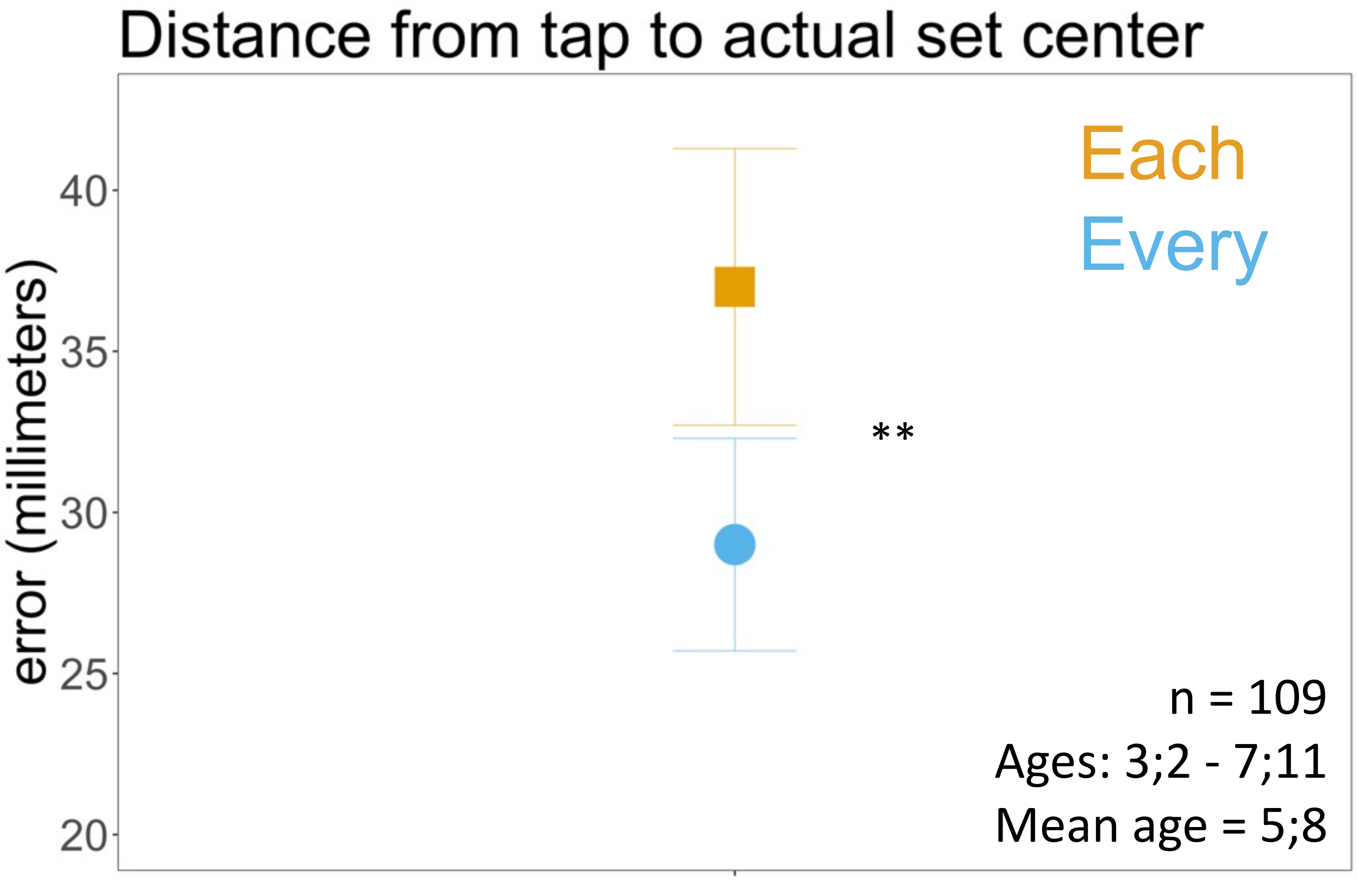
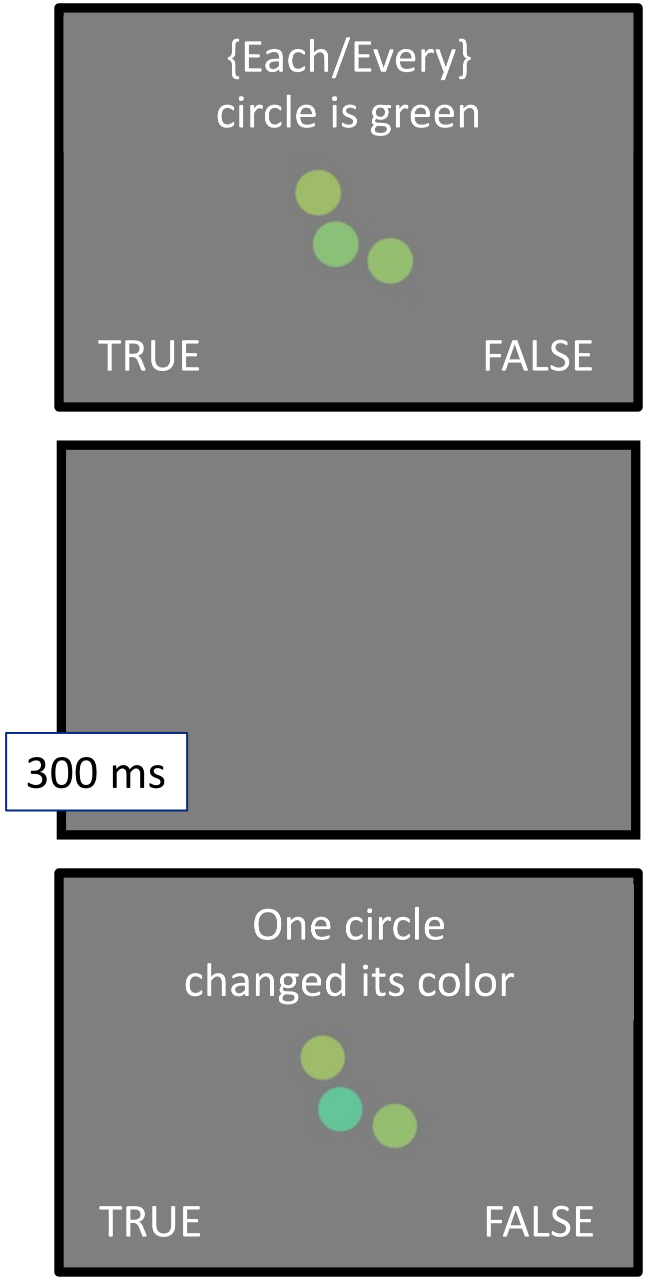
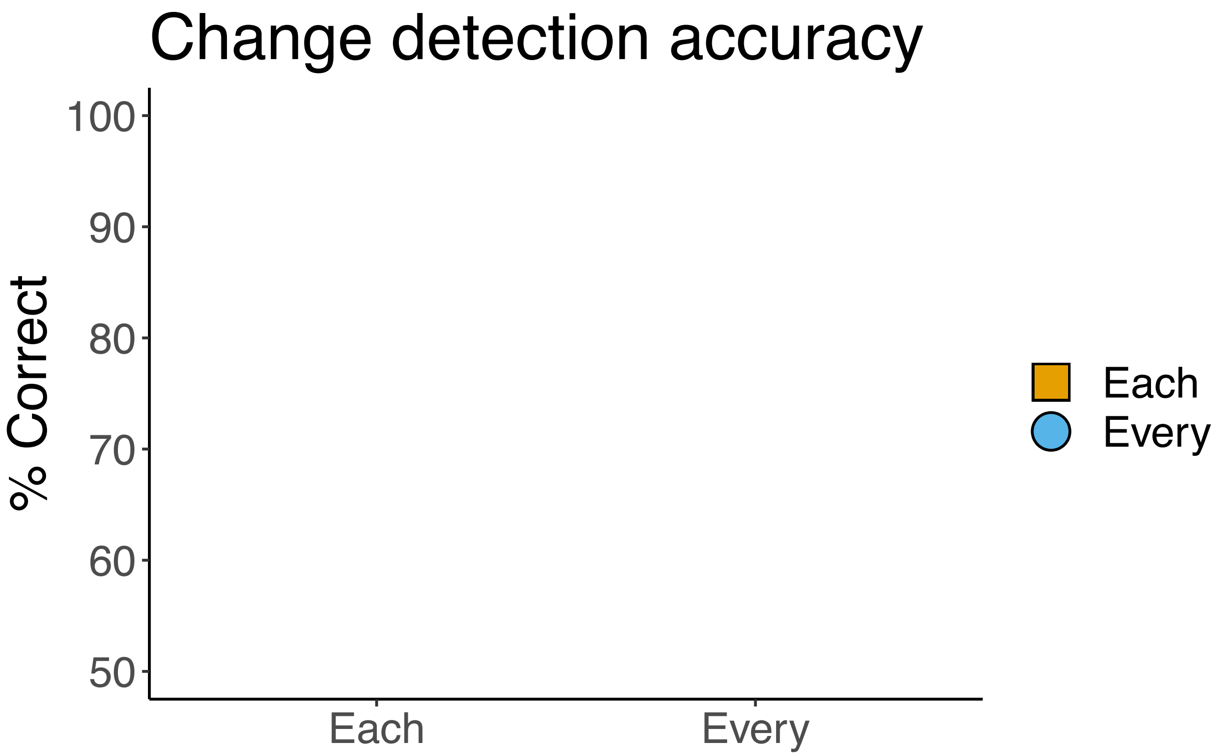




Color (individual property)





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Knowlton, Halberda, Pietroski & Lidz *under review*

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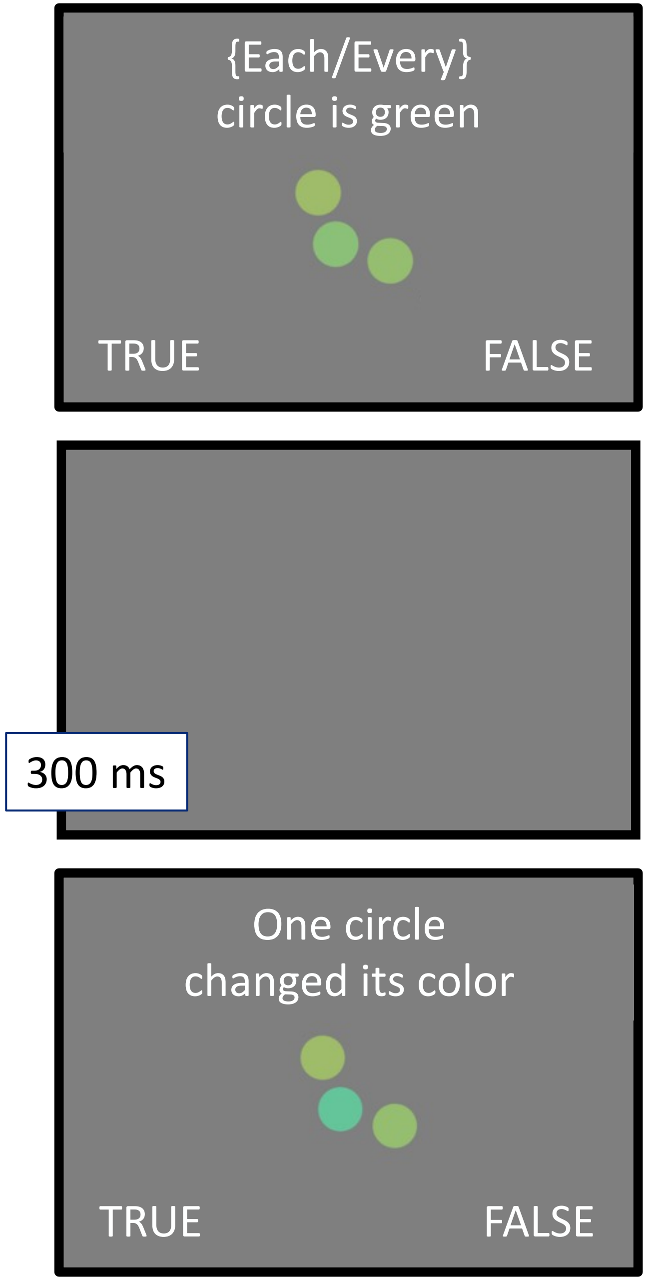

