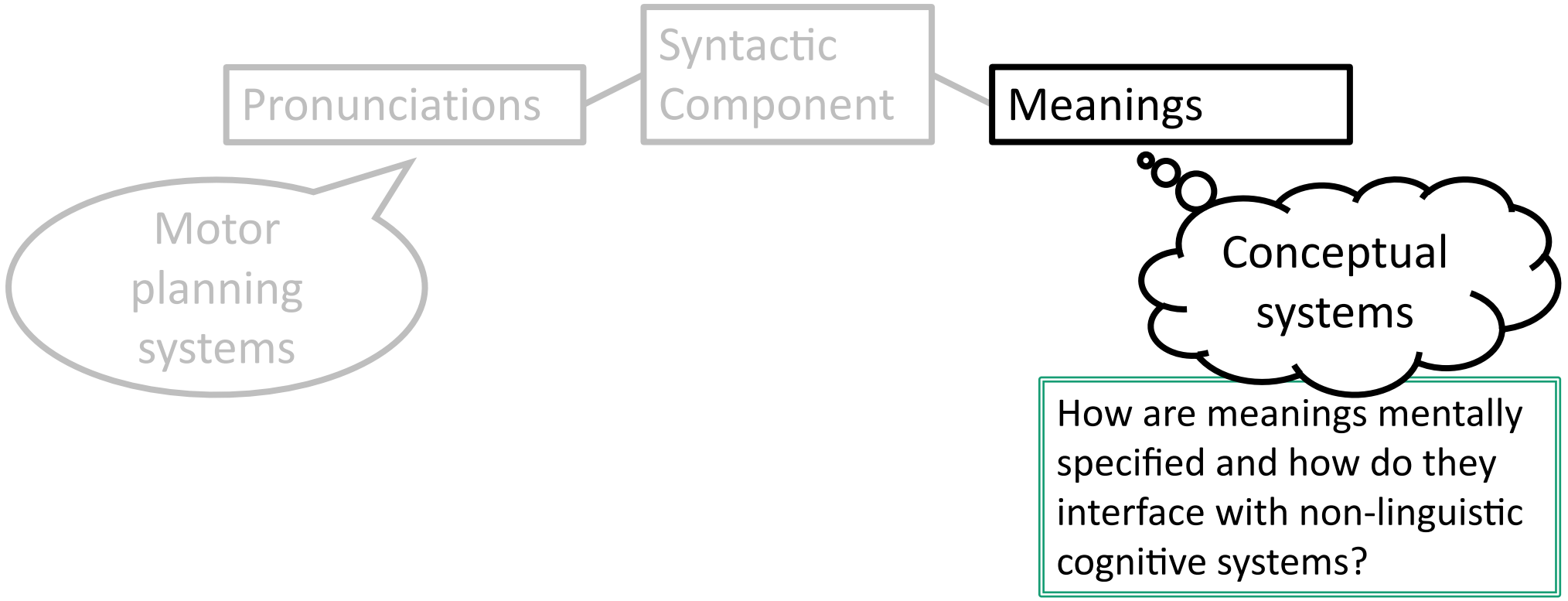
Universal quantifiers, objects, and ensembles: a case study in psychosemantics

Tyler Knowlton

University of Pennsylvania

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

Meanings in mental grammar



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

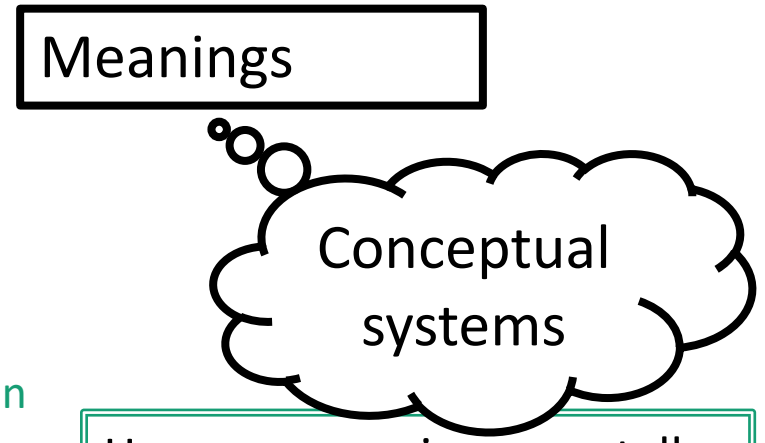
Textbook treatment of quantification:

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



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

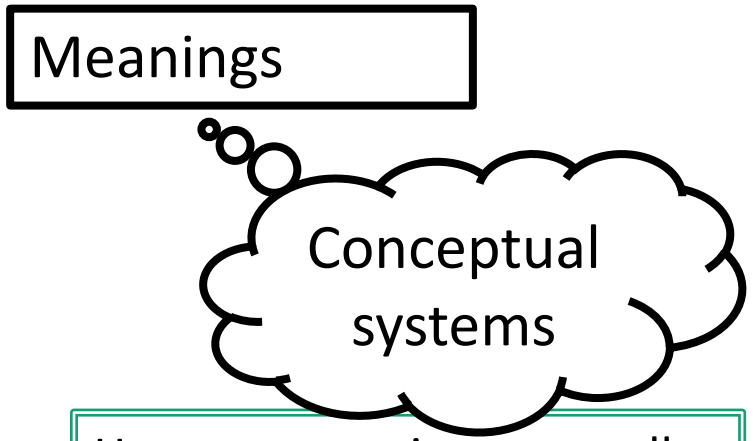
Meanings in mental grammar

Textbook treatment of quantification:

Each/every/most/some/… frogs are green

#(GREEN ∩ FROGS) > #(¬ GREEN ∩ FROGS)
#(GREEN ∩ FROGS) > #(FROGS) – #(GREEN ∩ FROGS)
OneToOne+(GREEN ∩ FROGS, ¬ GREEN ∩ FROGS)
.
.
.

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

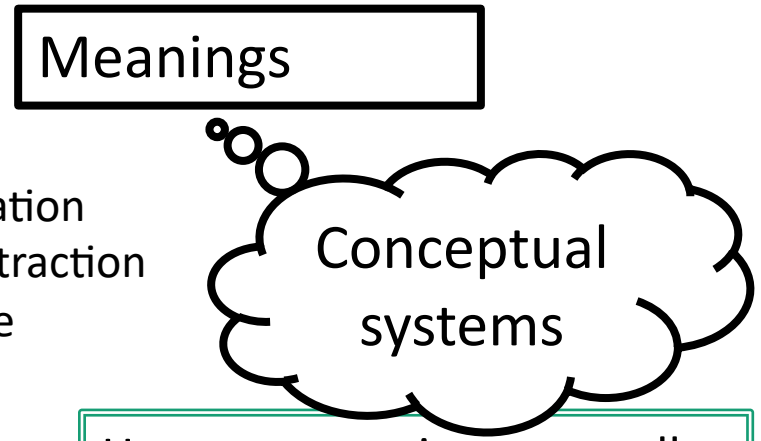
Meanings in mental grammar

Textbook treatment of quantification:

Each/every/most/some/… frogs are green

#(GREEN ∩ FROGS) > #(¬ GREEN ∩ FROGS)	predicate negation
#(GREEN ∩ FROGS) > #(FROGS) – #(GREEN ∩ FROGS)	numerical subtraction
OneToOne+(GREEN ∩ FROGS, ¬ GREEN ∩ FROGS)	cardinality-free
.	
.	
.	

