Universal quantifiers, objects, and ensembles: a case study in psychosemantics

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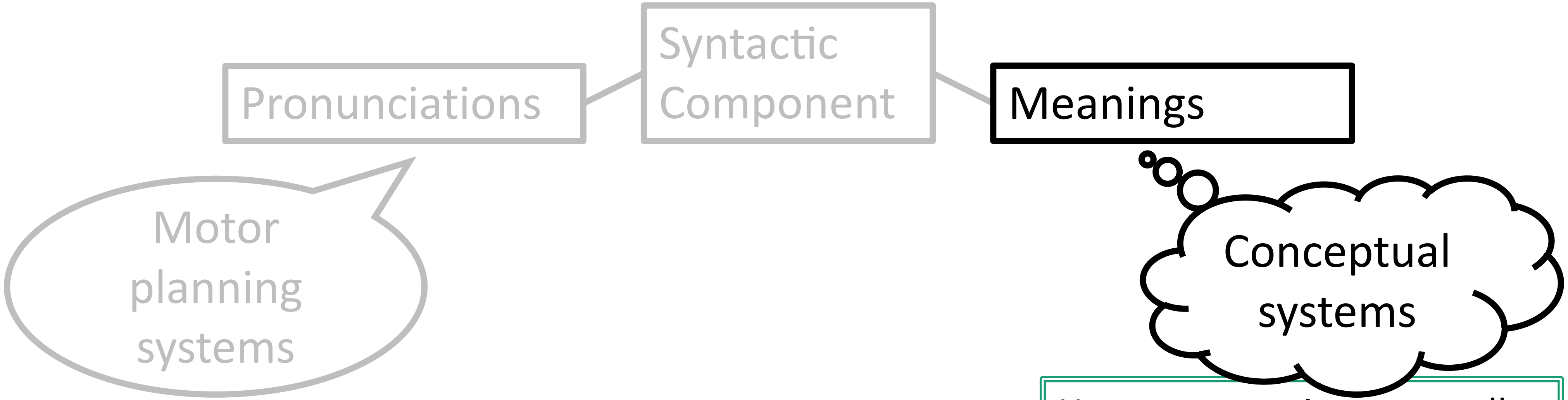
WoSSP 19 – Nantes Université
Slides available at: tylerknowlton.com/talks/WoSSP19.pdf

Meanings in mental grammar



How are meanings mentally specified and how do they interface with non-linguistic cognitive systems?

e.g., Halle 2003; Liberman & Mattingly 1985; Poeppel, Idsardi & van Wassenhove 2008; Chomsky 1964; Jackendoff 1983; Pietroski 2018; Knowlton et al. 2021

Meanings in mental grammar

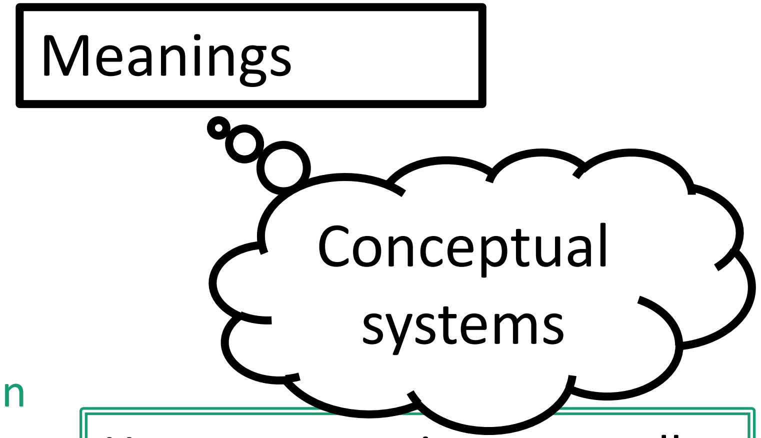
Textbook treatment of quantification:

Each/every/most/some/… frog is green

A function that takes an individual to TRUE iff it's green

A function that takes an individual to TRUE iff it's a frog

A function that essentially takes a pair of functions to TRUE iff their extensions are suitably related



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$$\#(GREEN \cap FROGS) > \#(\neg\, GREEN \cap FROGS)$$

$$\#(GREEN \cap FROGS) > \#(FROGS) - \#(GREEN \cap FROGS)$$

$$OneToOne+(GREEN \cap FROGS, \neg\, GREEN \cap FROGS)$$

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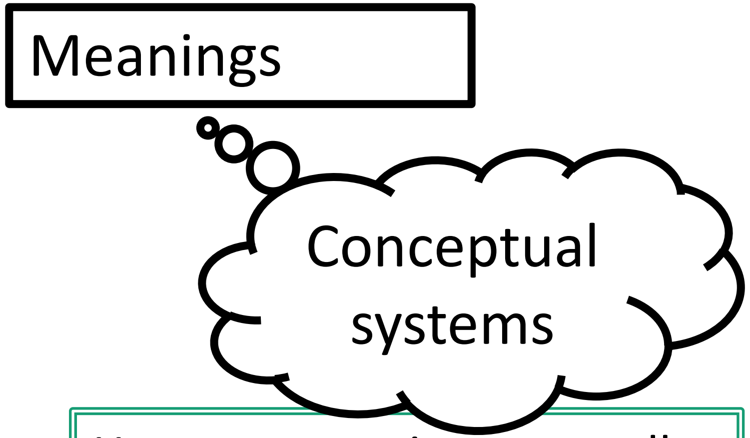

How are meanings mentally specified and how do they interface with non-linguistic cognitive systems?

A function that essentially takes a pair of functions to TRUE iff their extensions are suitably related

There are many logically equivalent ways of specifying the "*most* relation"

Pietroski et al. 2009; Lidz et al. 2011; Knowlton et al. 2021

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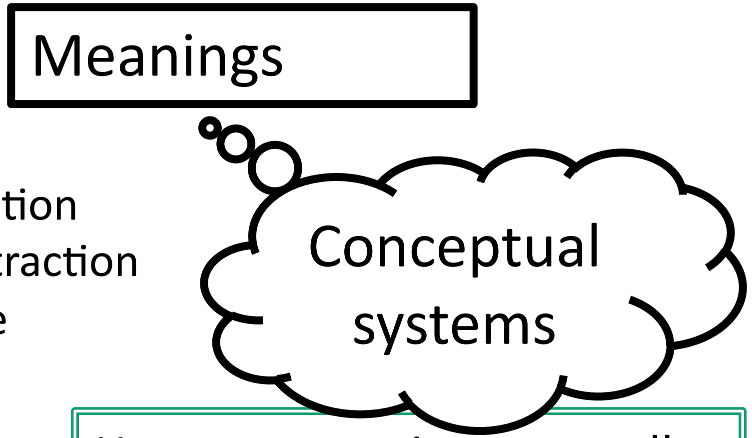

$\#(\text{GREEN} \cap \text{FROGS}) > \#(\neg\, \text{GREEN} \cap \text{FROGS})$ predicate negation

$\#(\text{GREEN} \cap \text{FROGS}) > \#(\text{FROGS}) - \#(\text{GREEN} \cap \text{FROGS})$ numerical subtraction

$\text{OneToOne+}(\text{GREEN} \cap \text{FROGS}, \neg\, \text{GREEN} \cap \text{FROGS})$ cardinality-free

.
.
.