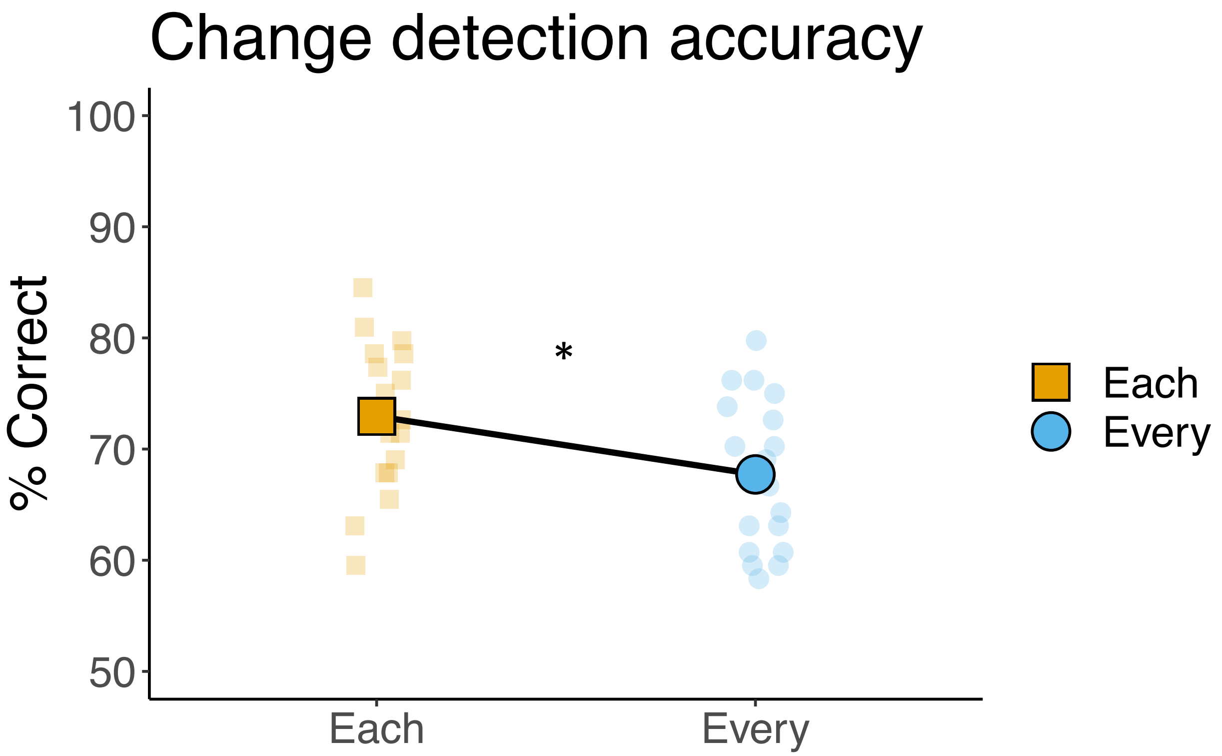

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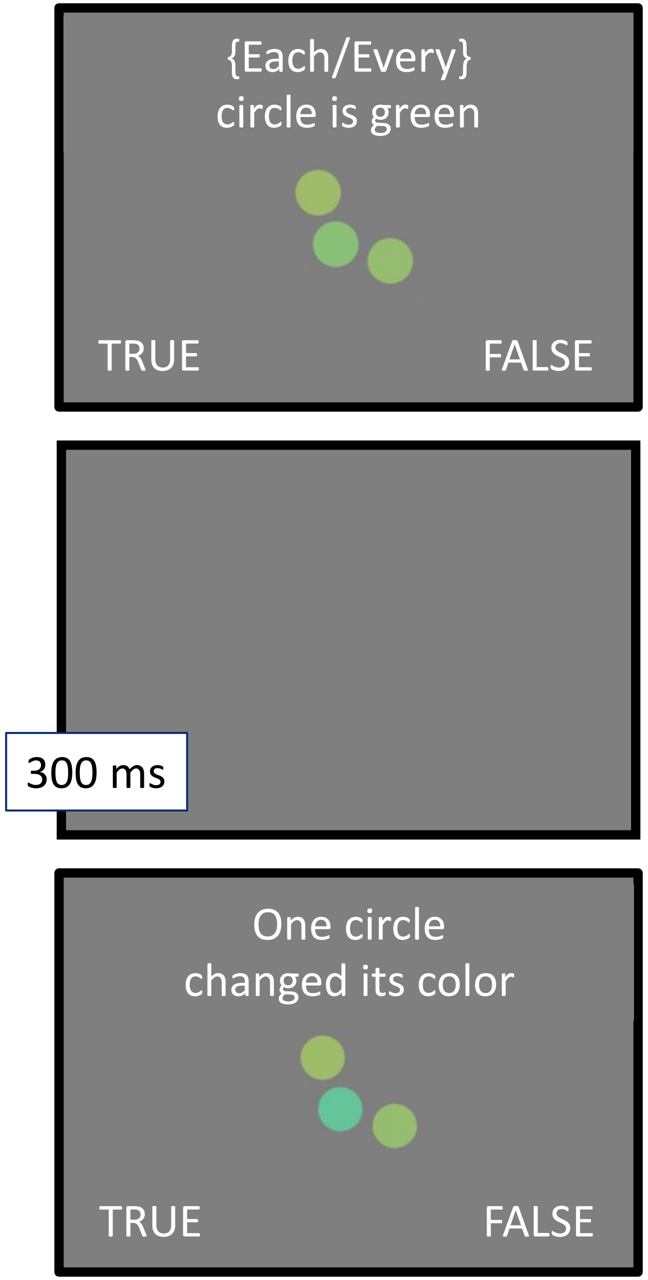
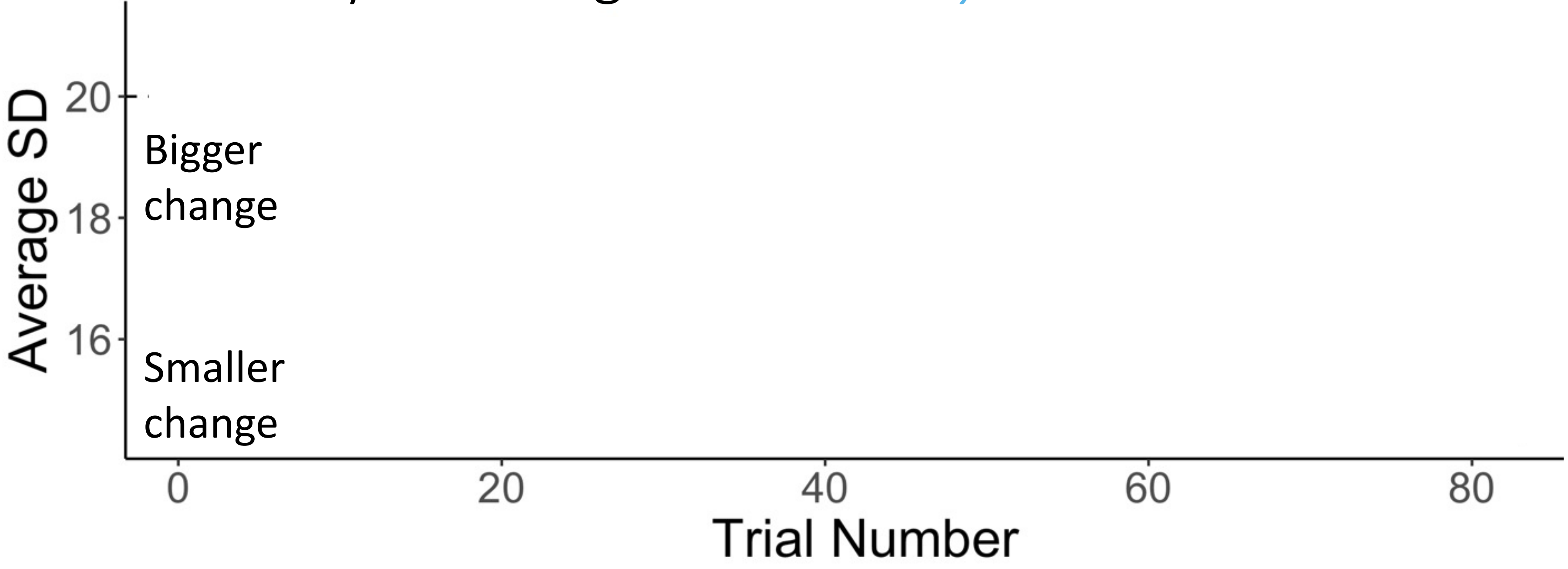


Color change detection: difficulty required for 70% accuracy following *each* or *every*



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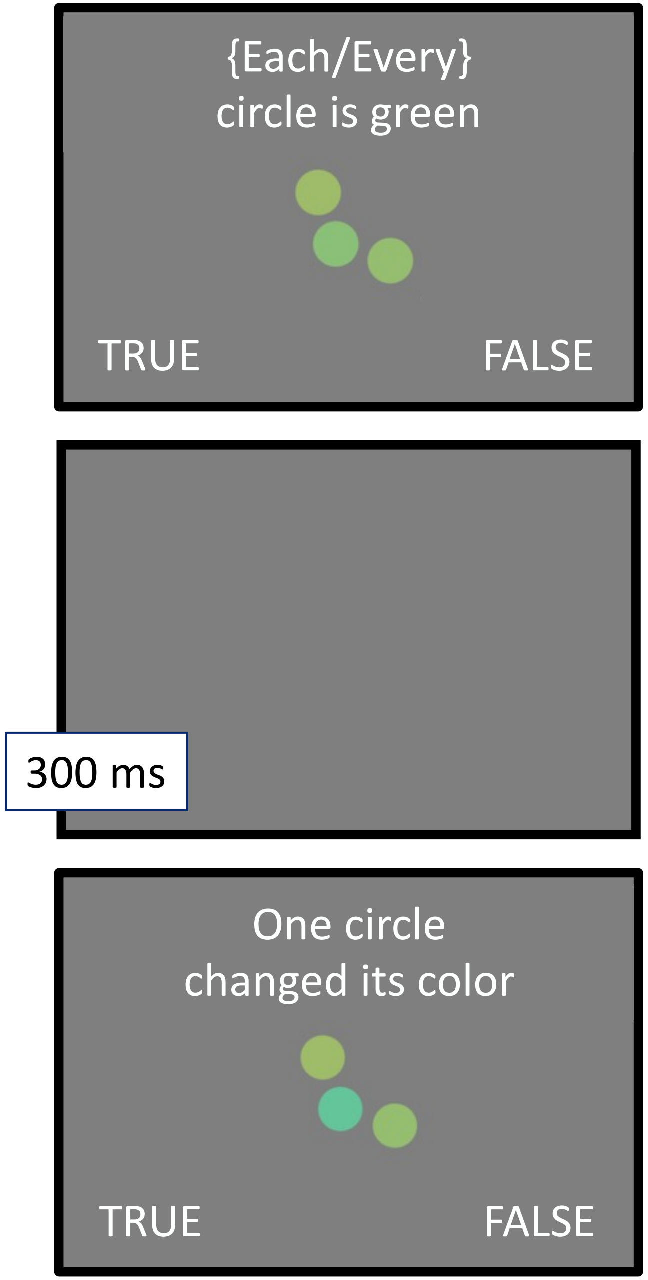

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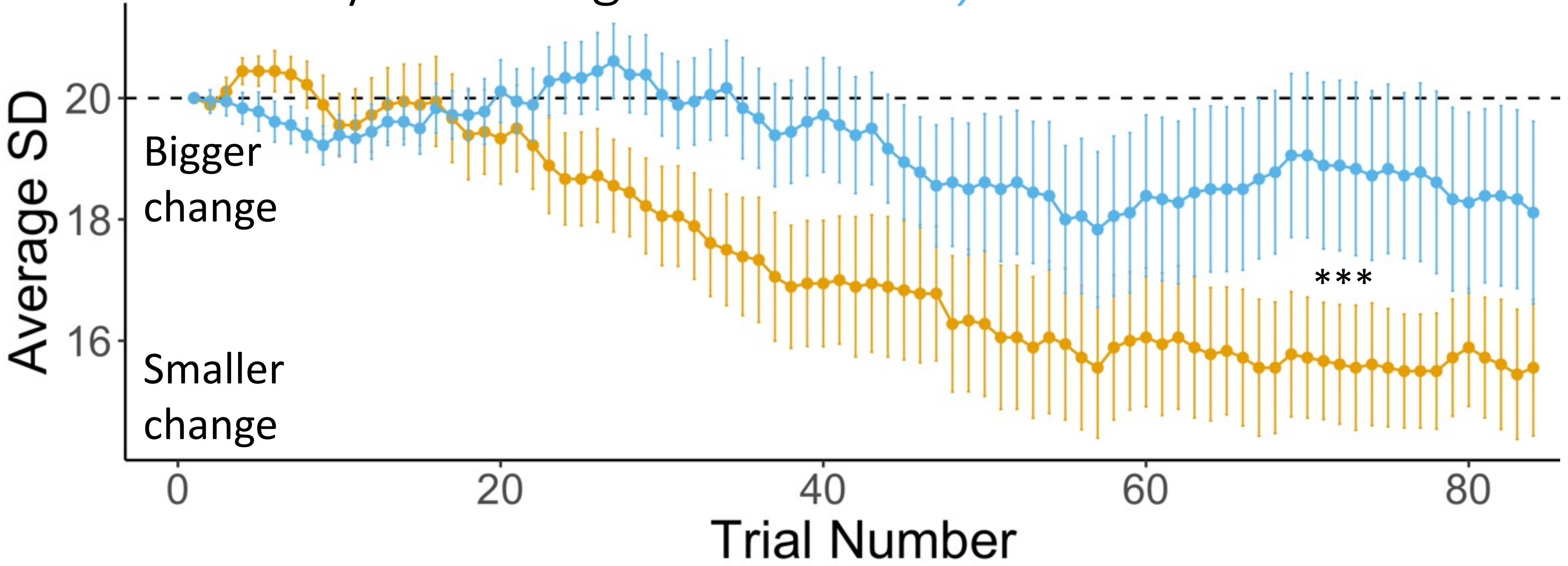

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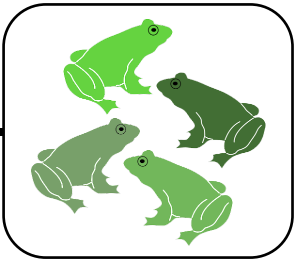

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(Second-order representation)

Kind: Frogs
Average Hue: Green
Average Size: .8" x .95"
Cardinality: 4
…

Ensemble

Object-files

➥ Individual properties encoded

(e.g., Kahneman & Treisman 1984; Kahneman et al. 1992; Xu & Chen 2009; Carey 2009)

➥ Strict working memory limit

(e.g., Vogel et al. 2001; Feigenson & Carey 2005; Wood & Spelke 2005; Alvarez & Franconeri 2007)

Ensembles

➥ Summary statistics encoded

(e.g., Ariely 2001; Chong & Treisman 2003; Haberman & Whitney 2011; Sweeny et al. 2015)

➥ No working memory limit

(e.g., Halberda et al. 2006; Zosh et al. 2011; Alvarez & Oliva 2008; Im & Halberda 2013)

Predictions

Those representations should lead to downstream pragmatic consequences:

All else equal, *every* should be preferred for

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➥ larger domains of quantification

➥ generalizing beyond locally-established domain

Every is better for larger domains

The bartender at the local tavern has made three martinis.

He said that {**each**/every} martini he made had an olive.

The bartender at the local tavern has made three thousand martinis.

He said that {each/**every**} martini he made had an olive.

12 items; within-subjects; n=100

Knowlton, Trueswell & Papafragou 2022 *CogSci proceedings*

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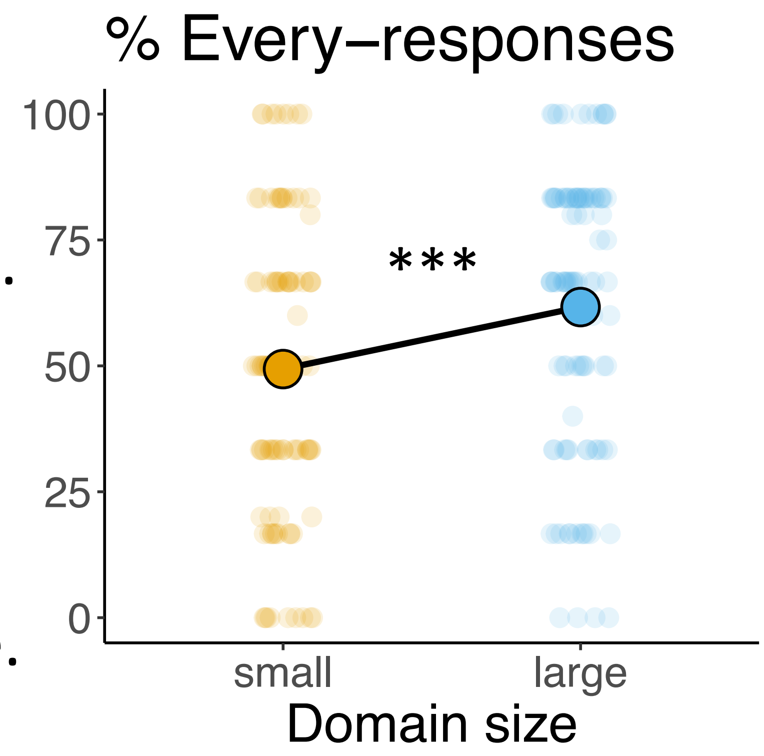


12 items; within-subjects; n=100

Every is better for larger domains

If someone said

Each martini needs an olive

Every martini needs an olive

how many martinis would you guess they have in mind?