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



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

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

Meanings in mental grammar

Textbook treatment of quantification:

Each/every/most/some/… frogs are gre

#(GREEN ∩ FROGS) > #(¬ GREEN ∩ FROGS) predica

#(GREEN ∩ FROGS) > #(FROGS) – #(GREEN ∩ FROGS) numer

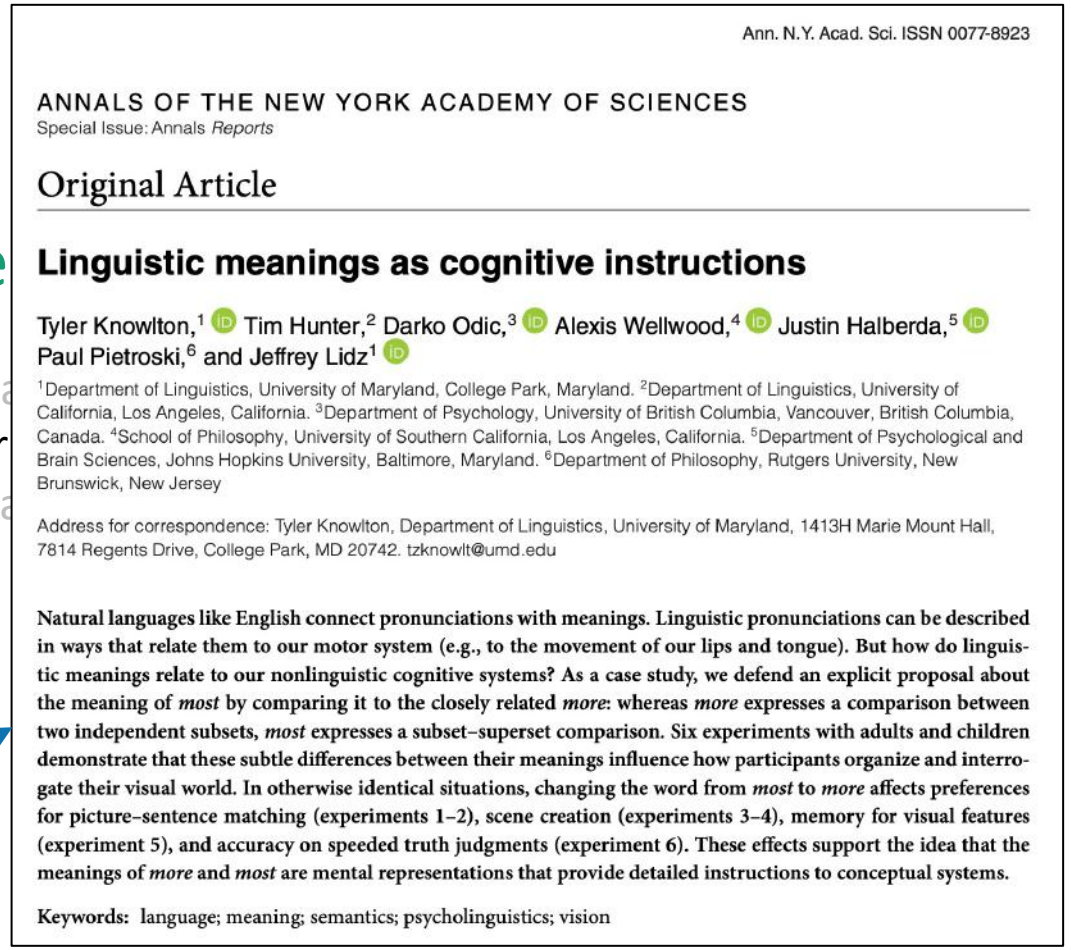
OneToOne+(GREEN ∩ FROGS, ¬ GREEN ∩ FROGS) cardina

.

.

.

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



Ann. N.Y. Acad. Sci. ISSN 0077-8923

ANNALS OF THE NEW YORK ACADEMY OF SCIENCES
Special Issue: Annals *Reports*

Original Article

Linguistic meanings as cognitive instructions

Tyler Knowlton,[1] Tim Hunter,[2] Darko Odic,[3] Alexis Wellwood,[4] Justin Halberda,[5] Paul Pietroski,[6] and Jeffrey Lidz[1]

[1]Department of Linguistics, University of Maryland, College Park, Maryland. [2]Department of Linguistics, University of California, Los Angeles, California. [3]Department of Psychology, University of British Columbia, Vancouver, British Columbia, Canada. [4]School of Philosophy, University of Southern California, Los Angeles, California. [5]Department of Psychological and Brain Sciences, Johns Hopkins University, Baltimore, Maryland. [6]Department of Philosophy, Rutgers University, New Brunswick, New Jersey

Address for correspondence: Tyler Knowlton, Department of Linguistics, University of Maryland, 1413H Marie Mount Hall, 7814 Regents Drive, College Park, MD 20742. tzknowlt@umd.edu

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

➥ Quantifying over small vs. large domains

➥ *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; Szabolcsi 2003

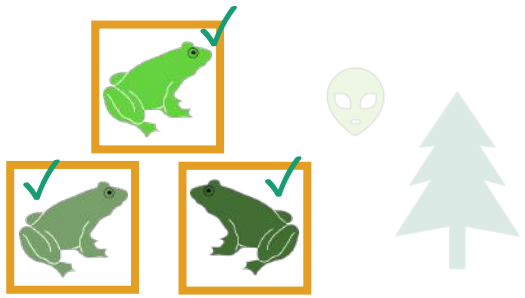
Proposed meaning difference

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

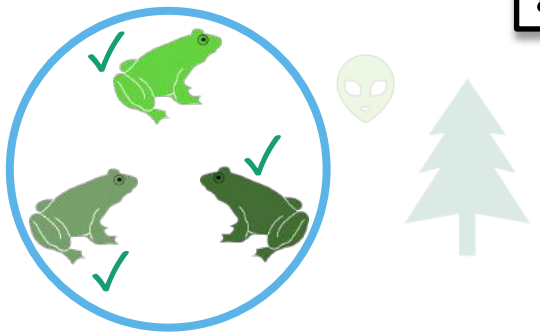
Every frog is green

TheX:Frog(X)[∀x:X(x)[Green(x)]]

≈ The Frogs are such that

any individual that's one of them

is such that it satisfies 'Green'



(Like *the frogs each are green*)

Proposed meaning difference & related cognition

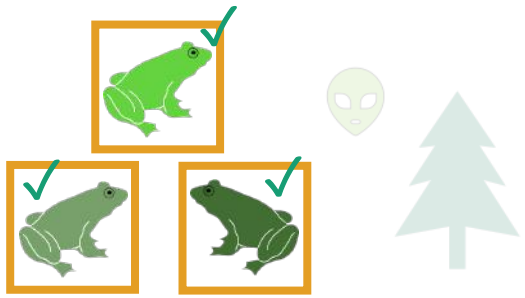
Each frog is green

∀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 &…)