How are meanings mentally specified and how do they interface with non-linguistic cognitive systems?

A function that essentially takes a pair of functions to TRUE iff their extensions are suitably related

There are many logically equivalent **but psychologically distinct** ways of specifying the "*most* relation"

Meanings in mental grammar

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Each/every/**most**/some/… frogs are gre

$\#(\text{GREEN} \cap \text{FROGS}) > \#(\neg\,\text{GREEN} \cap \text{FROGS})$ predica

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$\text{OneToOne+}(\text{GREEN} \cap \text{FROGS}, \neg\,\text{GREEN} \cap \text{FROGS})$ cardina

⋮

Leverage what's known about the cognitive system for cardinality representation to tease apart hypotheses about "psycho-logical form"

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Original Article

Linguistic meanings as cognitive instructions

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Natural languages like English connect pronunciations with meanings. Linguistic pronunciations can be described in ways that relate them to our motor system (e.g., to the movement of our lips and tongue). But how do linguistic meanings relate to our nonlinguistic cognitive systems? As a case study, we defend an explicit proposal about the meaning of *most* by comparing it to the closely related *more*: whereas *more* expresses a comparison between two independent subsets, *most* expresses a subset–superset comparison. Six experiments with adults and children demonstrate that these subtle differences between their meanings influence how participants organize and interrogate their visual world. In otherwise identical situations, changing the word from *most* to *more* affects preferences for picture–sentence matching (experiments 1–2), scene creation (experiments 3–4), memory for visual features (experiment 5), and accuracy on speeded truth judgments (experiment 6). These effects support the idea that the meanings of *more* and *most* are mental representations that provide detailed instructions to conceptual systems.

Keywords: language; meaning; semantics; psycholinguistics; vision

There are many logically equivalent **but psychologically distinct** ways of specifying the "*most* relation"

Pietroski et al. 2009; Lidz et al. 2011; Knowlton et al. 2021

Roadmap

✓ **Broad goal: Investigating "psycho-logical forms"**

➥ e.g., how *most* is mentally specified (cardinality vs. correspondence; negation vs. subtraction; …)

Current Case Study: *Each* vs. *Every*

➥ Proposed difference: first-order (individuals only) vs. second-order (group implicating) logic

➥ Proposed connection to non-linguistic cognition: object-files & ensembles

Evidence from sentence verification

➥ Encoding/recalling individual vs. group information

Downstream pragmatic consequences

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➥ *Every NP* is better able to provide a plural antecedent than *Each NP*

Each and *every* are obviously similar

(1) a. Each frog is green. ↔ Every frog is green. (both are universal quantifiers)

b. Some/Most/No frogs are green.

(2) a. *Each/?Every frog gathered by the pond. (both are distributive)

b. All the frogs gathered by the pond.

Each: ‘more individualistic’; *Every*: ‘friendlier to groups’

(3) a. Take every one of them.

b. Take each one of them…

and examine it for worms.

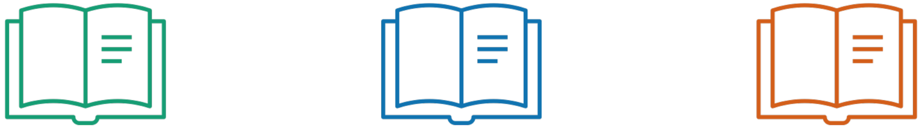
(4) The press is

a. every person who writes about the news.

b. # each person who writes about the news.

(5) Which book did you loan to each student?

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



(6) Which book did you loan to every student?

A: *There’s no one book I loaned to every student.*

The Challenge: How to accommodate these sorts of (subtle, non-categorical) observations while also explaining the (obvious) fact that *each* & *every* are distributive universal quantifiers?

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

Proposed meaning difference

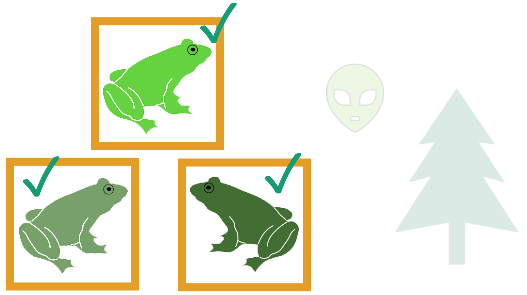
Each frog is green

∀x:Frog(x)[Green(x)]

≈ Any individual that satisfies ‘Frog’

is such that it satisfies ‘Green’

(Like a series of conjunctions: Frog_1 is green & Frog_2 is green &…)



Only *every*’s meaning has a semantic constituent corresponding to a grouping of the restricted domain

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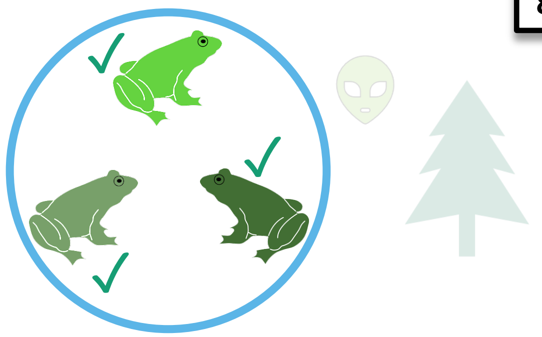
(Like *the frogs each are green*)



Knowlton, Halberda, Pietroski & Lidz (2023) *Glossa Psycholinguistics*

Proposed meaning difference & related cognition

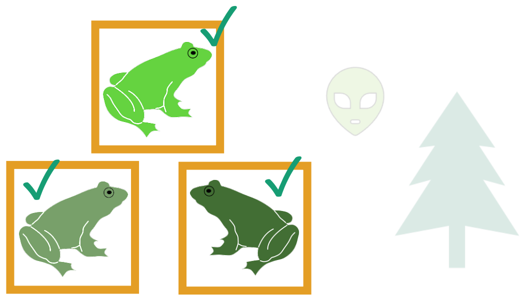
Each frog is green

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

≈ Any individual that satisfies 'Frog'

is such that it satisfies 'Green'

(Like a series of conjunctions: Frog$_1$ is green & Frog$_2$ is green &…)



Object-file representation
Index an individuated object and anchor list of associated individual properties (e.g., color, size, …)
(e.g., Kahneman & Treisman 1984; Kahneman, Treisman, & Gibbs 1992; Xu & Chen 2009; Carey 2009; Green & Quilty-Dunn 2020)

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Every frog is green

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

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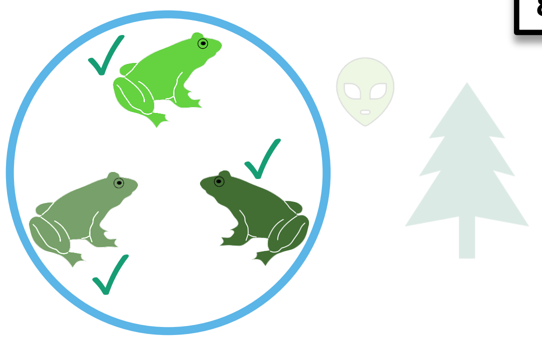

Ensemble representation
Abstract away from individual properties and encode collection in terms of summary statistics (e.g., average hue, cardinality, …)
(e.g., Ariely 2001; Chong & Treisman 2003; Haberman & Whitney 2011; Whitney & Yamanashi Leib 2018)