1 item; n=198

Every is better for larger domains

If someone said

Each martini needs an olive

Every martini needs an olive

how many martinis would you guess they have in mind?

% responses below “4”:
Each: 67%
Every: 30%

1 item; n=198

Every is better for larger domains

If someone said

Each martini needs an olive

Every martini needs an olive

"all martinis generally"
"all martinis!"
"every martini ever made"
"every one that is made"
"an unlimited amount"
"as many as there are in the world"

how many martinis would you guess they have in mind?

% responses below "4":
Each: 67%
Every: 30%

1 item; n=198

Knowlton, Trueswell & Papafragou 2022 *CogSci proceedings*

Every is better for generalizing

Each martini needs an olive ≈ some particular cocktails need garnishes

Every martini needs an olive ≈ part of a cocktail recipe

Every is better for generalizing

Each martini needs an olive ≈ some particular cocktails need garnishes

Every martini needs an olive ≈ part of a cocktail recipe

Ensembles

- ➥ No working memory limit (can support arbitrarily large domains)
  (e.g., Halberda et al. 2006; Zosh et al. 2011; Alvarez & Oliva 2008; Im & Halberda 2013)
- ➥ Represented in terms of summary statistics
  (e.g., Ariely 2001; Chong & Treisman 2003; Haberman & Whitney 2011; Sweeny et al. 2015)

Every is better for generalizing

The bartender at the local tavern made a few martinis.

He said that {**each**/every} martini that he made
has an olive.

He said that {each/**every**} martini that's worth drinking
has an olive.

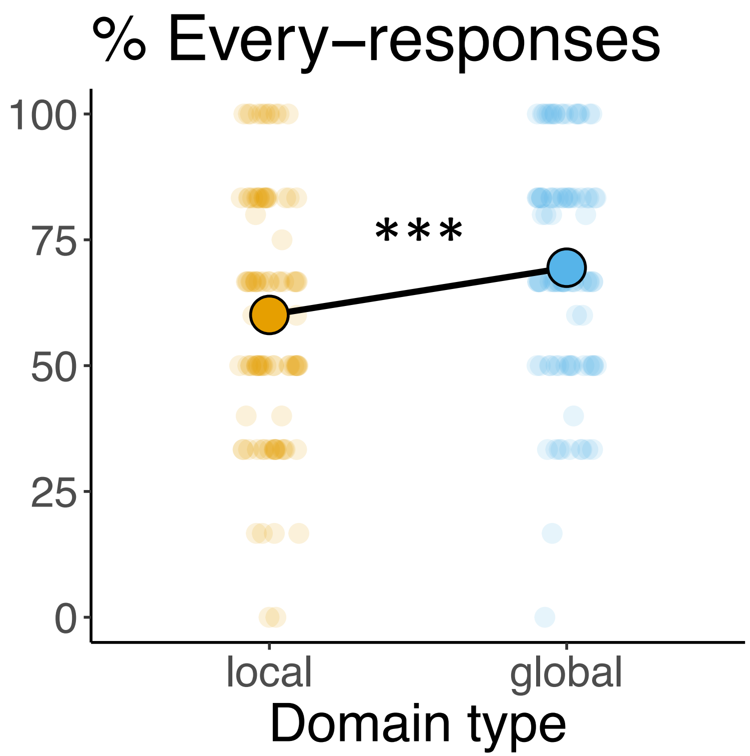
12 items; within-subjects; n=100

Every is better for generalizing

The bartender at the local tavern made a few martinis.

He said that {**each**/every} martini that he made has an olive.

He said that {each/**every**} martini that's worth drinking has an olive.



12 items; within-subjects; n=100

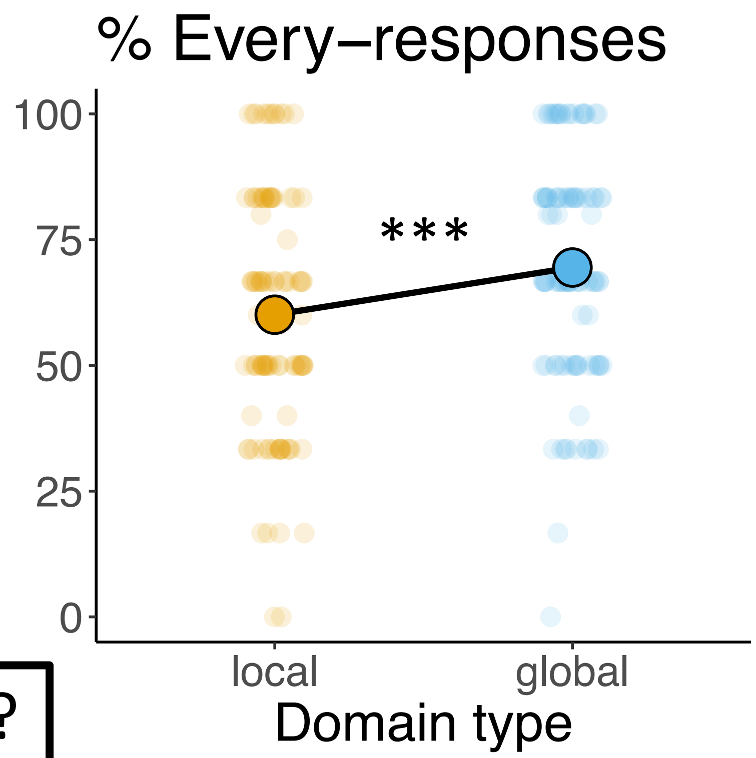
Every is better for generalizing

The bartender at the local tavern made <u>a few martinis</u>.

He said that {**each**/every} martini that he made has an olive.

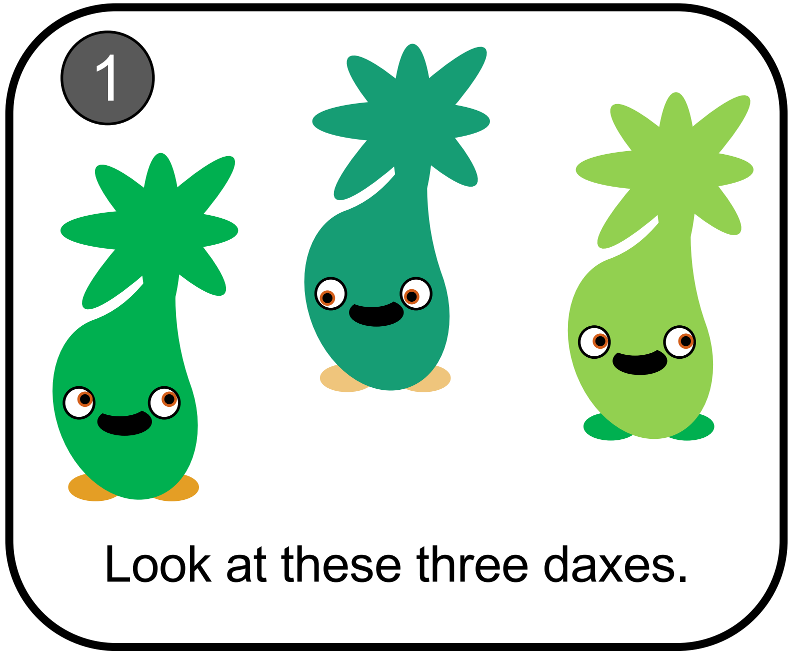
He said that {each/**every**} martini that's worth drinking has an olive.

Isn't this just domain size all over again?
|Martinis worth drinking| >
|Martinis the bartender made|

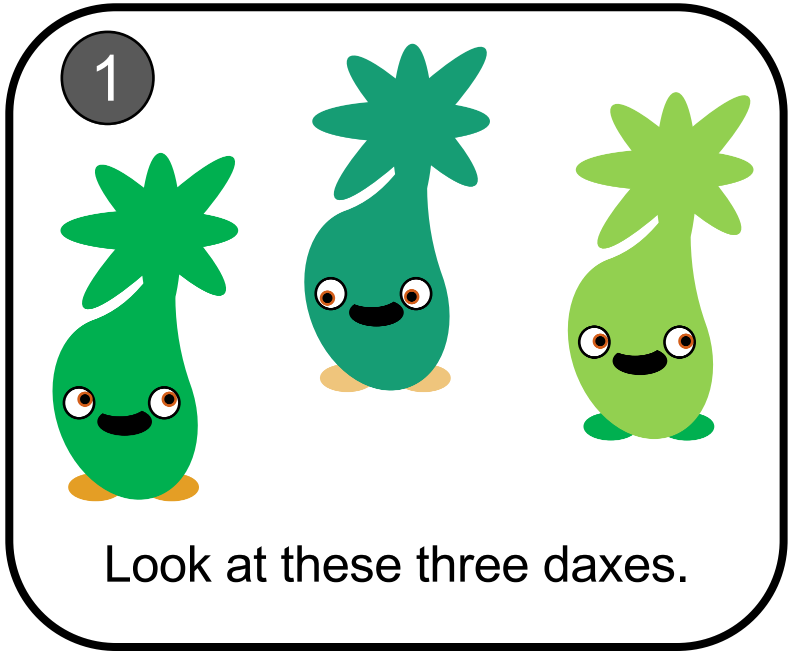


2 items; within-subjects; n=100

Knowlton, Trueswell & Papafragou 2022 *CogSci proceedings*

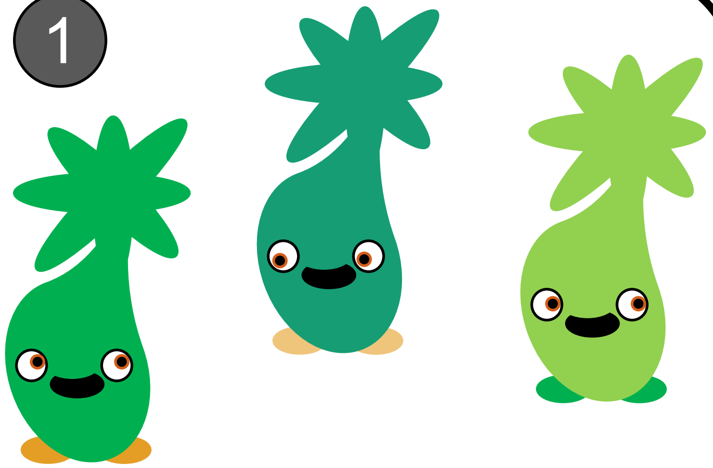


n=300



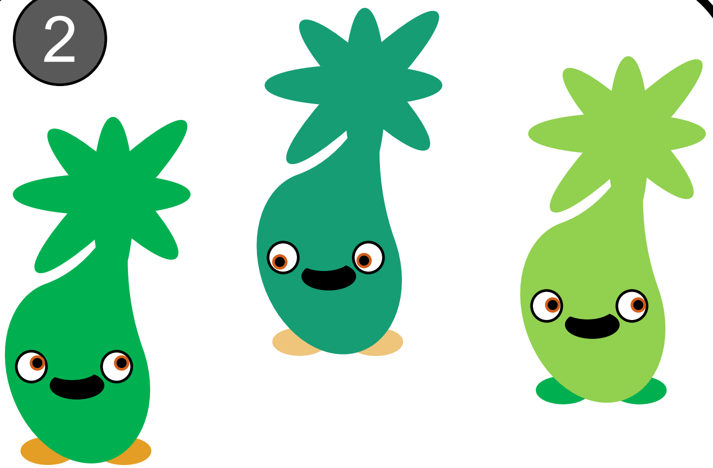
n=300

1



Look at these three daxes.

2

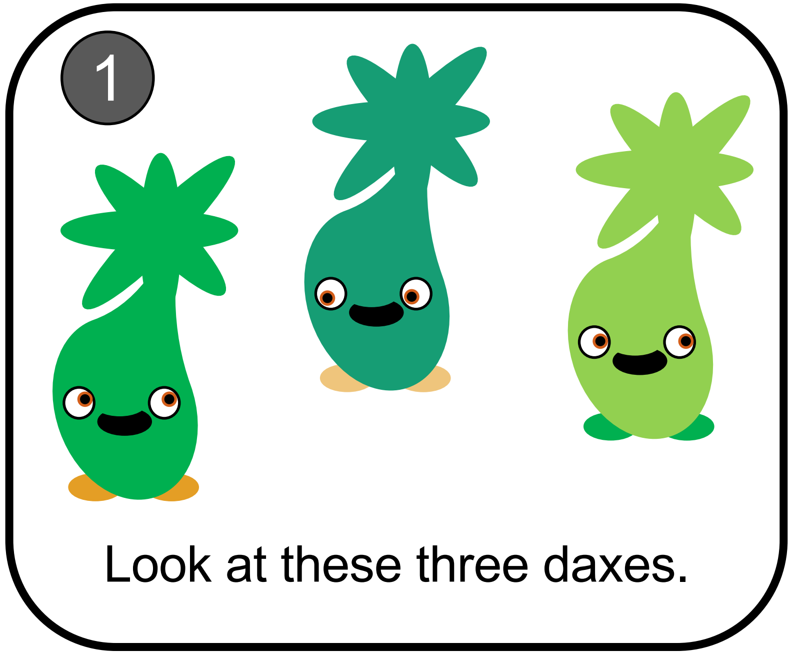


Each/Every dax is green.