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)

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

Every frog is green

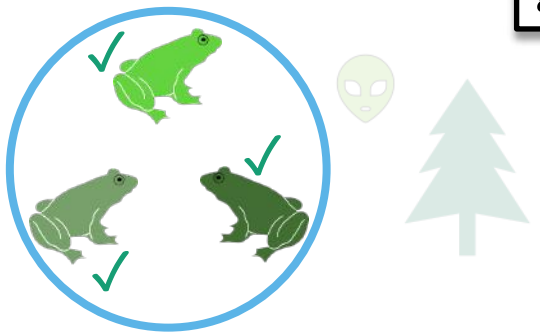
TheX:Frog(X)[∀x:X(x)[Green(x)]]

≈ The Frogs are such that

any individual that's one of them

is such that it satisfies 'Green'

(Like *the frogs each are green*)



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)

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

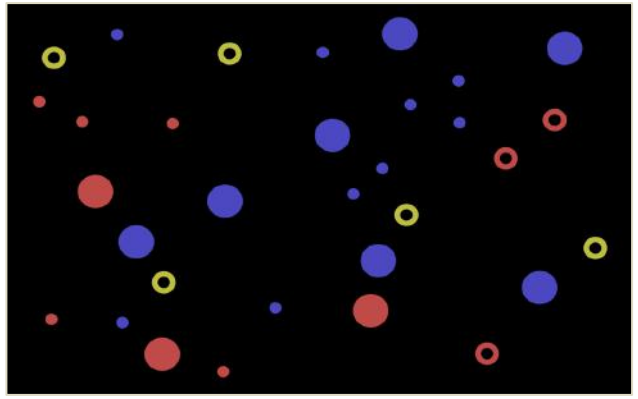
Downstream pragmatic consequences

➥ Quantifying over small vs. large domains

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

{Each/Every} big circle is blue

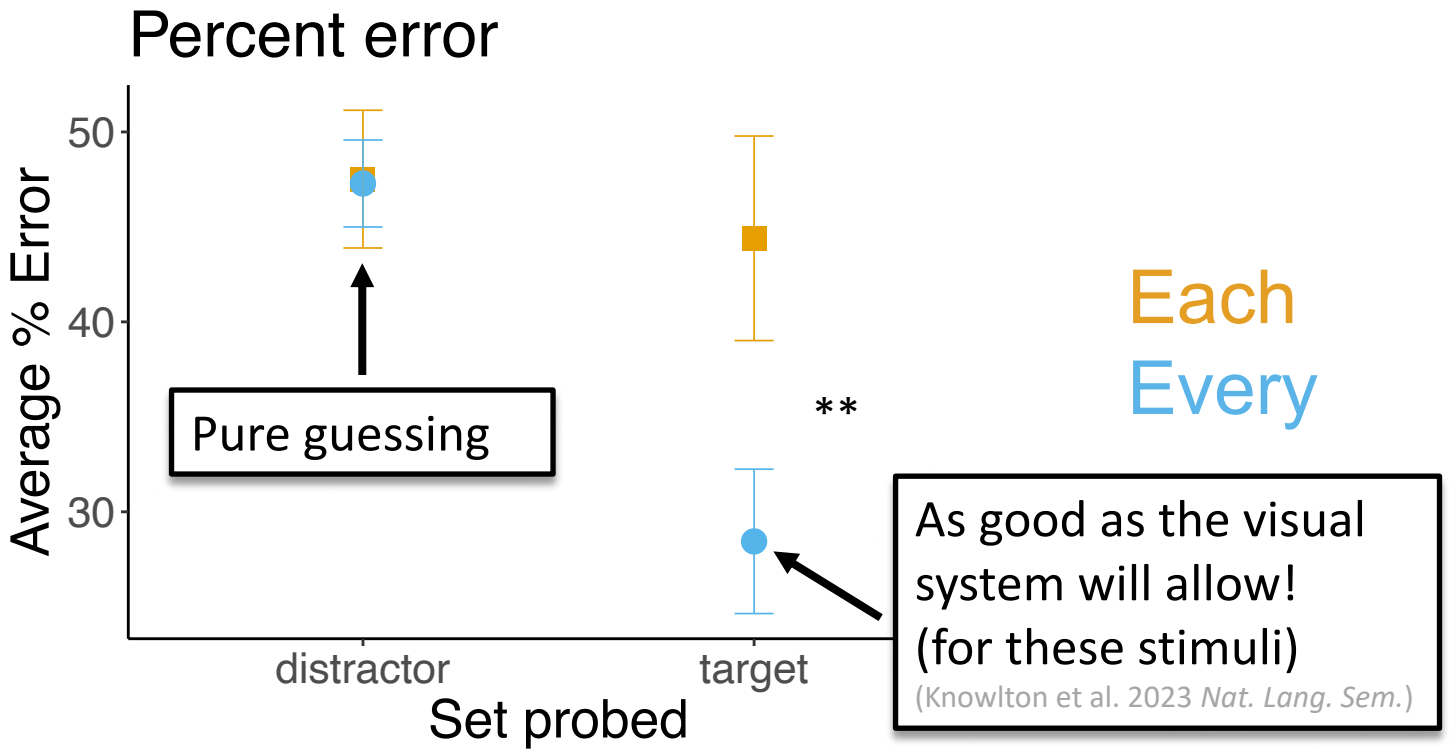
TRUE FALSE



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

Cardinality (ensemble property)

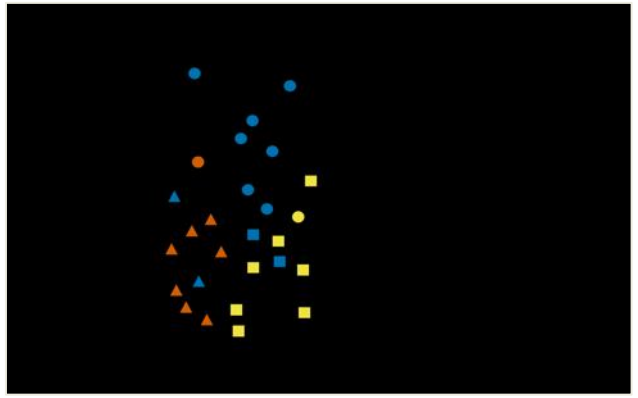
➥ If you initially represented the big circles, you should have a good estimate of their cardinality



n = 12

Is {each/every} circle blue?