Knowlton, Halberda, Pietroski & Lidz (2023) *Glossa Psycholinguistics*

Roadmap

✓ **Broad goal: Investigating "psycho-logical forms"**

➥ e.g., how *most* is mentally specified (cardinality vs. correspondence; negation vs. subtraction; …)

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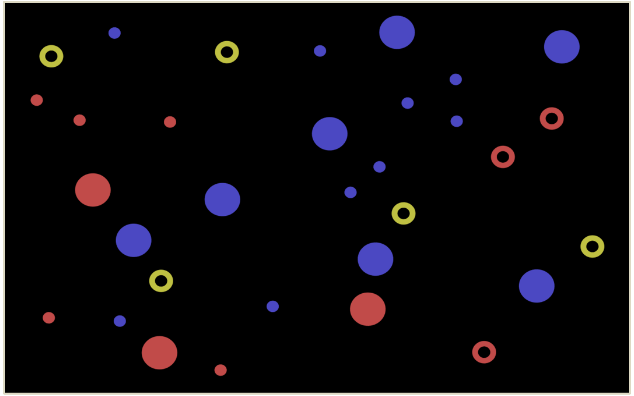
{Each/Every} big circle is blue

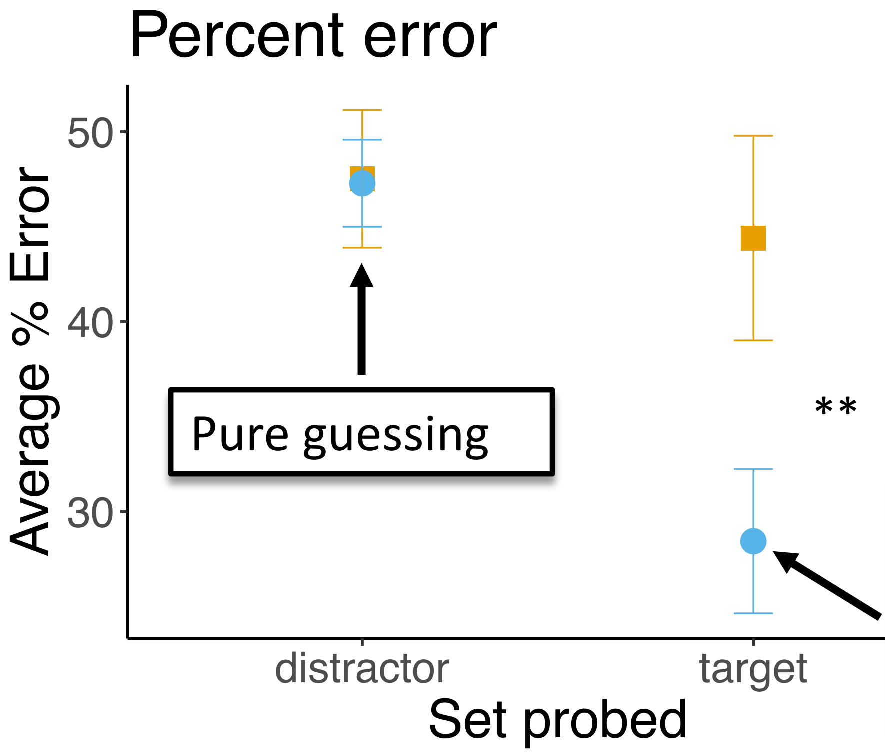
TRUE FALSE



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

Cardinality (ensemble property)

➥ If you initially represented the big circles, you should have a good estimate of their cardinality



Each
Every

As good as the visual system will allow! (for these stimuli)
(Knowlton et al. 2023 *Nat. Lang. Sem.*)

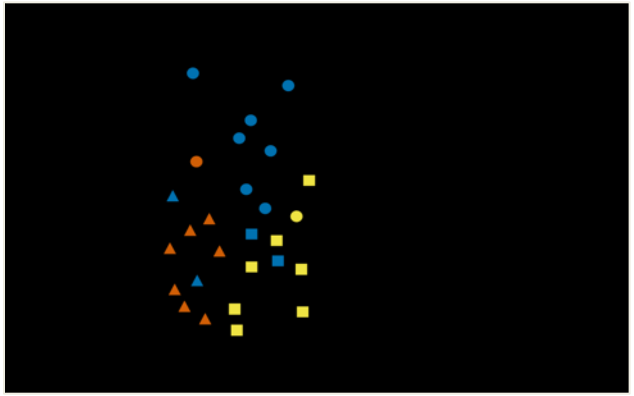
n = 12

Center of Mass (ensemble property)

(with 3- to 8-year-olds)

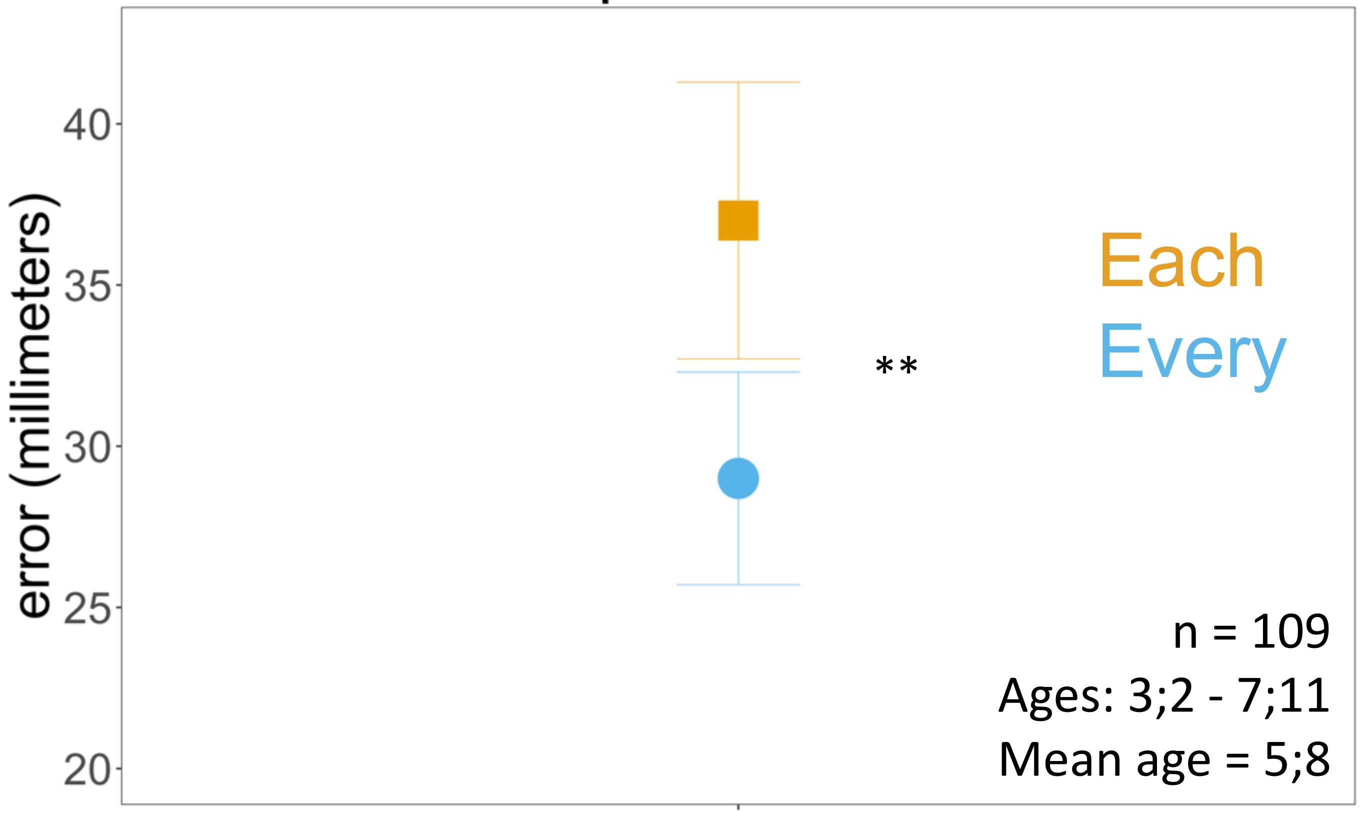
Is {each/every} circle blue?