3

There’s another dax under that tree, hidden by the shadow.

n=300


1
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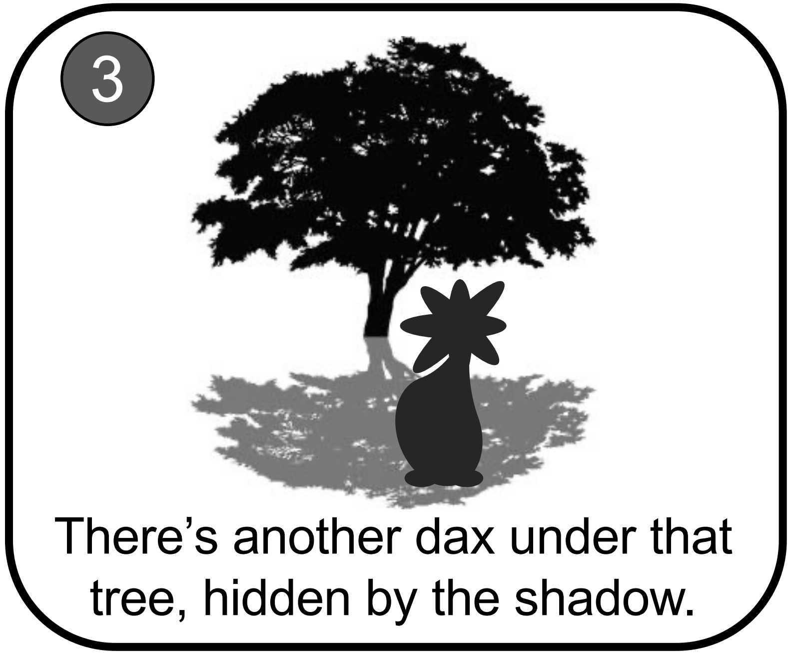
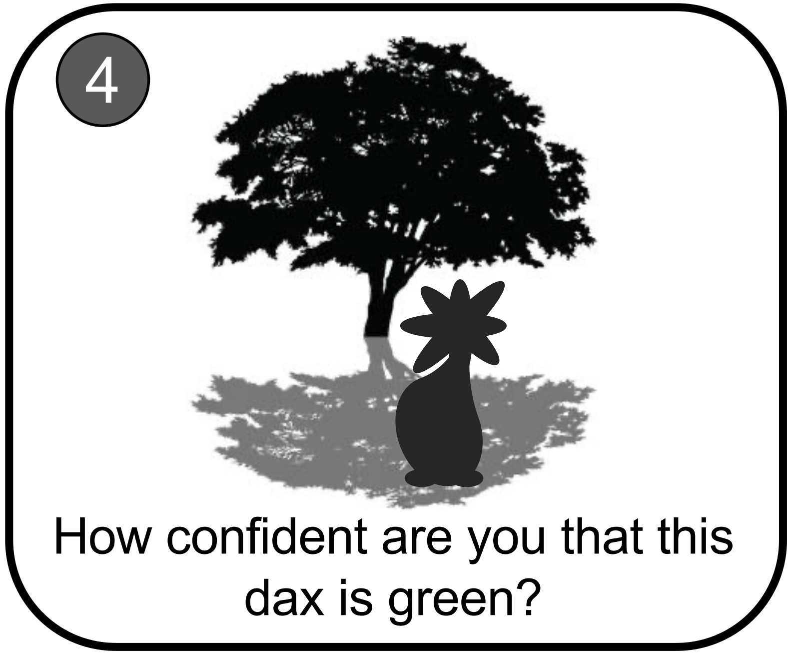
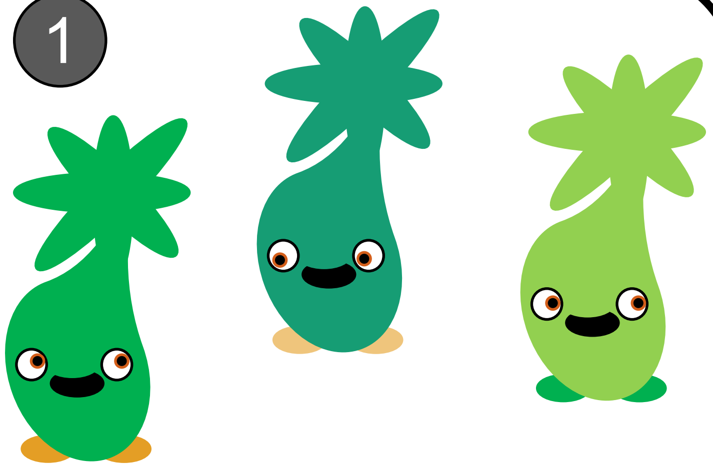

3
There's another dax under that tree, hidden by the shadow.


4
How confident are you that this dax is green?

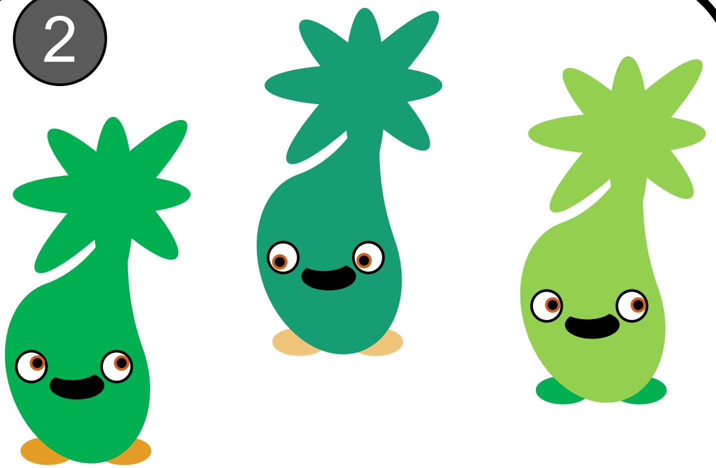
n=300

1



Look at these three daxes.

2



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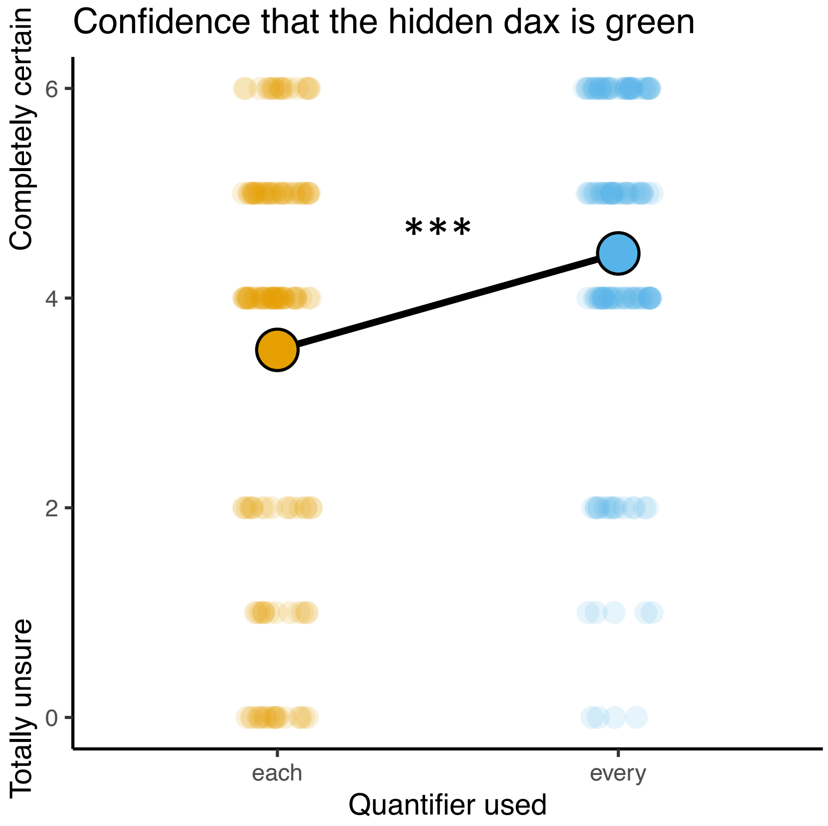
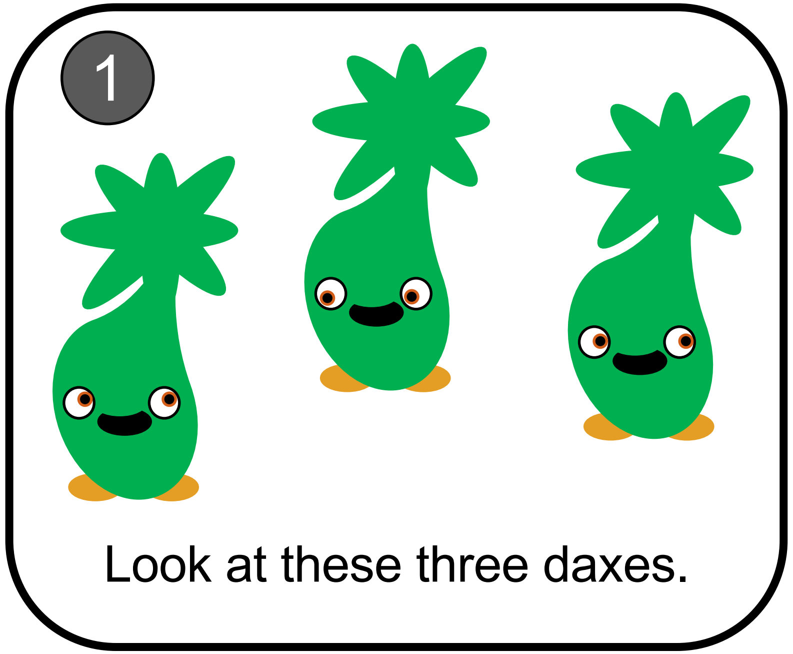


n=300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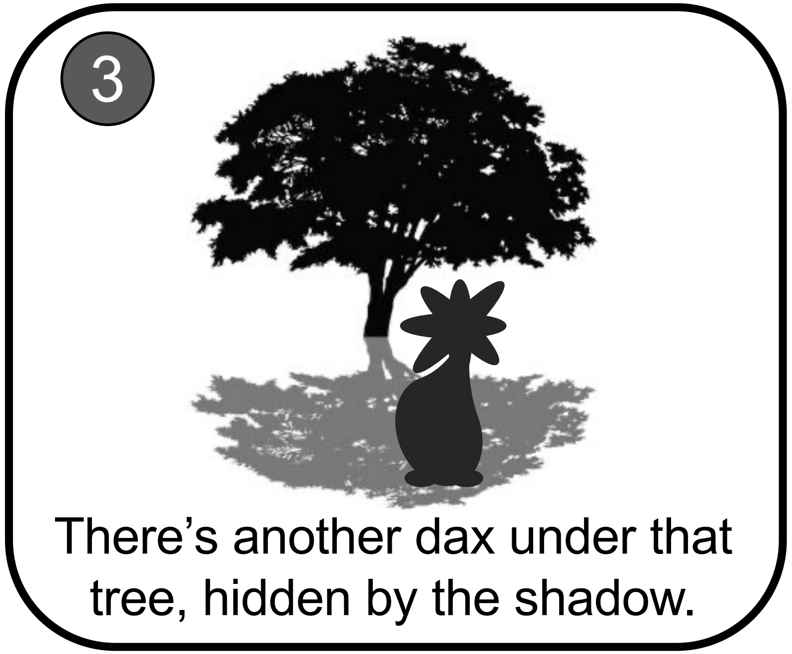
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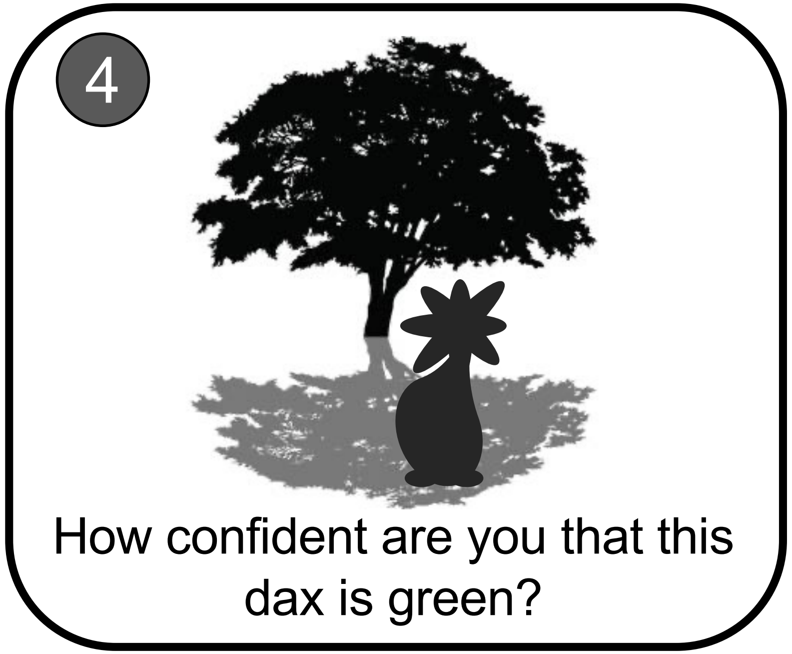
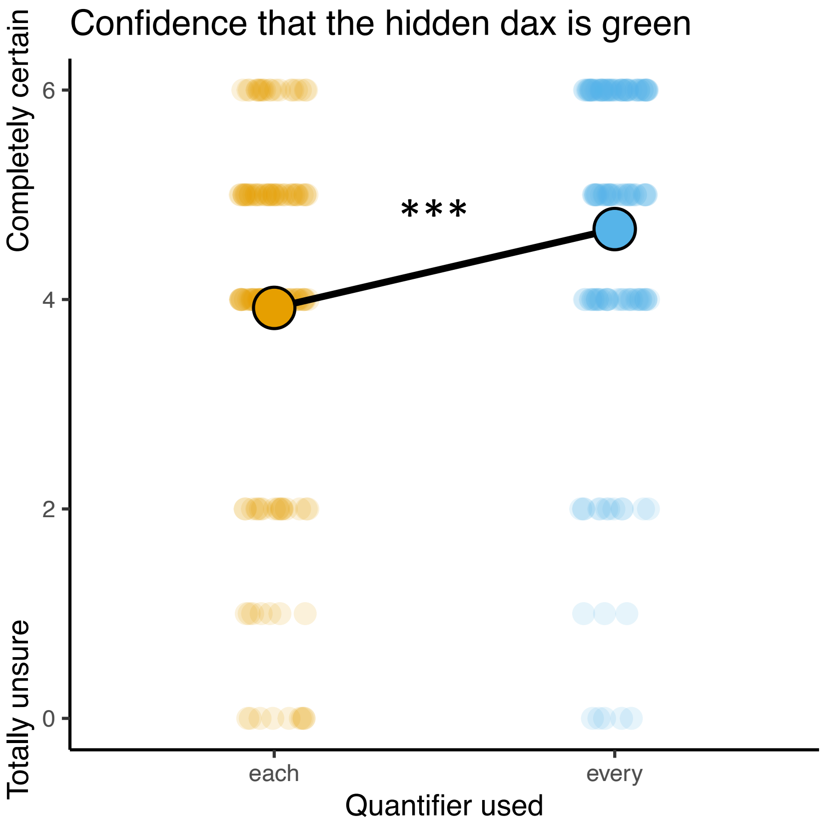
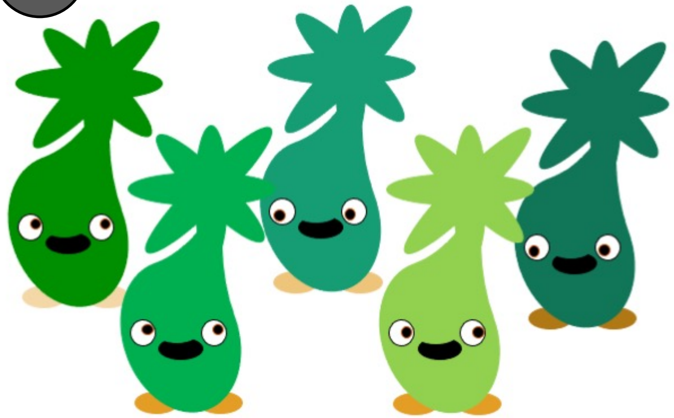

4
How confident are you that this dax is green?


Confidence that the hidden dax is green
Completely certain
Totally unsure
6
4
2
0
***
each
every
Quantifier used

n=300

1



Look at these daxes.