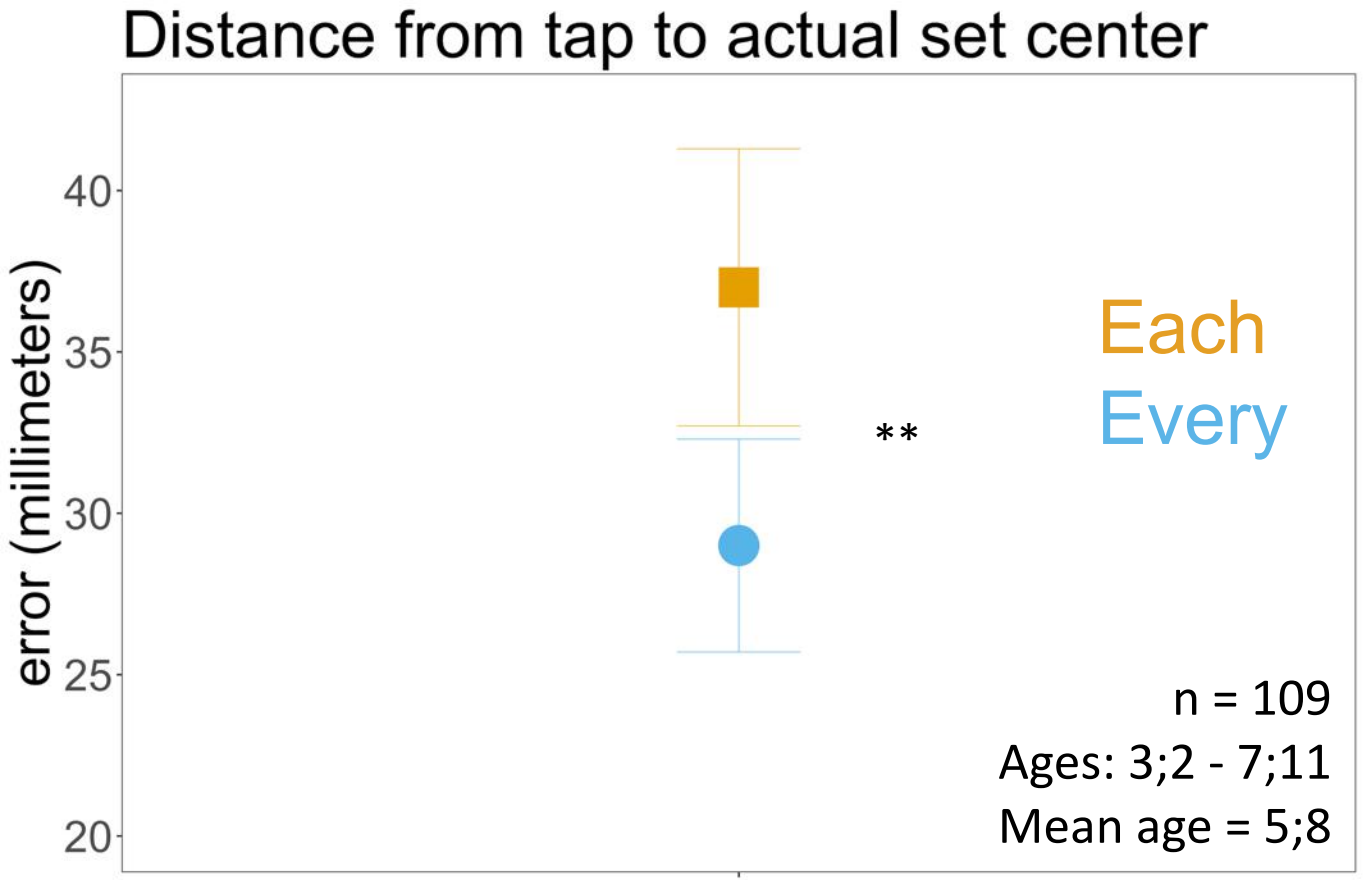
"Yes" "No"

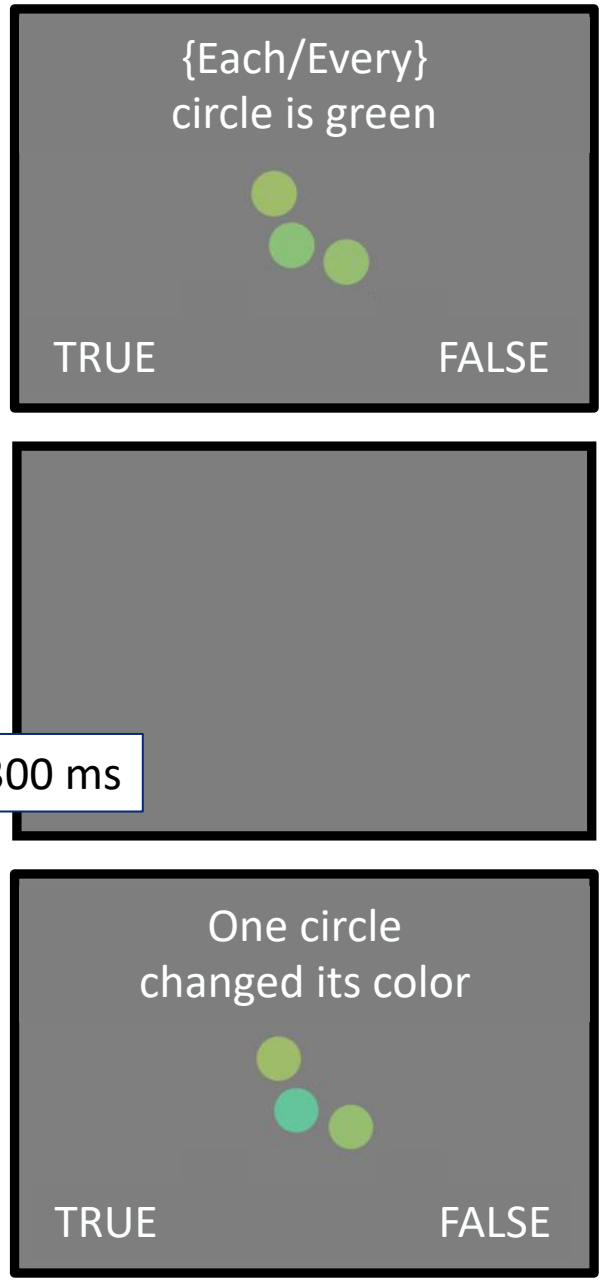


Where was the middle of the circles?

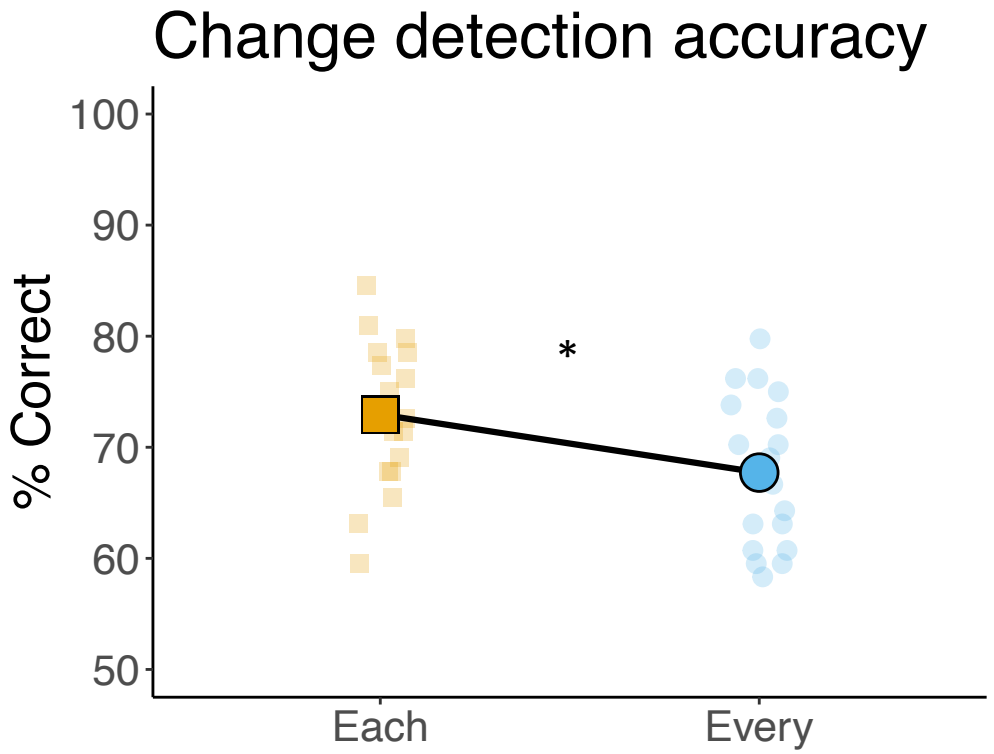
Center of Mass (ensemble property)