“Yes” “No”

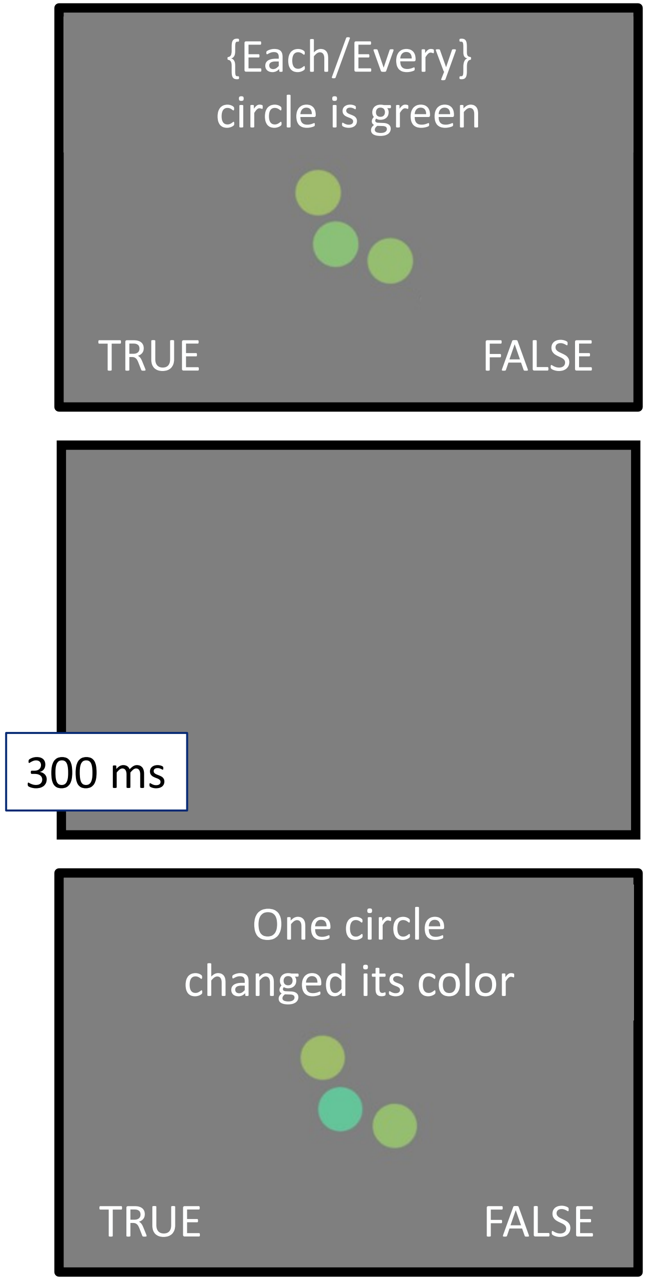


Where was the middle of the circles?