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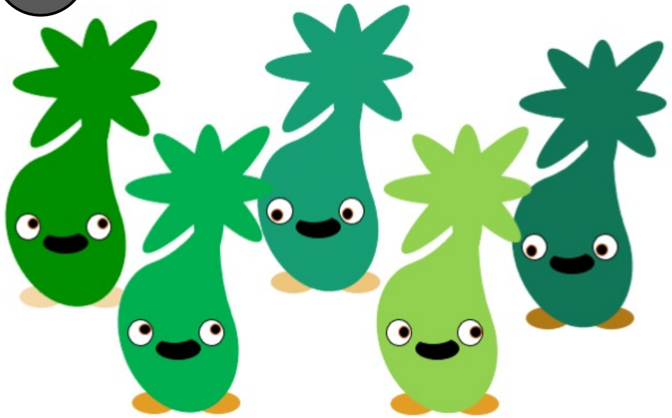

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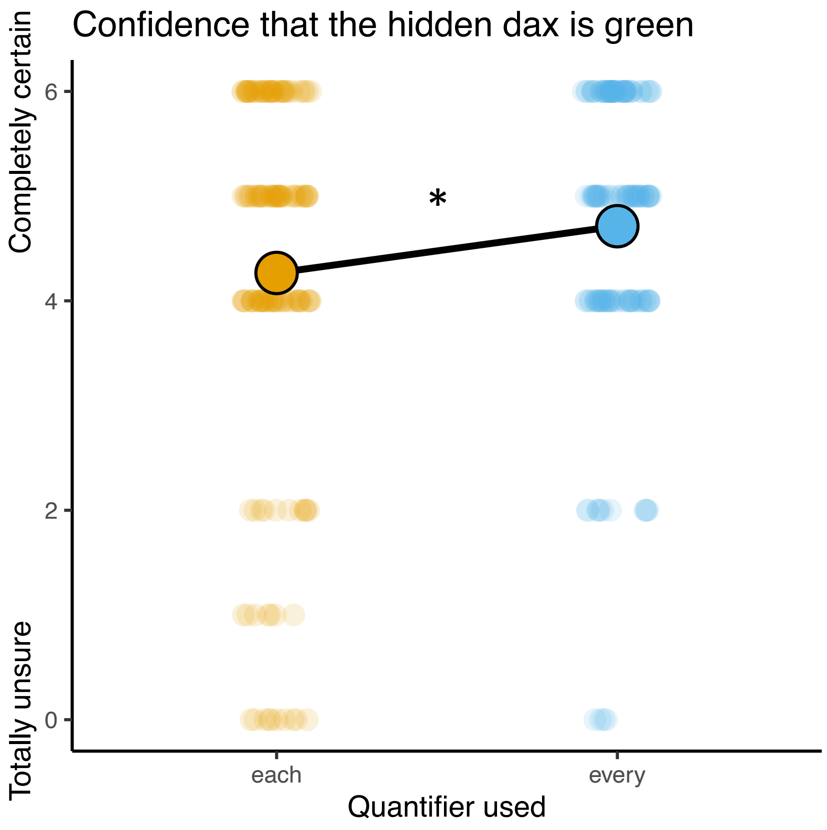

n=300

Roadmap

✓ **Big picture**

✓ Linguistic meaning in the mind

✓ **Psychosemantic proposal**

✓ First-order *each*; Second-order *every*

Evidence

✓ Sentence verification: Encoding & recalling individual properties vs. summary statistics

✓ Pragmatic use: Quantifying over small & local vs. large & global domains

➡ Language acquisition: Object-files vs. ensembles as evidence for learners

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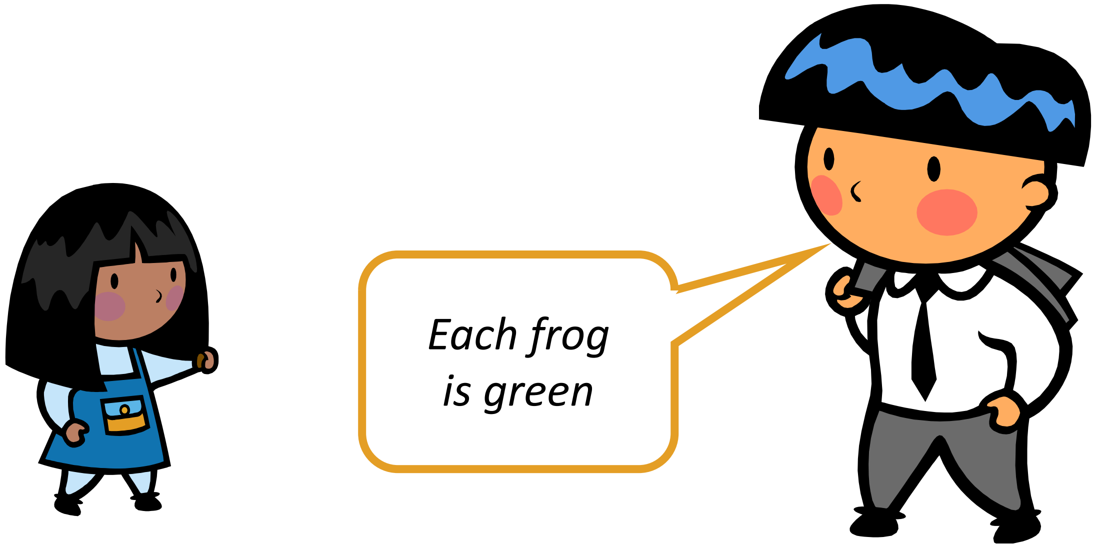
Learners need to figure out:

Semantic category:
Quantity (not property)
➥ Syntactic bootstrapping



CATEGORY: Wellwood, Gagliardi & Lidz 2016; Syrett, Musolino & Gleitman 2012; CONTENT: Rasin & Aravind 2021; Piantadosi et al. 2008

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Universal (not proportional, existential, etc.)
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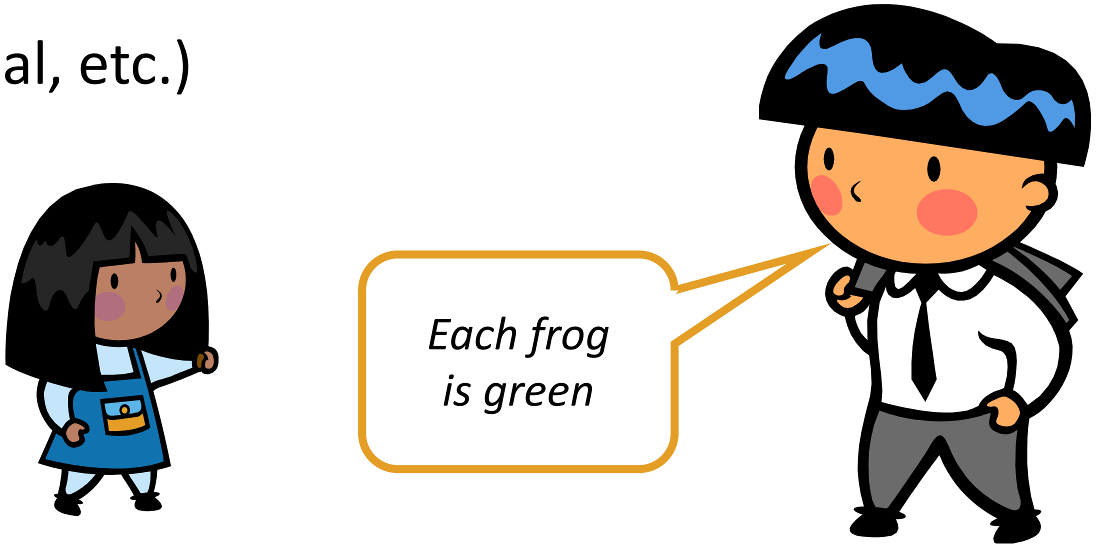

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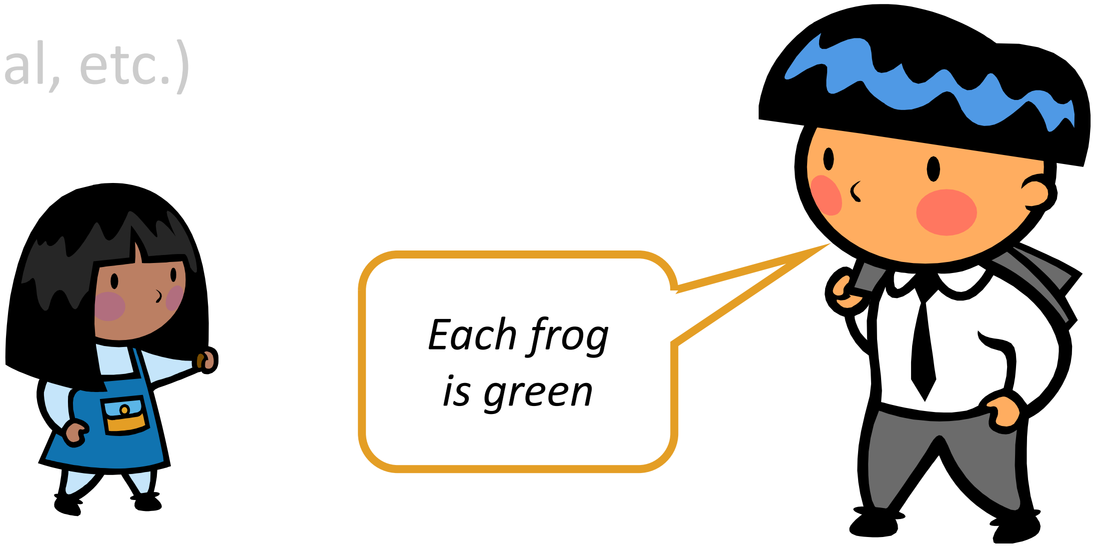
Representational format:
First- vs. second-order universal



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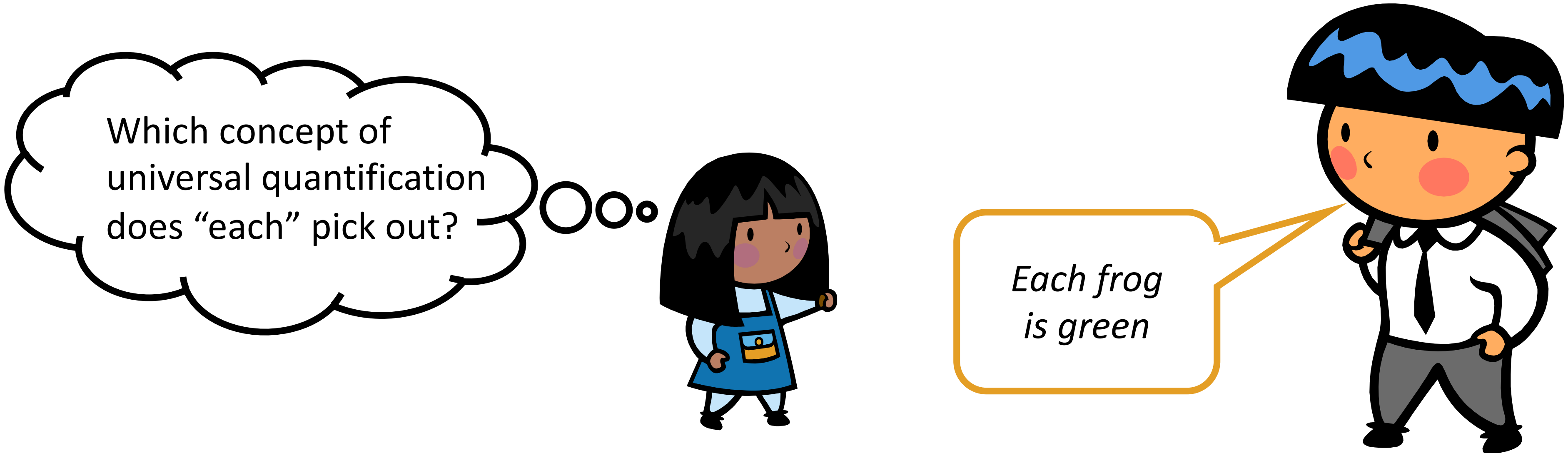
Object-files as route of semantic access



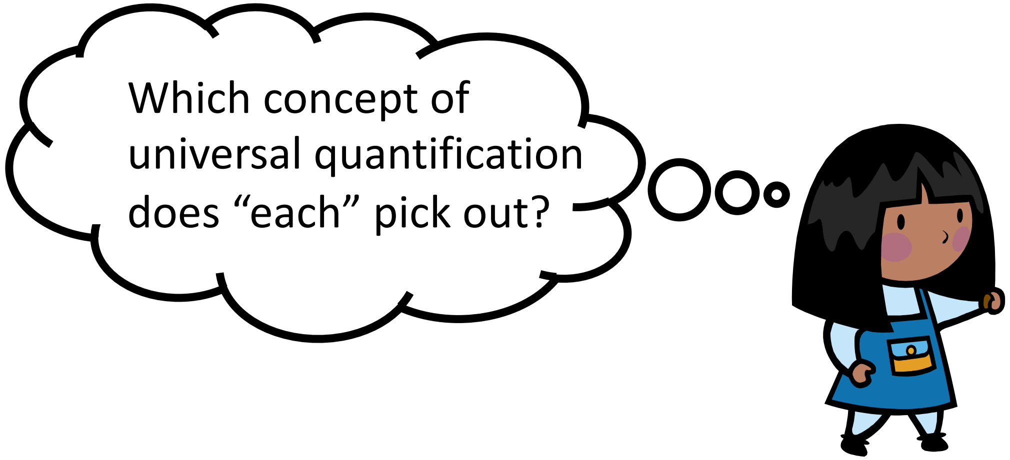
Object-files as route of semantic access