(with 3- to 8-year-olds)



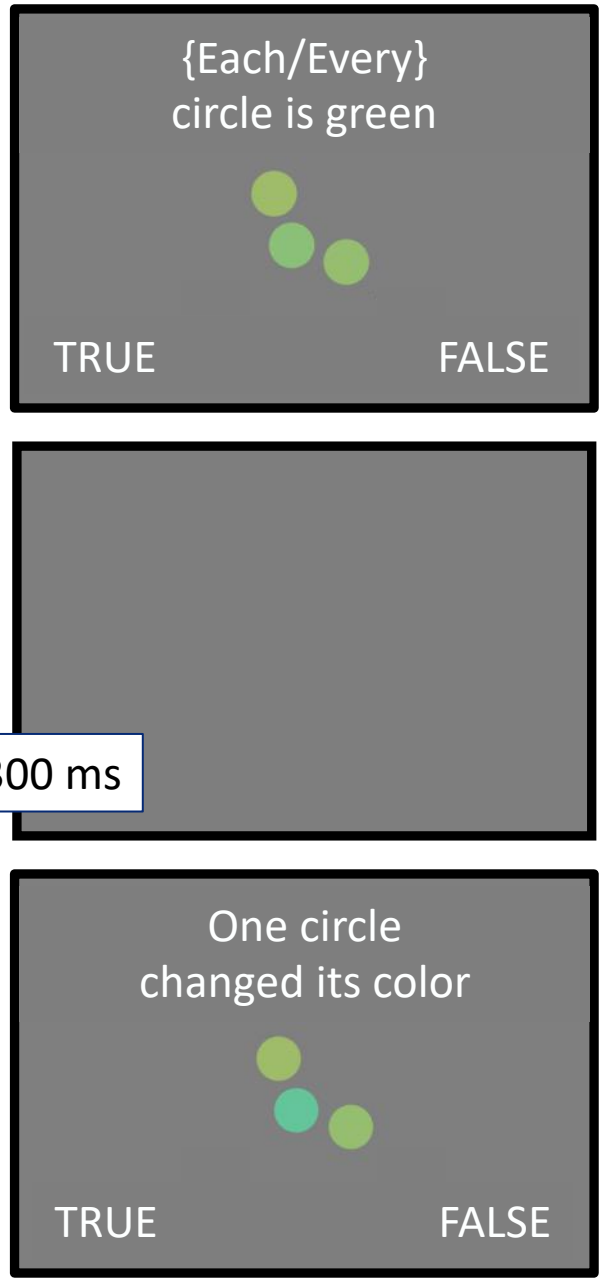


Color (individual property)



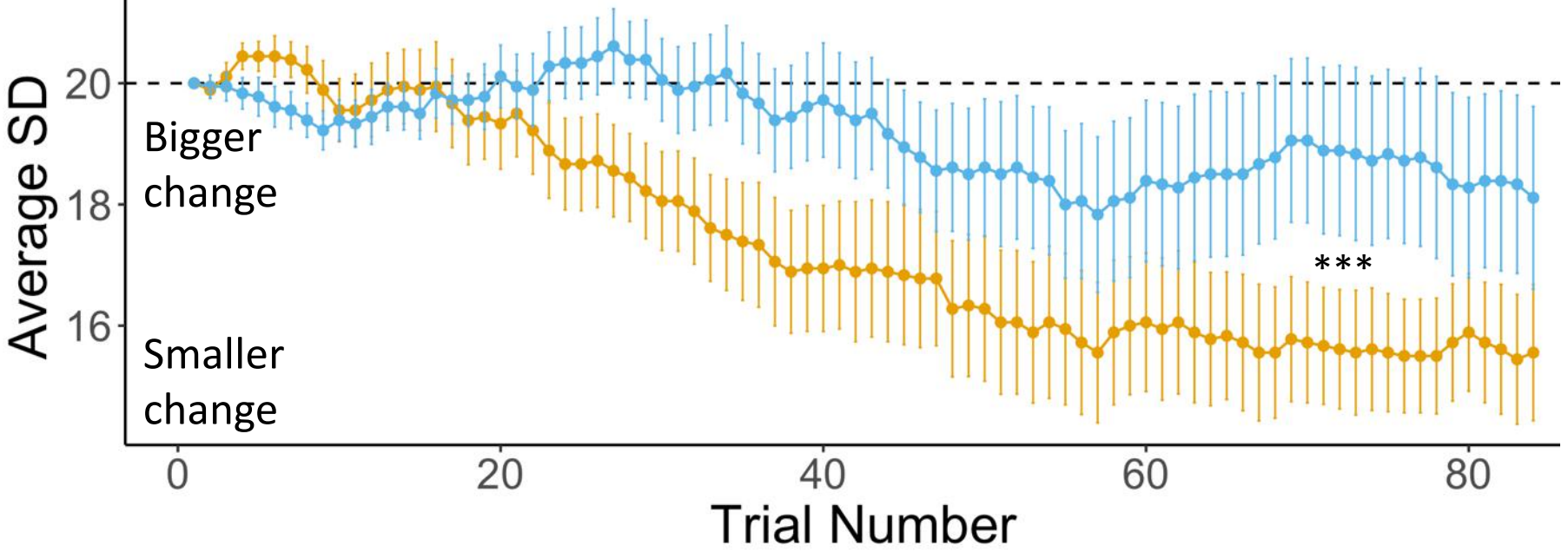
Each
Every

n = 36



Color (individual property)

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

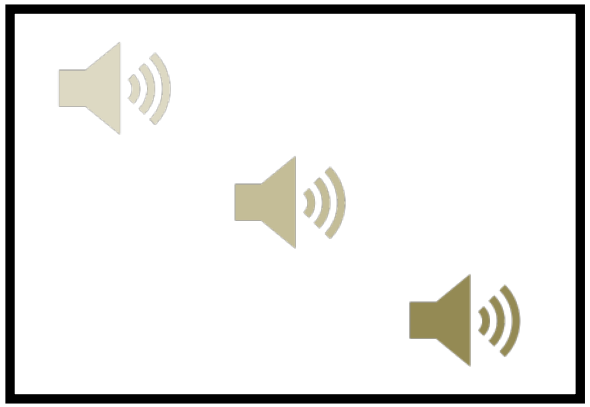


n = 36

Position (individual property) & Average (ensemble property)