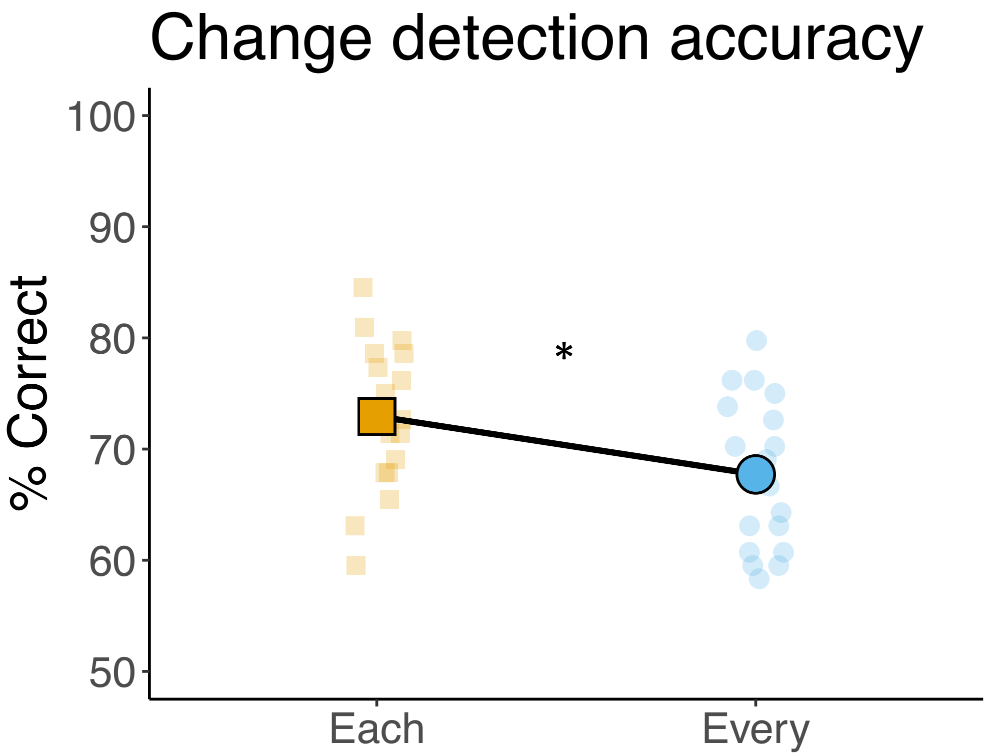
Distance from tap to actual set center



Knowlton 2021 *UMD dissertation*



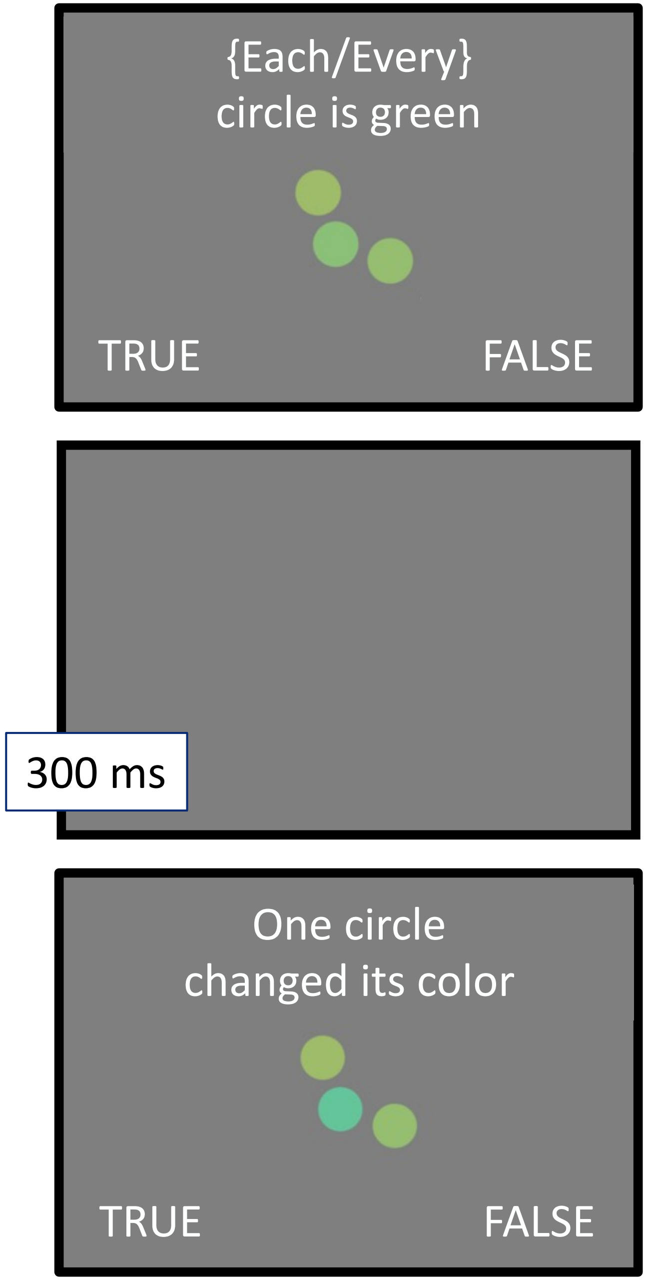
Color (individual property)



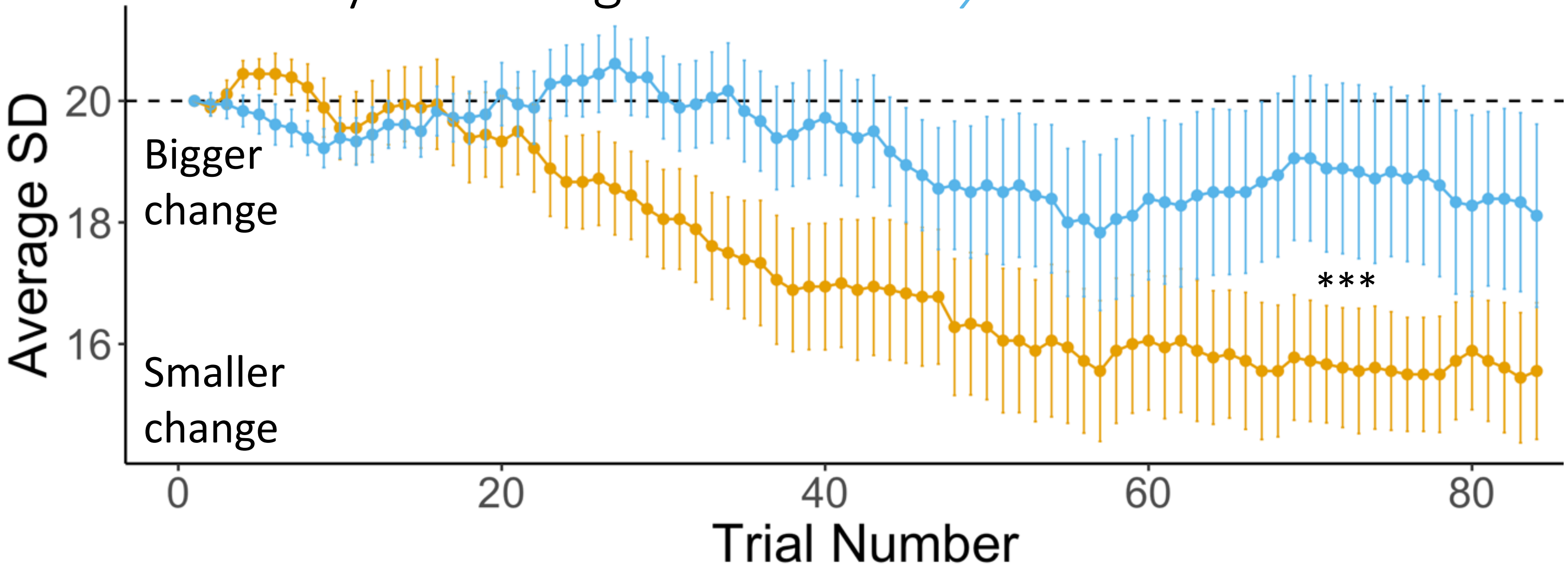
Each
Every

n = 36

Color (individual property)



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



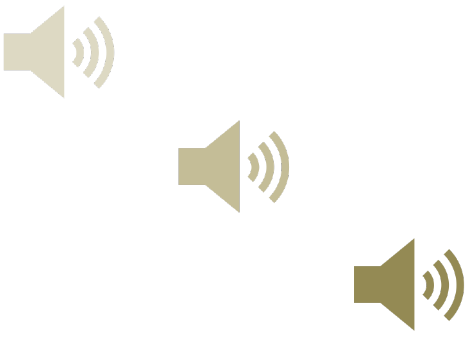
n = 36

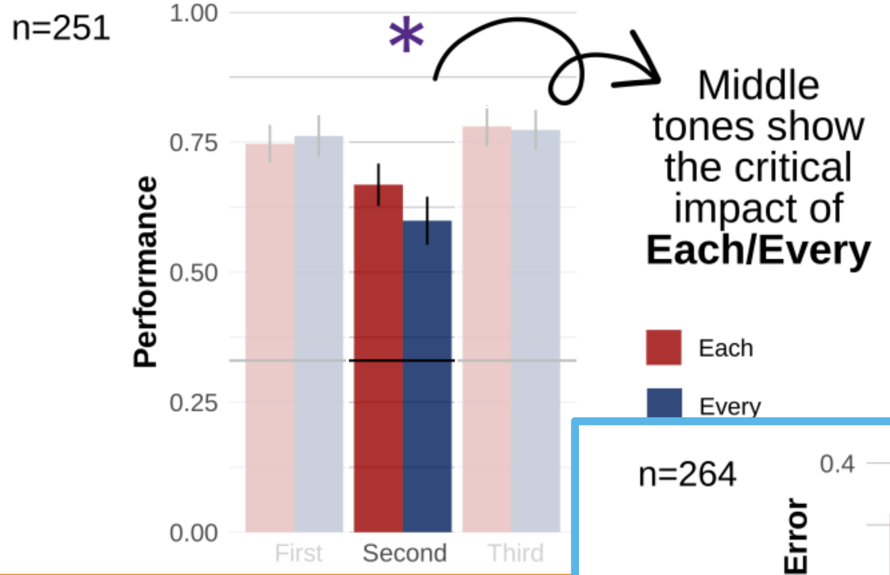
Knowlton, Halberda, Pietroski & Lidz (2023) *Glossa Psycholinguistics*