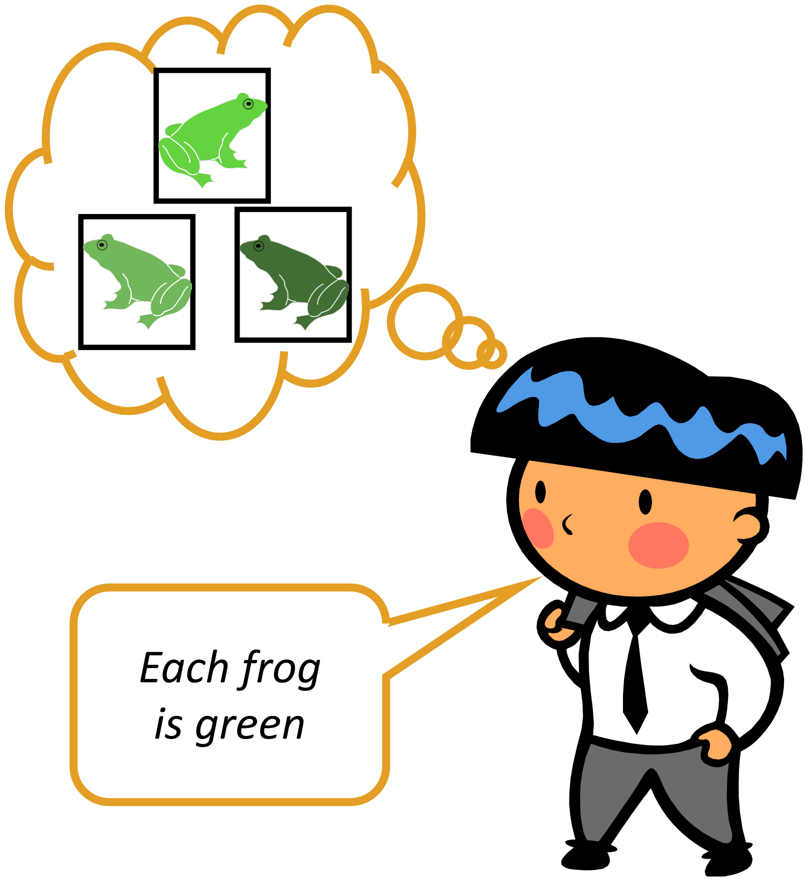
each *frog is green*

≈Any thing that is a frog is s.t. it is green

Object-file representations (e.g., Kahneman, Treisman & Gibbs 1992)

➥ Working memory limit of 3 (e.g., Feigenson & Carey 2005)





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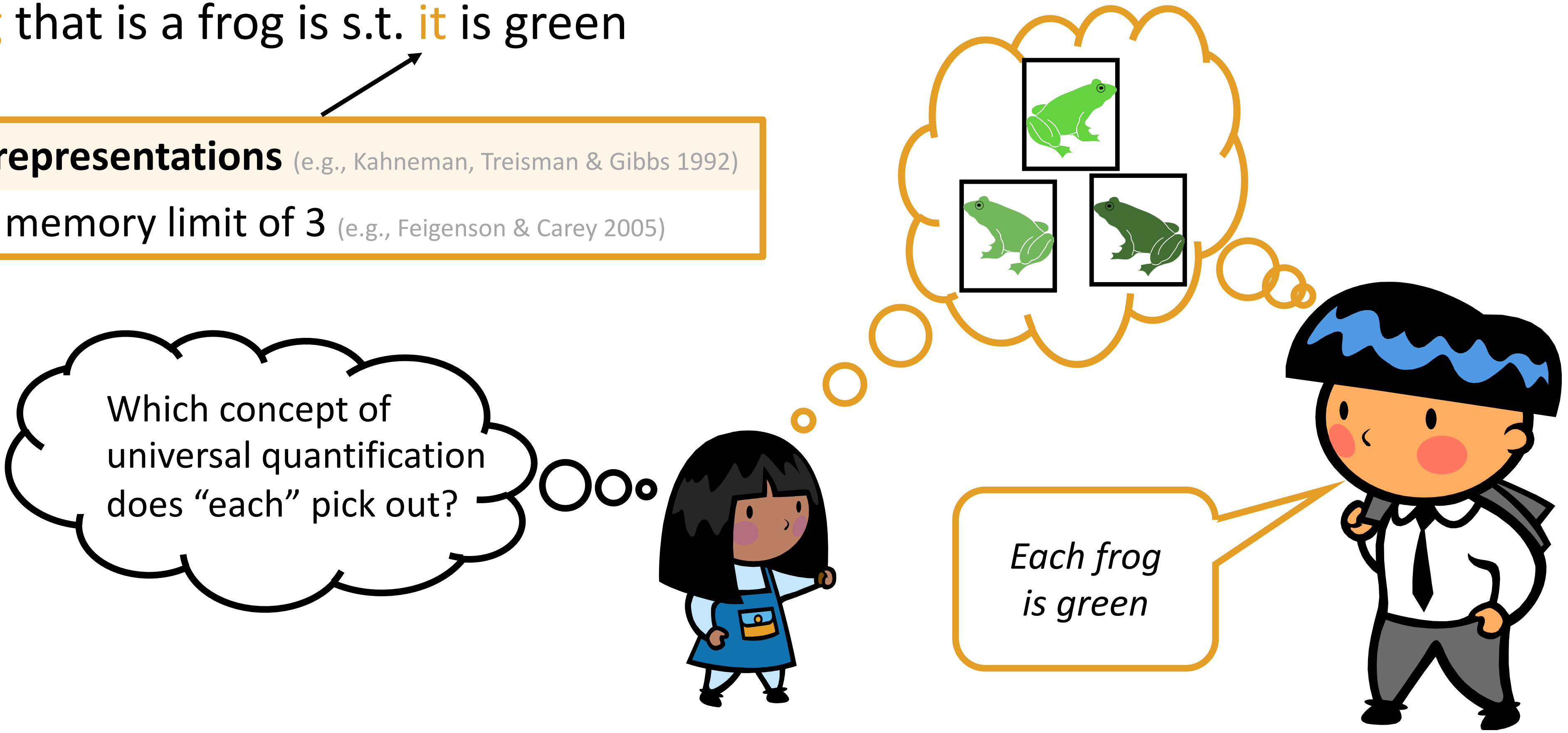

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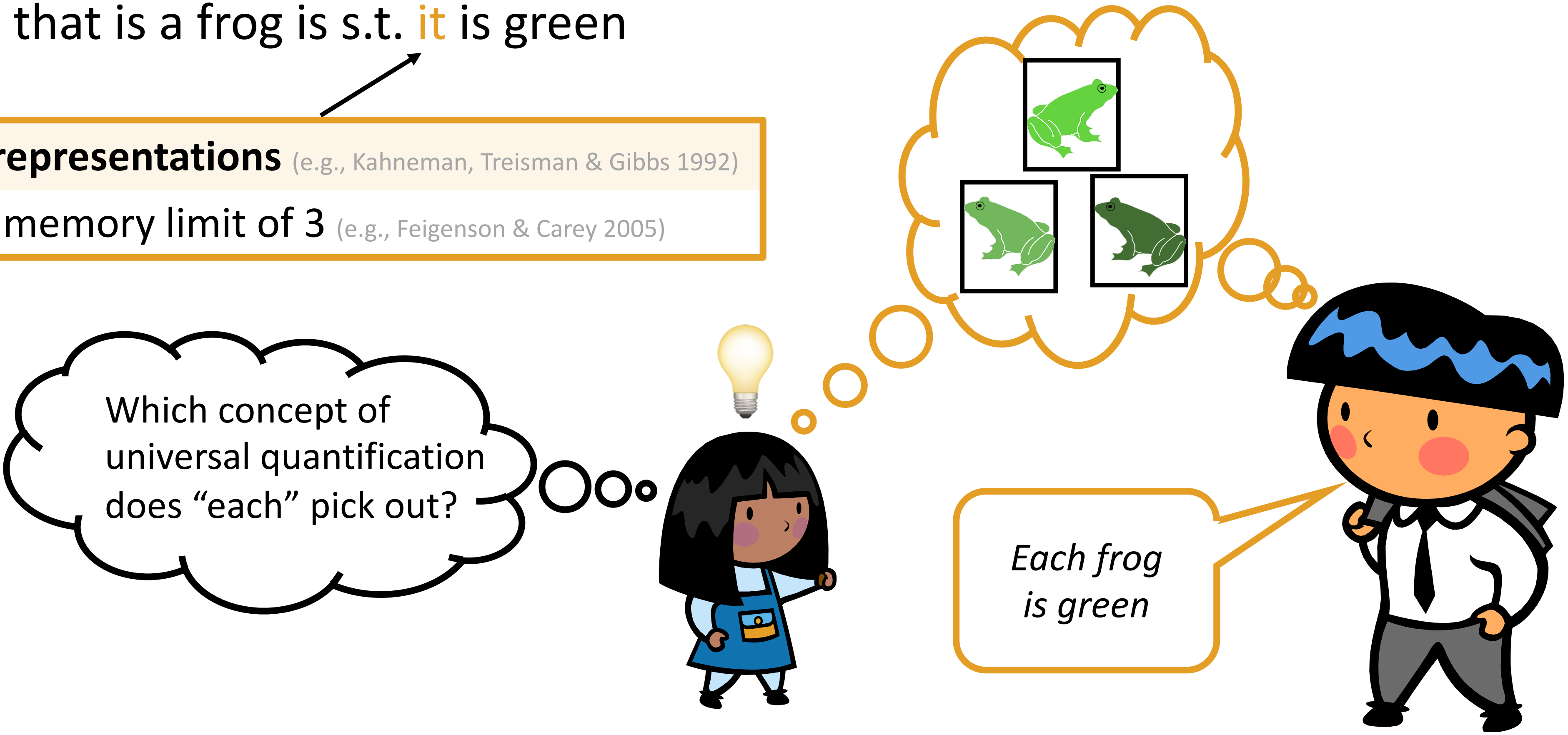

Each and *every* in child-directed speech

"You want one bite of each piece, huh?"

Each and *every* in child-directed speech

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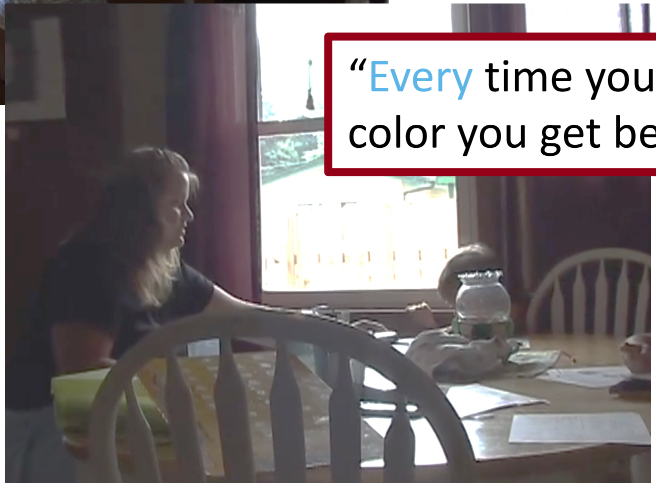

"Every time you color you get better"

Each and *every* in child-directed speech

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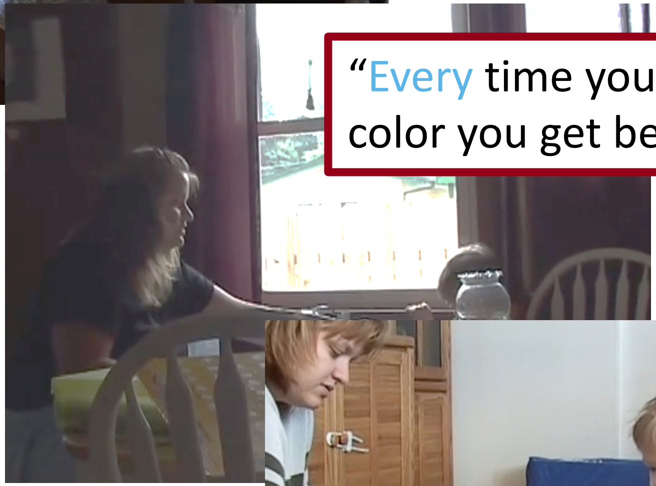
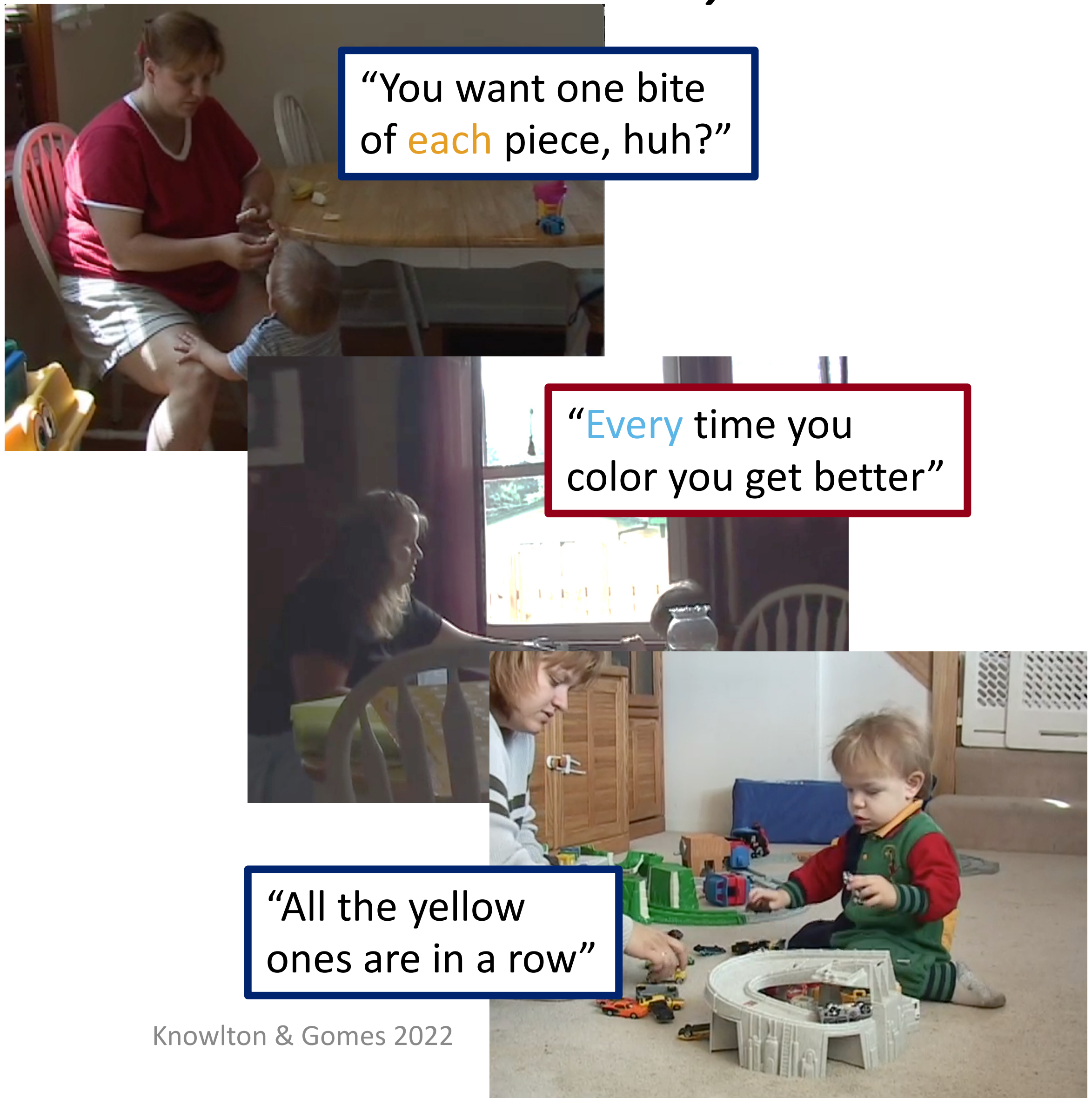