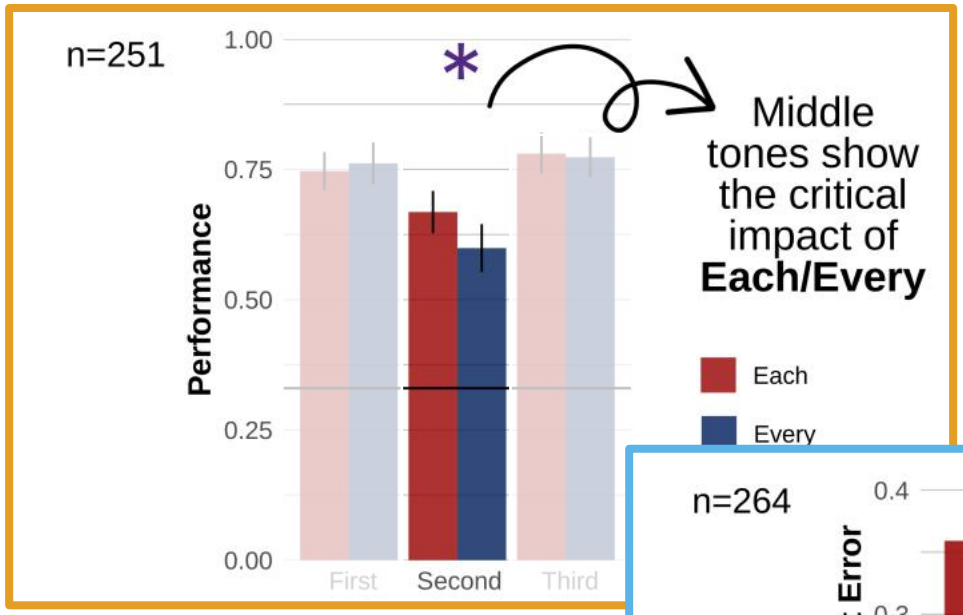
Each/Every tone is pleasant

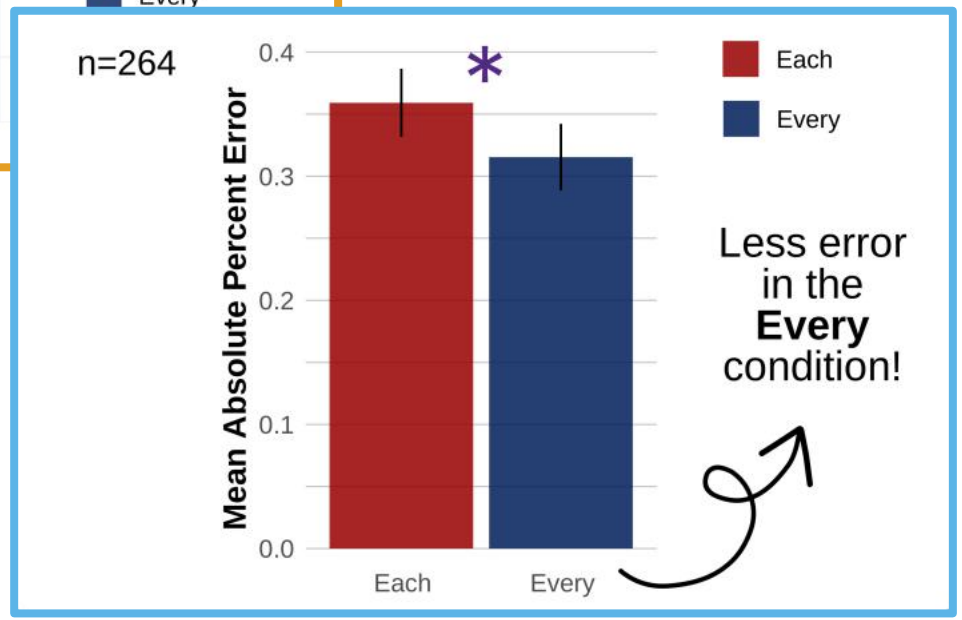
TRUE FALSE

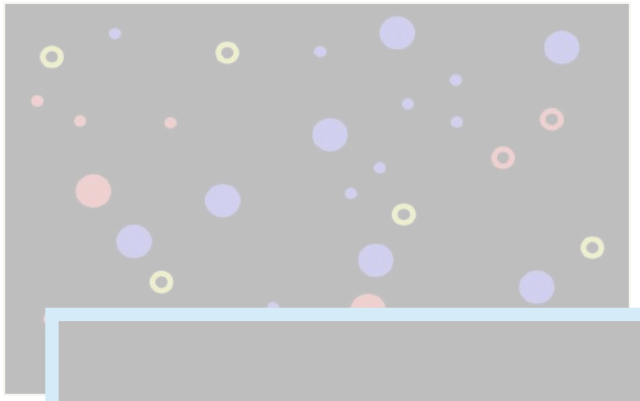


Was this the first, second, or third tone?

Reproduce the average tone

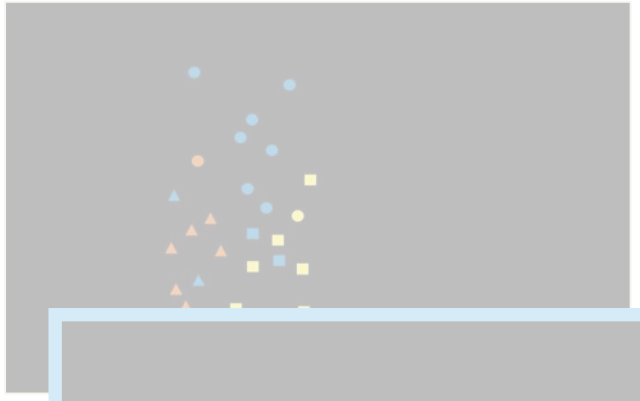






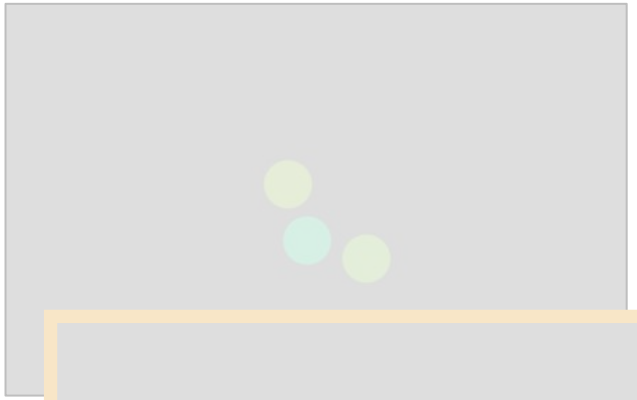
How many big circles were there?

Every > *Each*



Where was the middle of the circles?

Every > *Each*



Did one circle change its color?