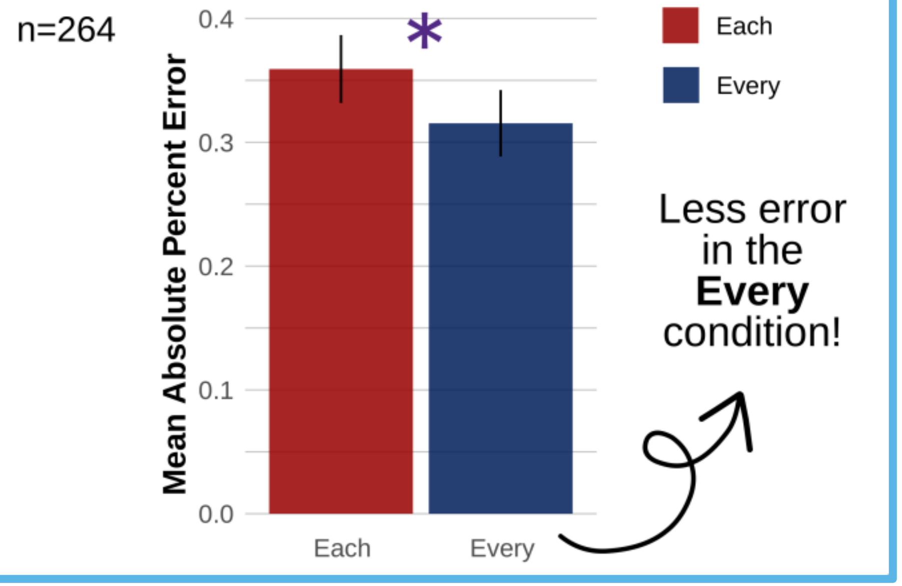
Position (individual property) & Average (ensemble property)

Each/Every tone is pleasant

TRUE FALSE



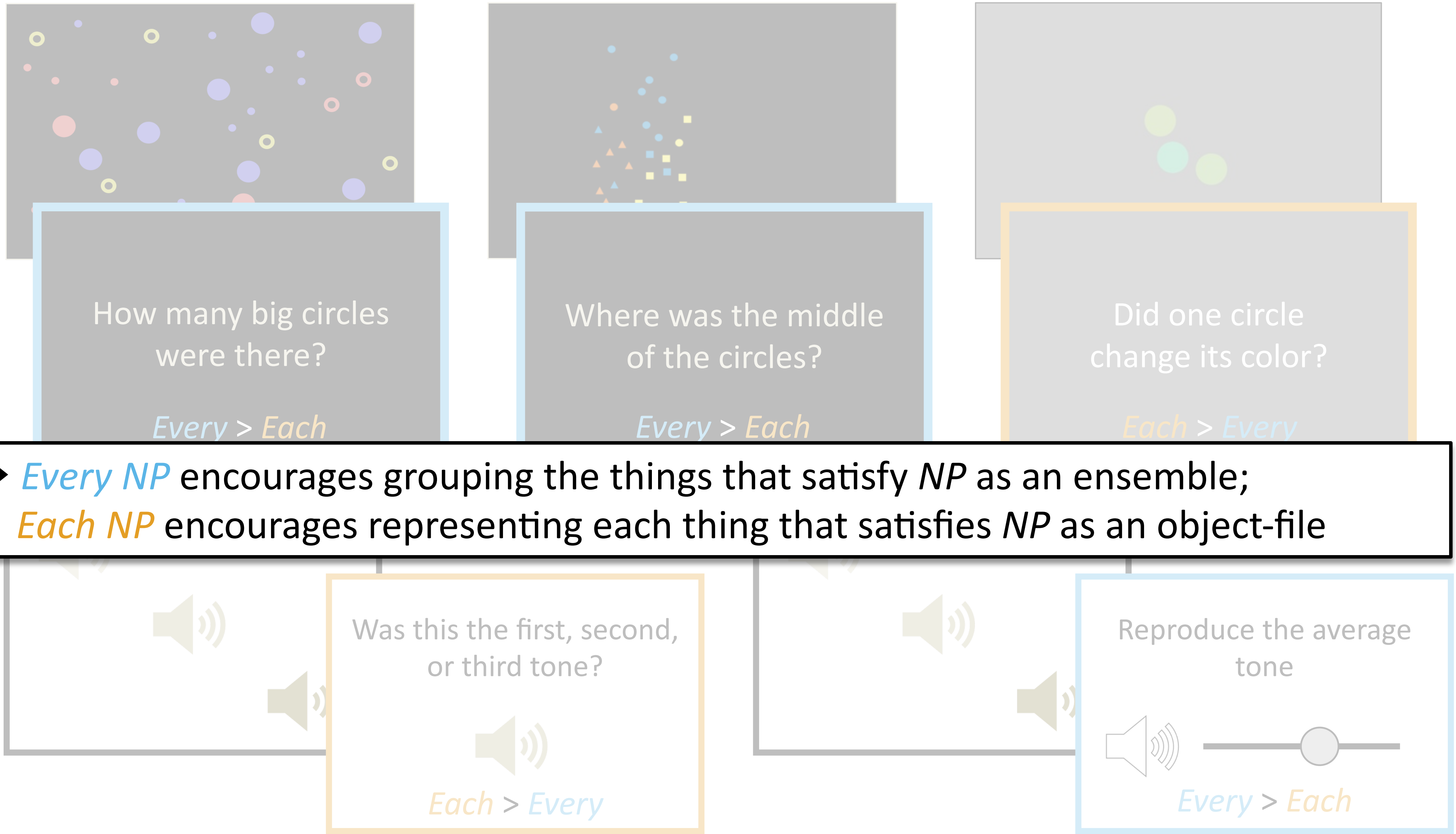




Was this the first, second, or third tone?

Reproduce the average tone

Ongchoco, Knowlton, & Papafragou (2023) *Cog Sci*



➥ *Every NP* encourages grouping the things that satisfy *NP* as an ensemble;
Each NP encourages representing each thing that satisfies *NP* as an object-file

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Downstream pragmatic consequences?

Each frog is green

∀x:Frog(x)[Green(x)]

≈ Any individual that satisfies 'Frog'

is such that it satisfies 'Green'

Strict working memory limit of 3

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

Object-file representation

Index an individuated object and anchor list of associated individual properties (e.g., color, size, …)

(e.g., Kahneman & Treisman 1984; Kahneman, Treisman, & Gibbs 1992; Xu & Chen 2009; Carey 2009; Green & Quilty-Dunn 2020)

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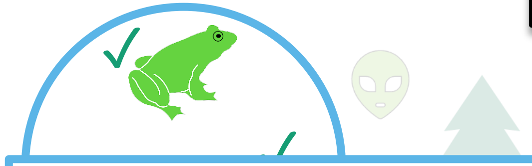