"Every time you color you get better"

"All the yellow ones are in a row"

Knowlton & Gomes 2022

Each and *every* in child-directed speech



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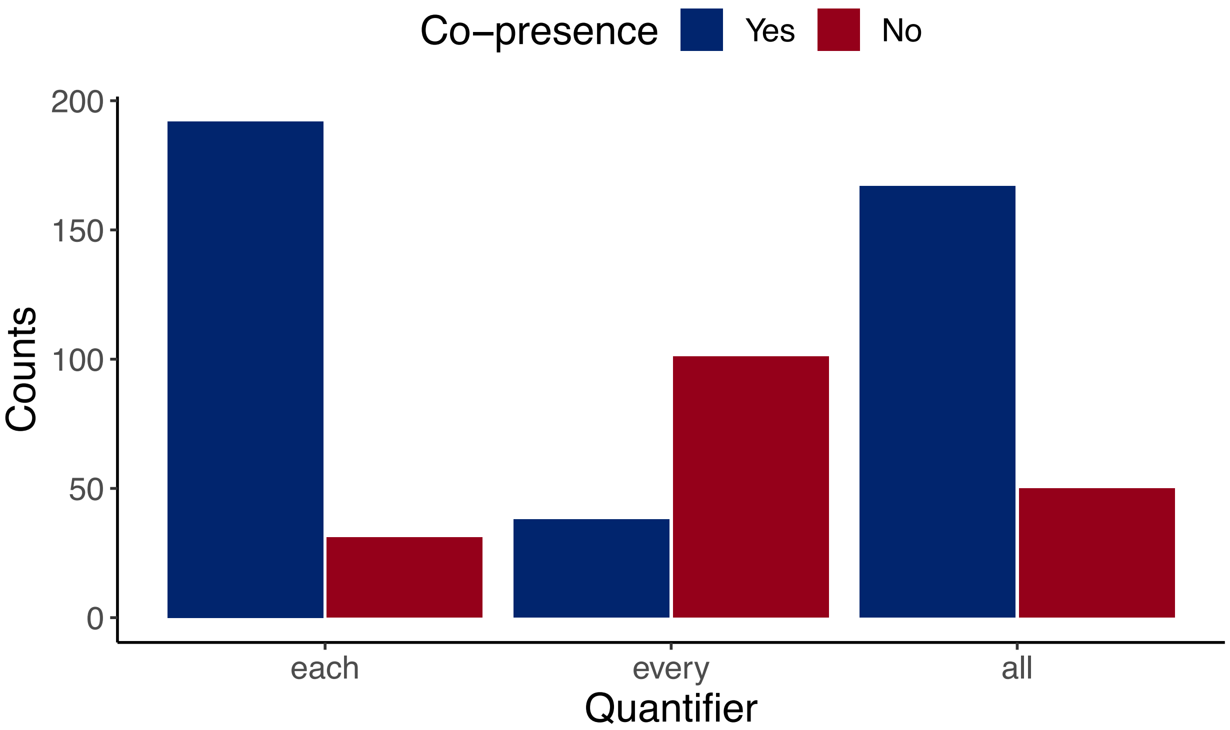
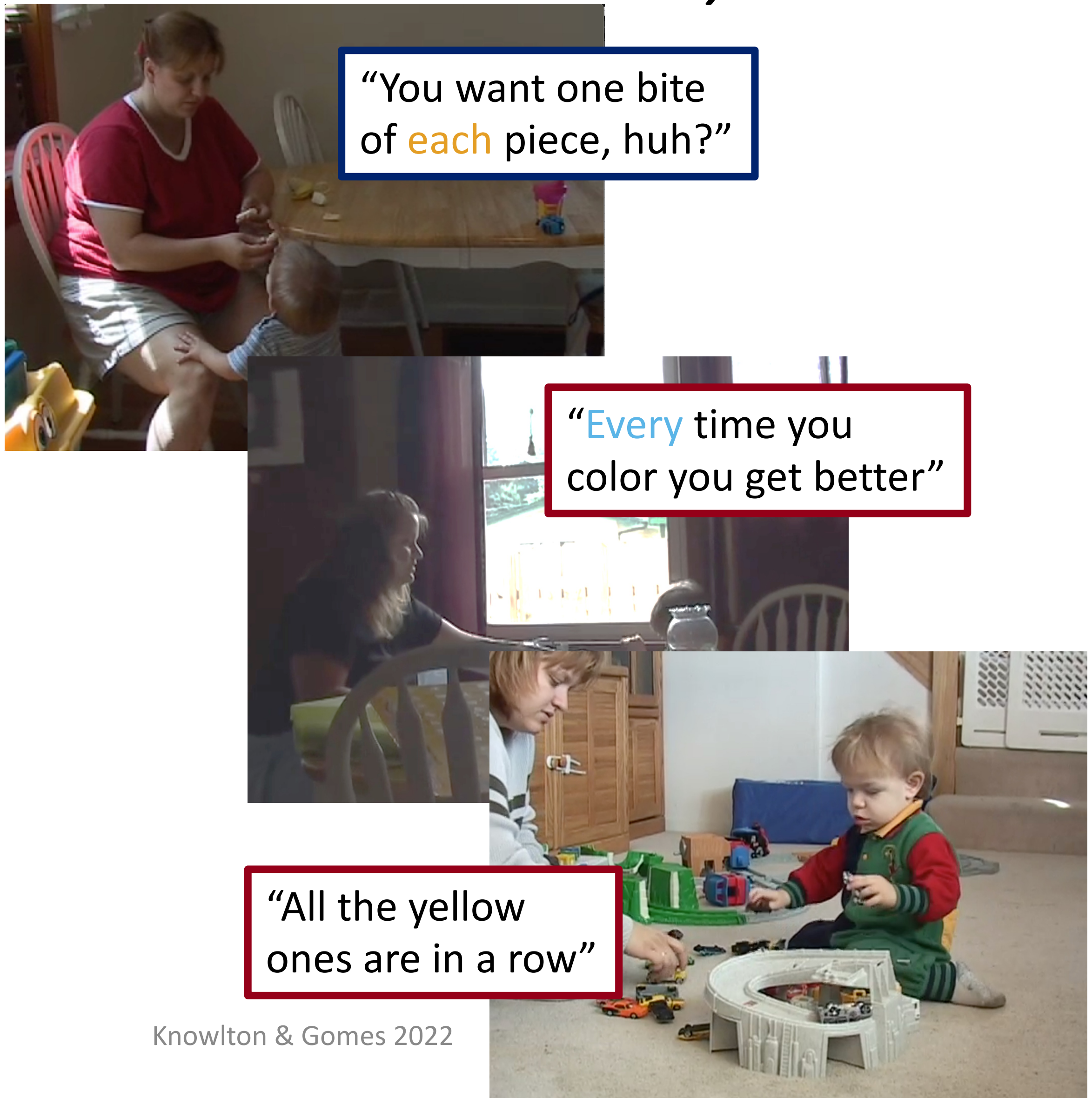


each vs. *every*: $\chi2=133.87$, $p<.001$

each vs. *all:* $\chi2=5.37$, $p<.05$

Each and *every* in child-directed speech



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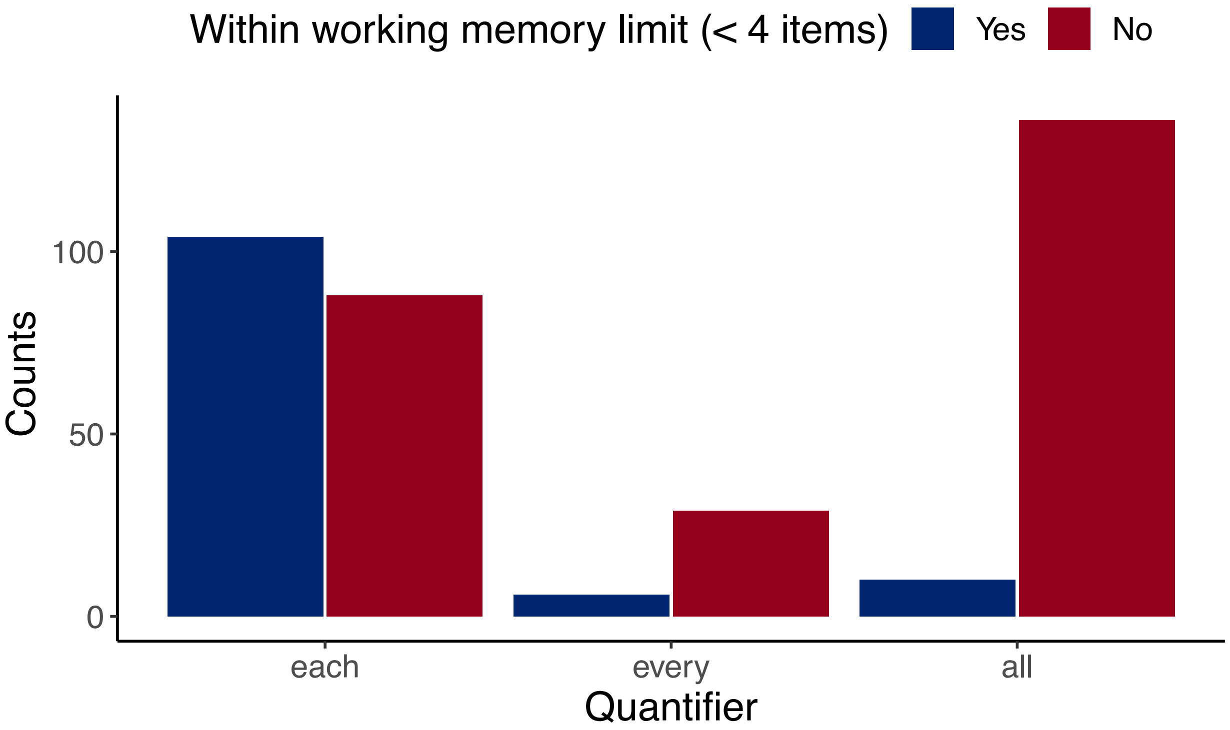


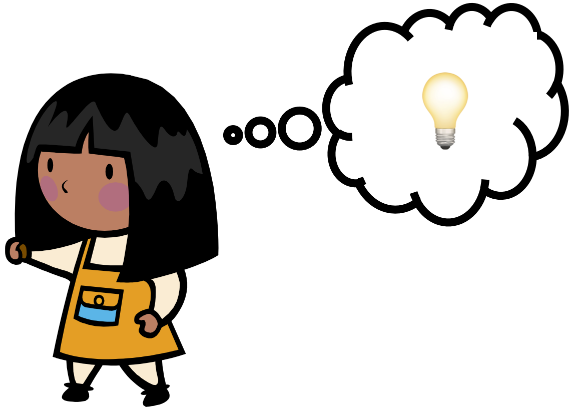
each vs. *every*: χ2=16.25, p<.001

each vs. *all*: χ2=80.97, p<.001

Knowlton & Gomes 2022

How are *each* & *every* acquired?

$\forall x{:}\mathrm{Frog}(x)$
$[\mathrm{Green}(x)]$



$\mathrm{The}F{:}\mathrm{Frog}(F)$
$[\forall x{:}F(x)[\mathrm{Green}(x)]]$

Knowlton & Gomes 2022 *Proceedings of the LSA*; Knowlton & Lidz 2021 *BUCLD proceedings*

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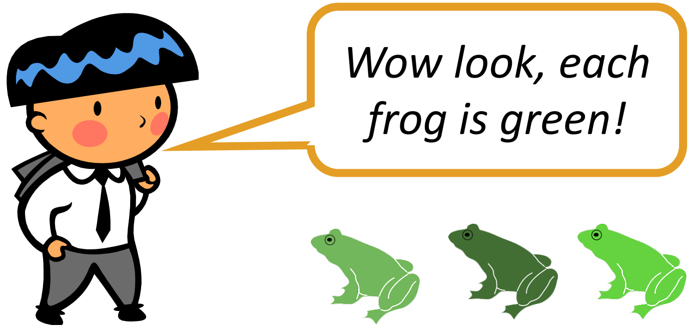
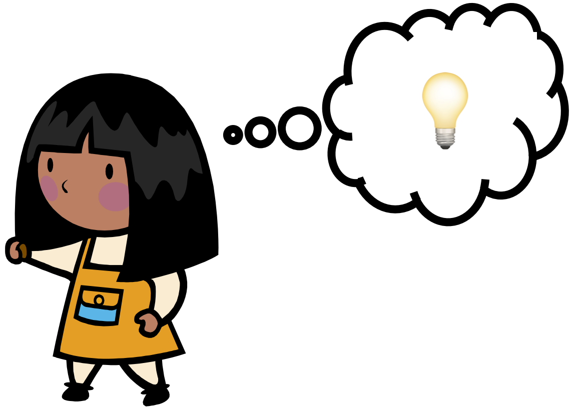


Domain present in small #s

$\forall x{:}Frog(x)$
$[Green(x)]$



$The F{:}Frog(F)$
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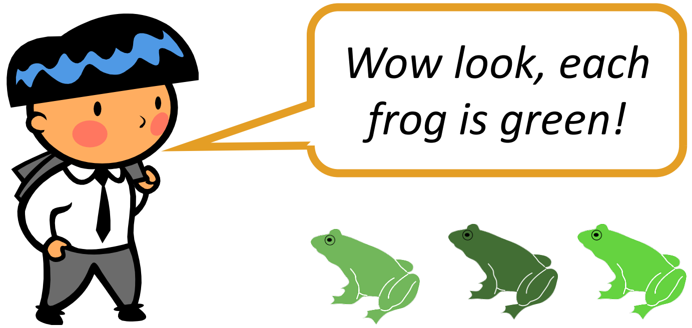
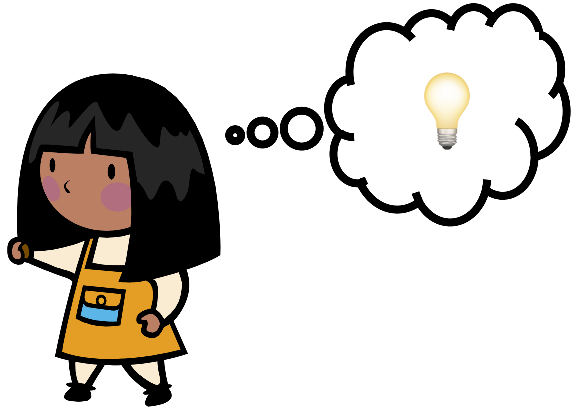


Domain present in small #s

Triggers

Object-files

$\forall x$:Frog(x) [Green(x)]



The$F$:Frog(F) [$\forall x$:F(x)[Green(x)]]