Each > *Every*

➥ *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

Was this the first, second, or third tone?

Each > *Every*

Reproduce the average tone

Every > *Each*

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

➥ Quantifying over small vs. large domains

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

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)

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

Every frog is green

TheX:Frog(X)[∀x:X(x)[Green(x)]]

≈ The Frogs are such that

any individual that's one of them

is such that it satisfies 'Green'

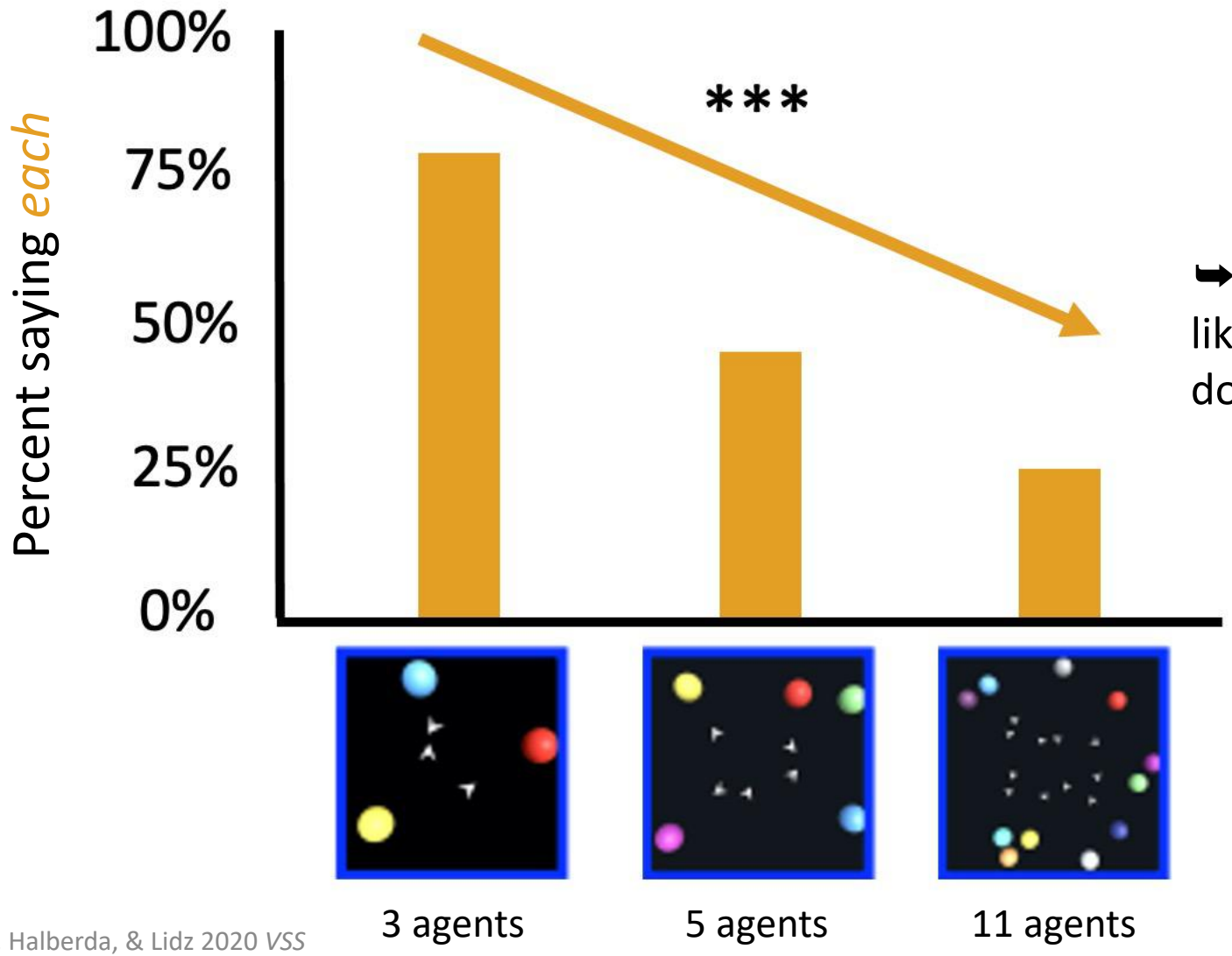
No limit to the number of individuals represented as an ensemble

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

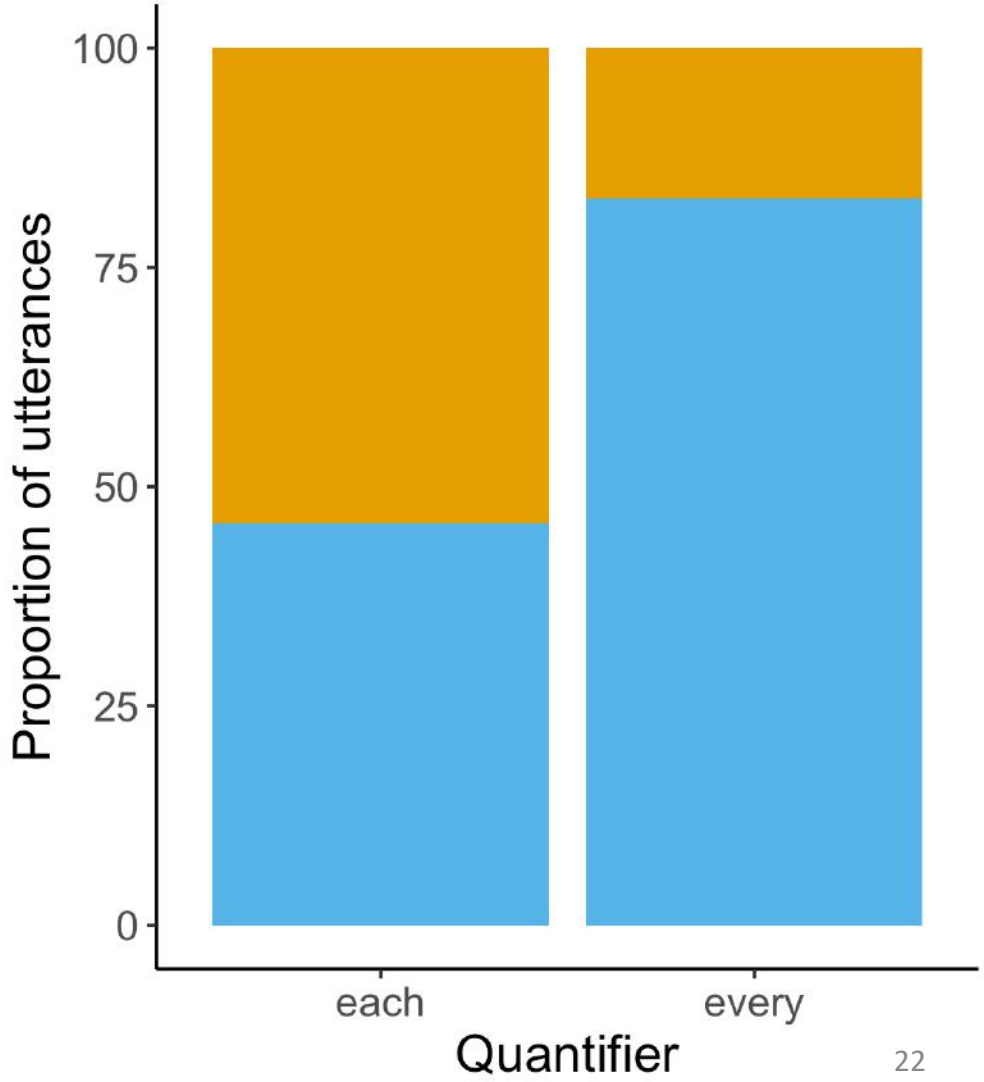


➥ Participants are more likely to use *each* when domains are small!