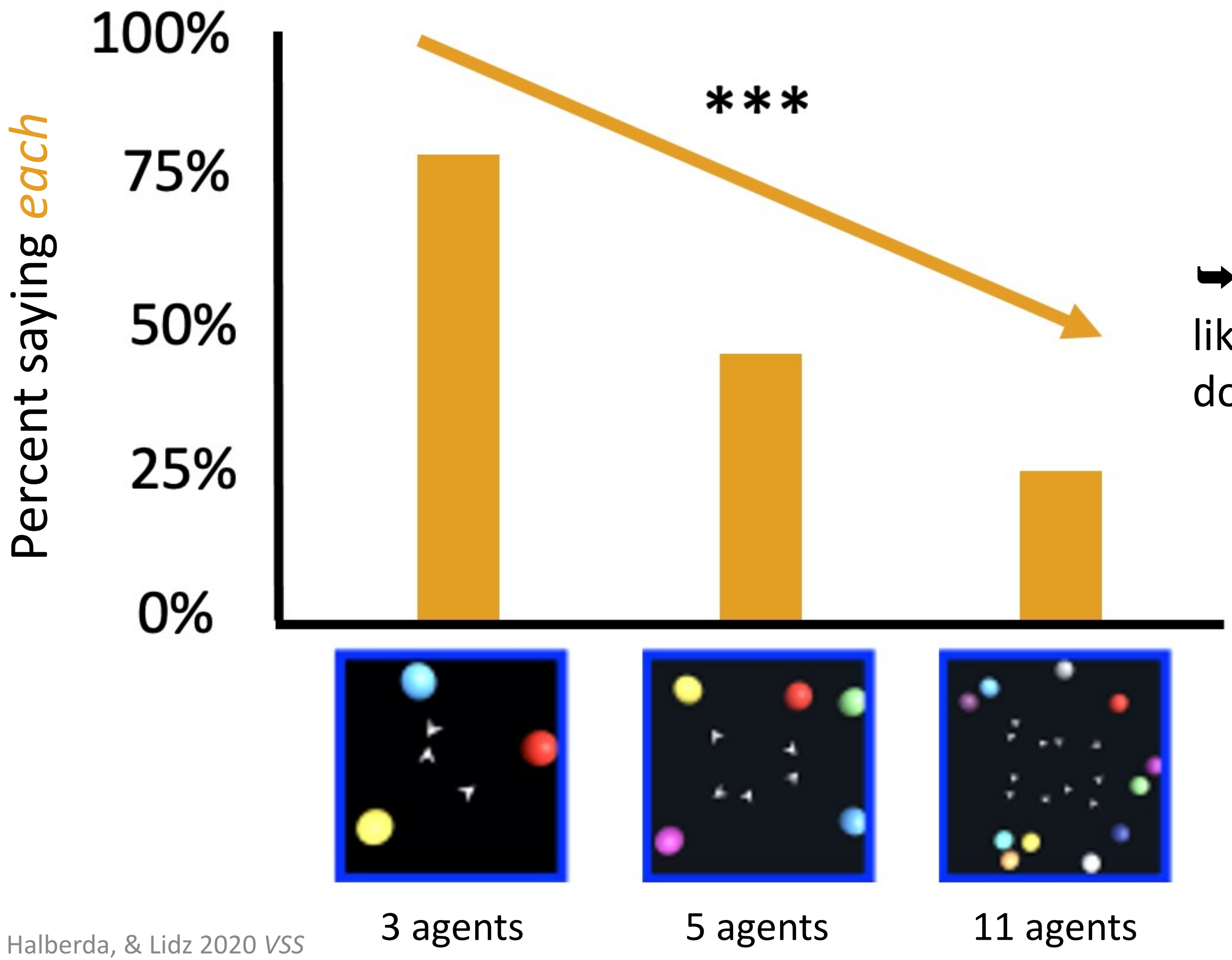
No limit to the number of individuals represented as an ensemble

Ensemble representation

Abstract away from individual properties and encode collection in terms of summary statistics (e.g., average hue, cardinality, …)

(e.g., Ariely 2001; Chong & Treisman 2003; Haberman & Whitney 2011; Whitney & Yamanashi Leib 2018)

Effects of domain size in spontaneous descriptions



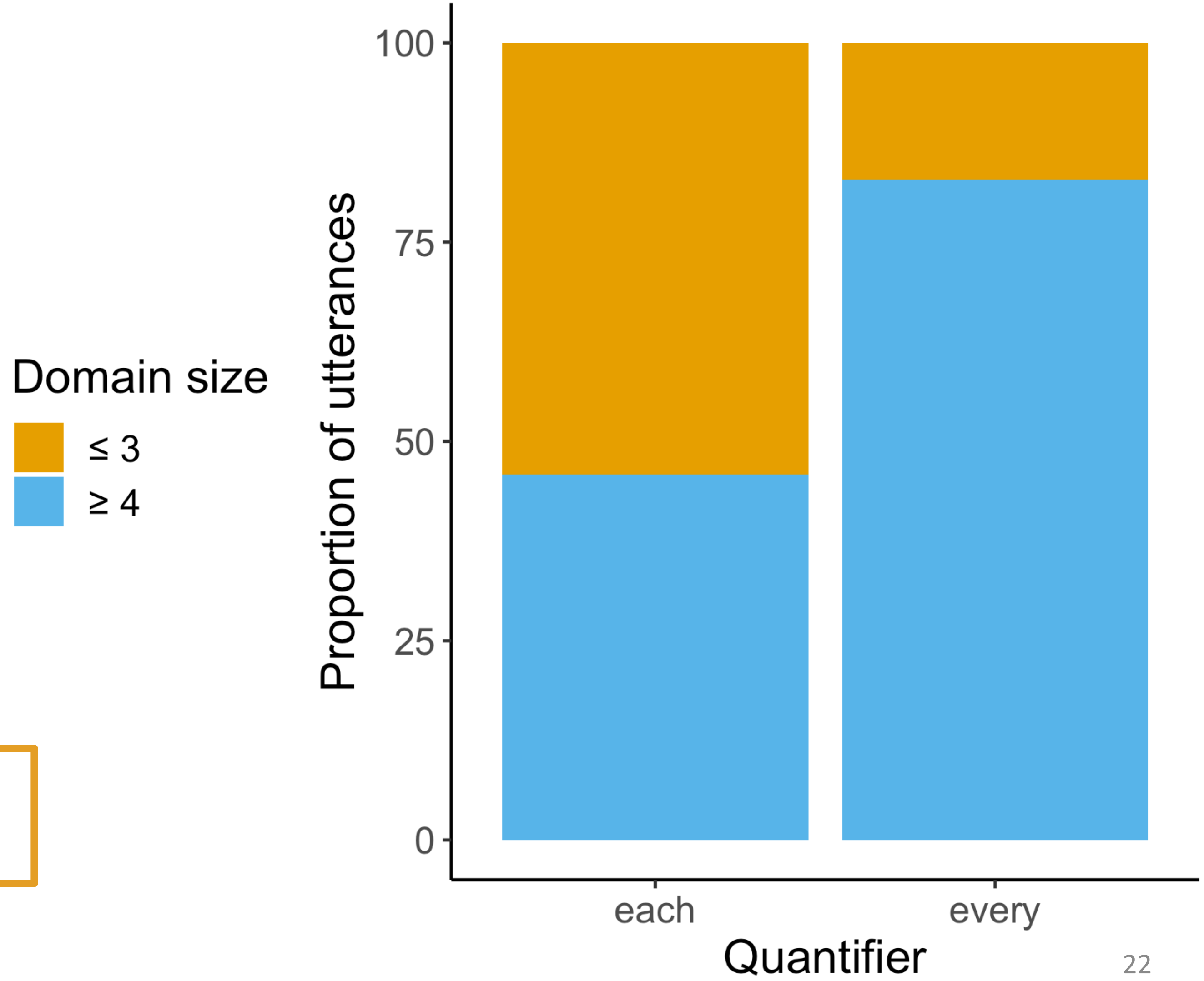
➥ Participants are more likely to use *each* when domains are small!