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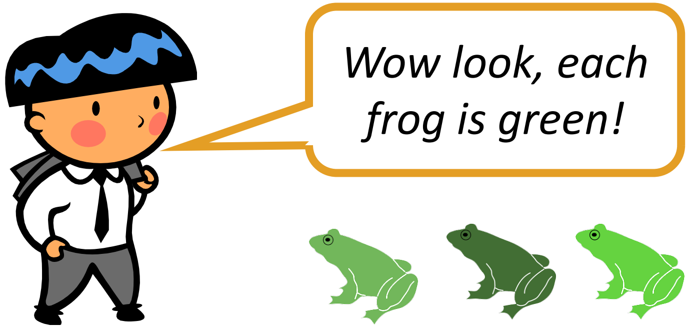
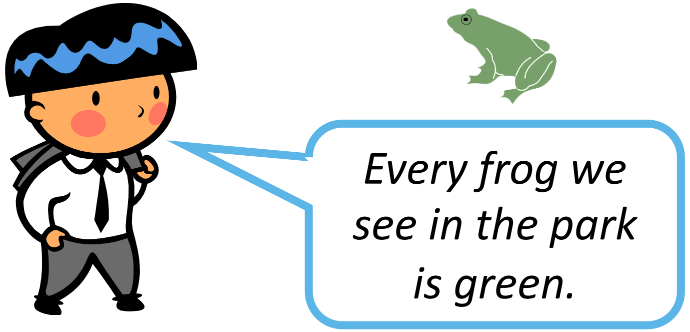


Domain present in small #s

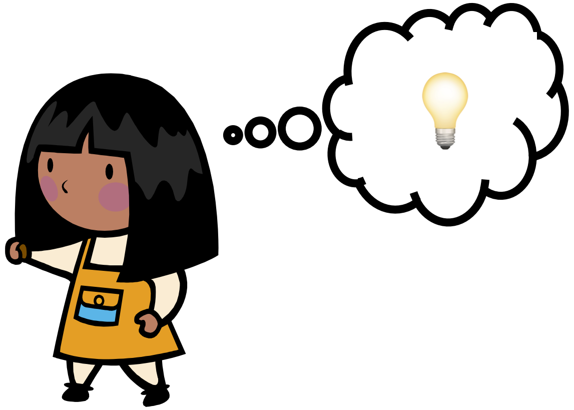
Domain generalized beyond



Triggers

Object-files

∀x:Frog(x)
[Green(x)]



TheF:Frog(F)
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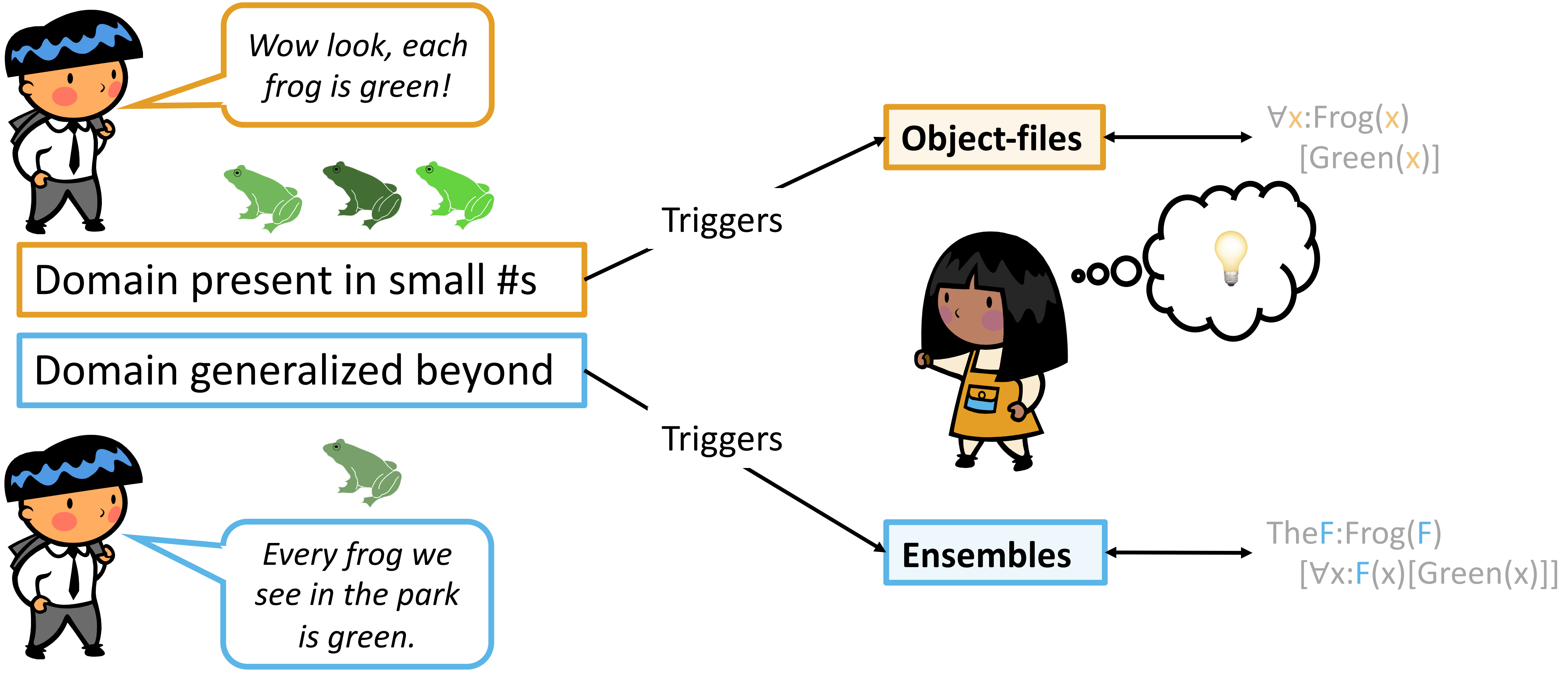

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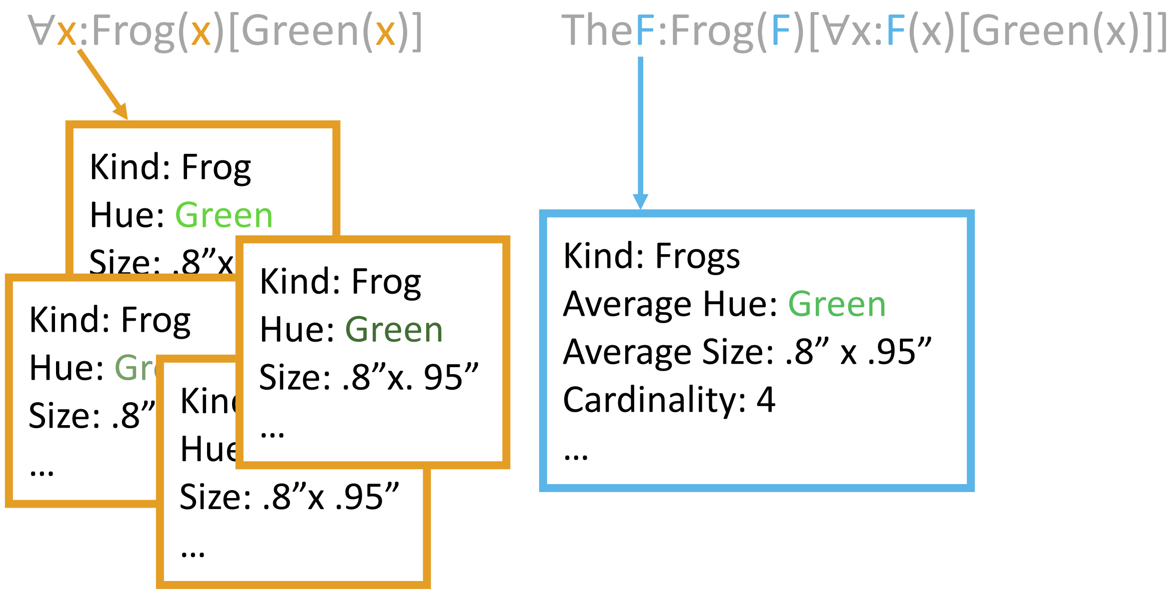

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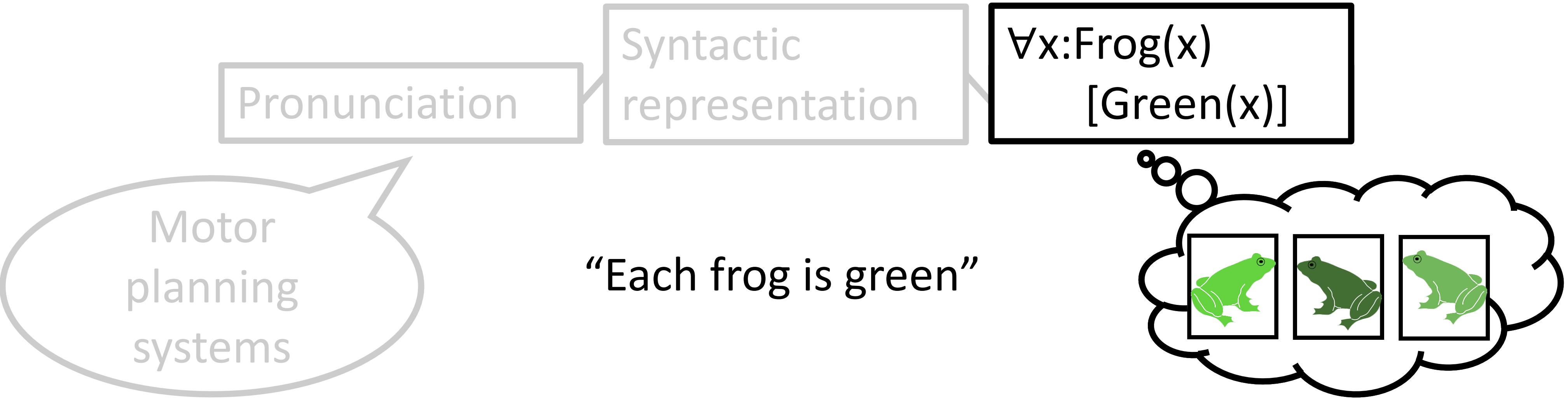
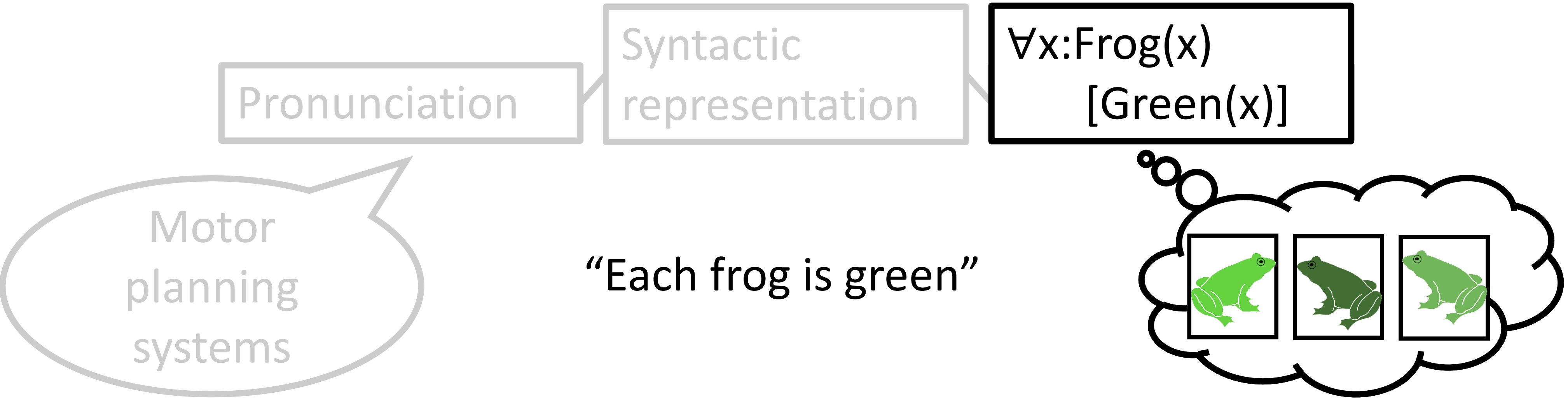


Probing the interface between linguistic meanings & non-linguistic cognitive systems can lead to a better understanding of:

➥ What meanings are



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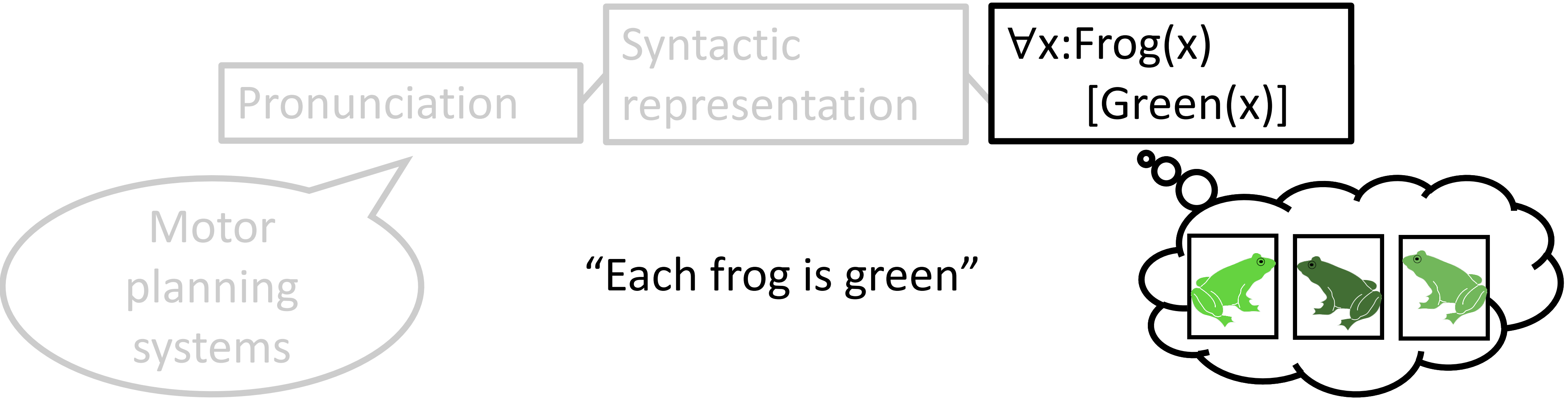
- ➥ How they’re used



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- ➥ How they’re used
- ➥ How they’re acquired

Thanks (to each & every one of you) for listening!

Collaborators on presented work:

Jeff Lidz

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Paul Pietroski

John Trueswell

Justin Halberda

Victor Gomes

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Valentine Hacquard
Ellen Lau
Florian Schwarz
Zoe Ovans
Darko Odic
Dan Swingley
Charles Yang
Liz Brannon
Sandy LaTourrette
Adam Liter
Yu'an Yang

RAs:

Simon Chervenak
Ebony Goldman
Alessandra Pintado-Urbanc

Language at Maryland

Penn University of Pennsylvania

mindCORE Center for Outreach, Research, and Education

NSF NRT-1449815 & NSF BCS-2017525