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

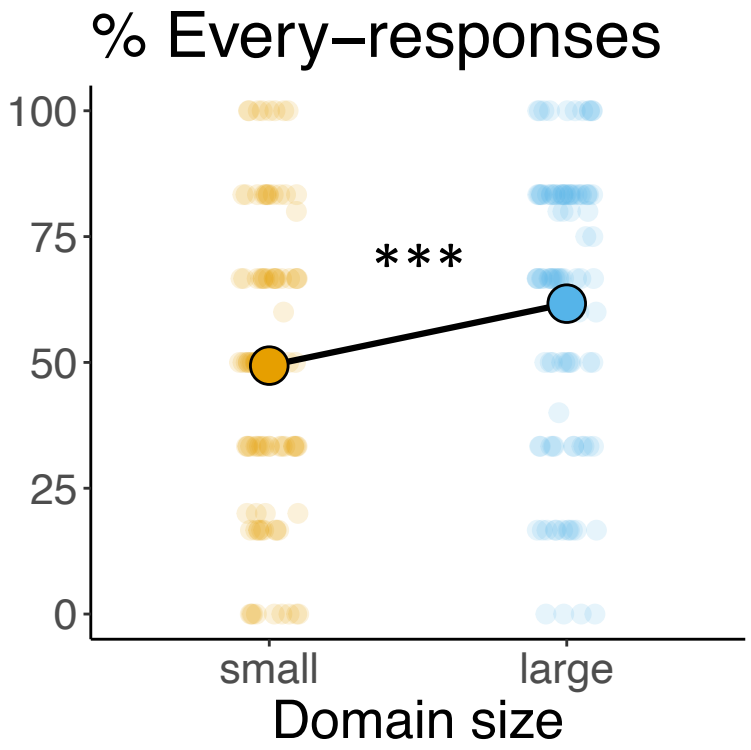
The bartender at the local tavern has made

three martinis/three thousand martinis.

He said that (select a word) martini he made

each
every

had an olive.



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

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

how many martinis would you guess they have in mind?

1 item; n=198

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

➥ Quantifying over small vs. large domains

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

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

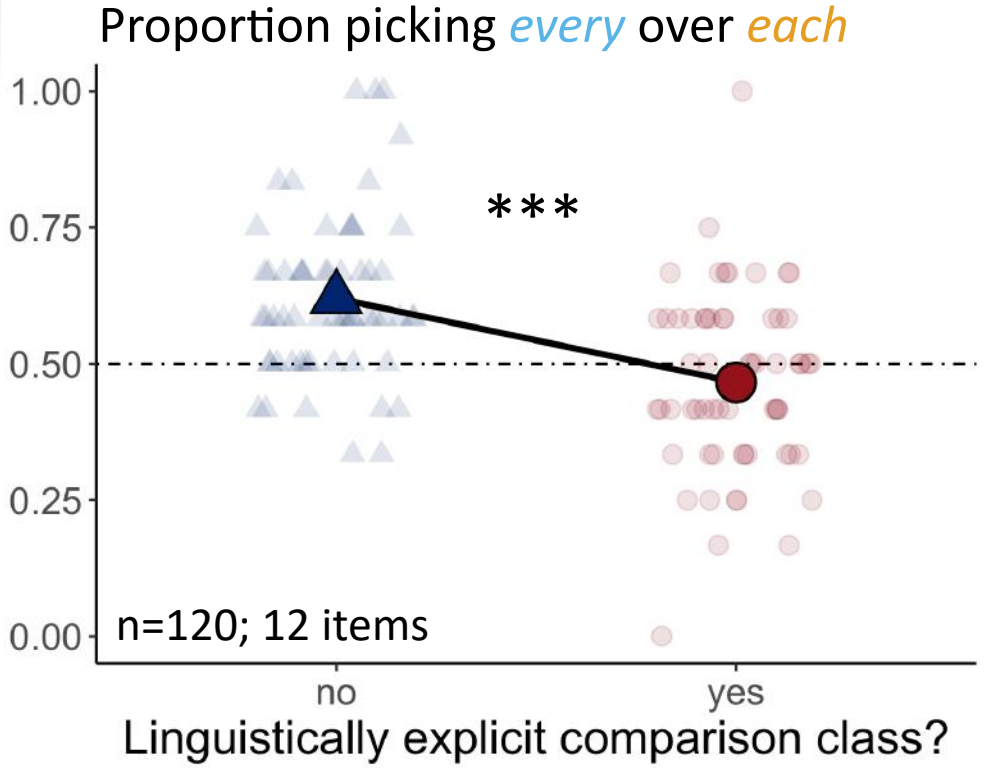
Sentence-internal *same*: forced-choice judgment

Ann and Frank decided to throw a school Halloween party.

Surprisingly, (select a word) student showed up in the same costume { Ø. / as their classmates. }

each
every

➥ 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*

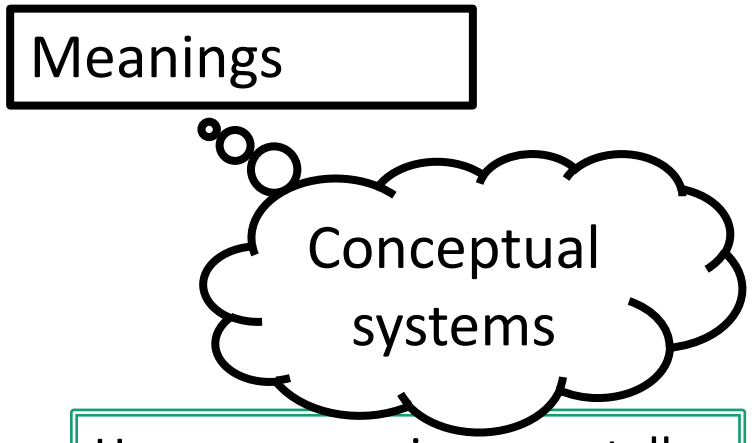
➥ First-order *each*; (partially) Second-order *every*

➪ Connections to well-studied cognitive systems

➥ Consequences for pragmatics

➪ Properties of interfacing systems affect expression use

➥ Consequences for language acquisition



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

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

Collaborators on presented work:


Jeff Lidz


Paul Pietroski


Alexander Williams


Justin Halberda


Nico Cesana-Arlotti


Anna Papafragou


John Trueswell


Florian Schwarz


Victor Gomes


Julia Ongchoco

NSF NRT-1449815 & NSF BCS-2017525