Cesana-Arlotti, Knowlton, Halberda, & Lidz 2020 *VSS*

Effects of domain size in child-directed speech

How many things are being quantified over in speech to kids? (362 utterances)

“You want one bite of each piece, huh?”



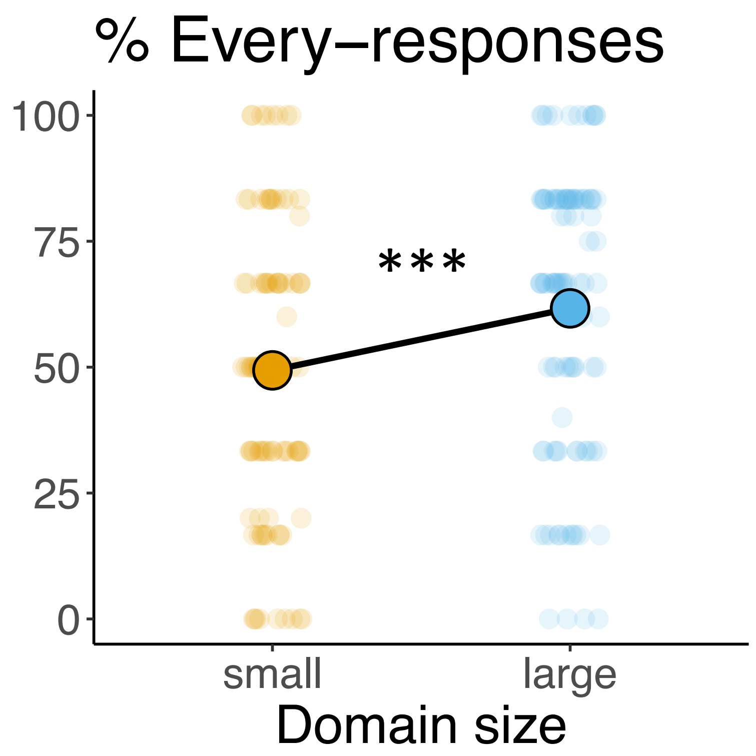
Effects of domain size: forced-choice judgment

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

He said that (select a word) martini he made had an olive.

each

every



12 items; within-subjects; n=100

Effects of domain size: free response

If someone said

Each martini I made has an olive

Every martini I made has an olive

how many martinis would you guess they have in mind?

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

1 item; n=198

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Predicates with *same* require a comparison class

(11) a. #Kermit is the same color (same as what??)

b. The frogs are the same color

Prediction: Because *every frog* implicitly introduces the frogs, it should behave more like (11b);

each frog doesn't introduce such a group, so should behave more like (11a)

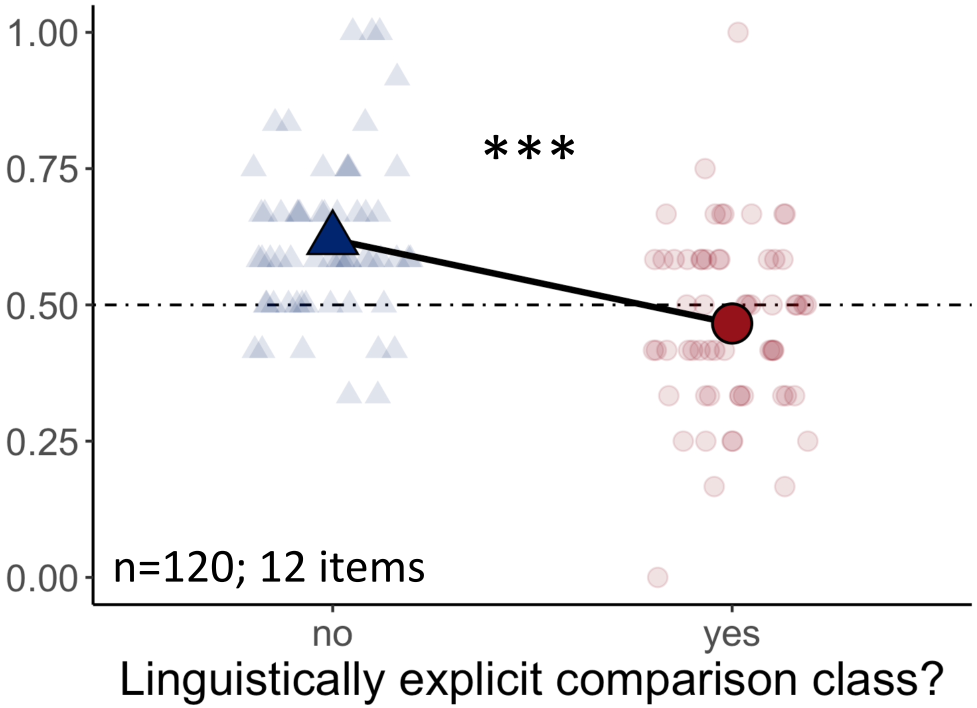
see e.g., Kuhn 2015; Brasoveanu & Dotlačil 2015

Sentence-internal *same*: forced-choice judgment

Ann and Frank decided to throw a school Halloween party.

Surprisingly, (select a word) [each / every] student showed up in the same costume { ∅. / <u>as their classmates</u>. }

Proportion picking *every* over *each*



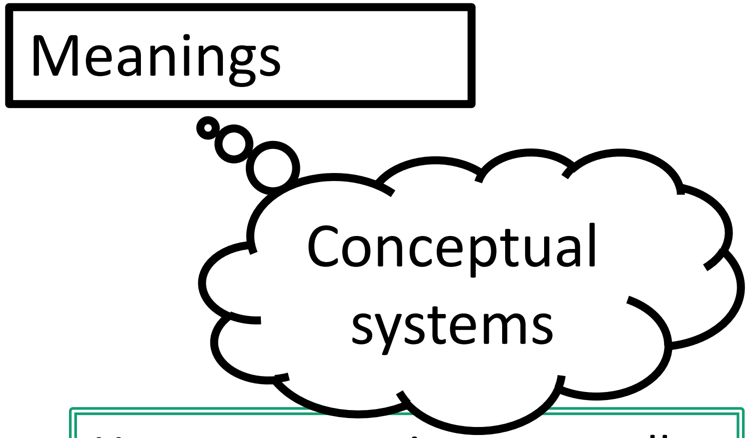
➥ Participants favored *every* in the absence of another source of the comparison class for *same*

➥ This preference disappeared when the comparison class was made linguistically explicit

Meanings in mental grammar

Case study: the universal quantifiers *each* and *every*

- ➡ First-order *each*; (partially) Second-order *every*
  - ➩ Connections to well-studied cognitive systems
- ➡ Consequences for pragmatics
  - ➩ Properties of interfacing systems affect expression use
- ➡ Consequences for language acquisition



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

Collaborators on presented work:

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Paul Pietroski

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Anna Papafragou

John Trueswell

Florian Schwarz

Victor Gomes

Julia Ongchoco

Language at Maryland

MindCORE
Center for Outreach, Research, and Education
University of Pennsylvania

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