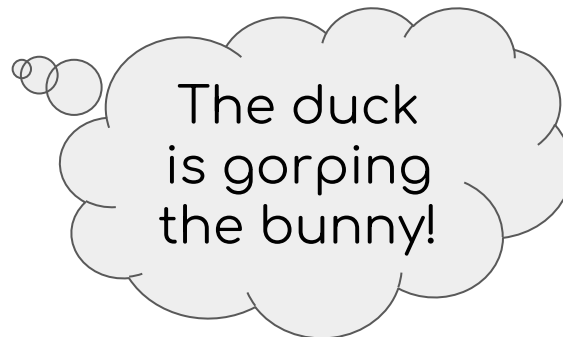


# Quantifying the syntactic bootstrapping effect in verb learning: A meta-analytic synthesis



Guest Lecture - Modern Research Methods

10/27/2021

Anjie Cao

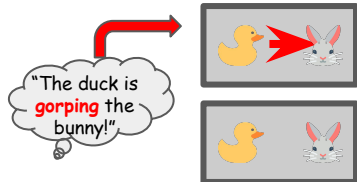
# Did the duck really gorp the bunny?

## A meta-analysis of syntactic bootstrapping literature

Anjie Cao, Maya Greenholt, Alana Littleman, and Izzy Stephen  
 Carnegie Mellon University  
 Department of Psychology | Modern Research Methods

### Background

- Due to the fleeting nature of the references, verbs are more difficult to learn than nouns for English speaking children.
- One potential mechanism that could aid verb learning is the semantic constraints imposed by syntactic structure. This mechanism is known as “**syntactic bootstrapping**” (SB).

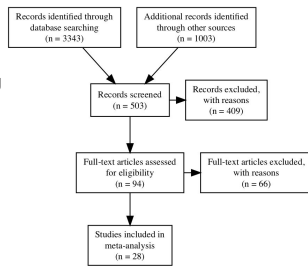


- Seminal Paper: Naigles, 1990
- Using a preferential looking paradigm, Naigles found that 2 year olds looked longer at the causative event when they heard the novel verbs were embedded in a transitive structure and vice versa for non-causative event and intransitive structure.
- Since then, the paper has been cited over 1000 times. The effect has been replicated with many methodological changes:
  - Using pointing as measurement
  - The content of the visual stimuli and linguistic stimuli
  - The timing of presentation

**Research Goal:** Evaluate the degree of publication bias in the SB literature, estimate the size of the effect, and examine potential moderators.

### Method

- Meta-analytic approach
- Conducted database search on google scholar using term “syntactic bootstrapping”, forward search on seminal paper
- Inclusion criteria: all English speaking participants, looking/pointing paradigm, and used fake verbs in linguistic stimuli.
- Calculated effect size (Cohen’s *d*) as the proportion of children pointing to the correct screen (transitive or intransitive) versus chance (0.5)
- Coded moderators: sentence type, fake or real verb, stimuli type, population type, age, presentation type.
- Estimated effect size using *metafor* package in R (Viechtbauer, 2019)



### Results

- Little evidence for publication bias (N = 100, fig. 1)
- The effect size for transitive sentences (N = 62) is larger than for intransitive (N = 38), and there is no age effect or interaction between sentence structure and age (fig. 2)
- We did not see a strong effect for other moderators

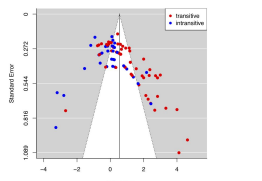


Figure 1: Funnel plot after excluded outlier (d=5): Colored by sentence type, N = 95

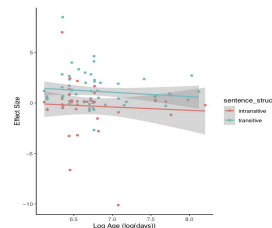


Figure 2: Moderating effects of Age and Sentence type

### Conclusion and Next Steps

- Syntactic bootstrapping is a robust effect with a **medium** effect size of 0.57 (N = 100, CI = [0.28, 0.85]; fig. 3)
- Found little evidence of publication bias; significant effect of transitivity but no effect of age or other moderators
- Next steps: investigate underlying mechanisms responsible for the advantages of transitive structure, seek additional literature with expanded search protocol

#### References:

- Naigles, L. (1990). Children use syntax to learn verb meanings. *Journal of child language*, 17(2), 357-374.
- Viechtbauer, W. (2010). Conducting meta-analyses in R with the metafor package. *Journal of Statistical Software*, 36(3), 1-48. URL: <http://www.jstatsoft.org/v36/i03/>

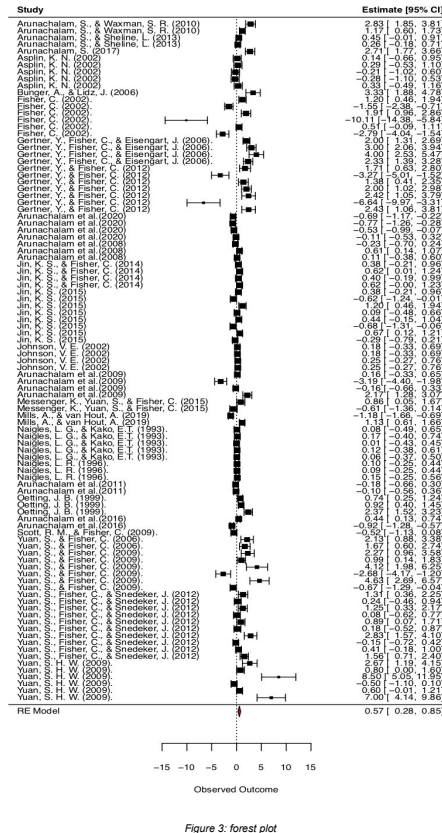
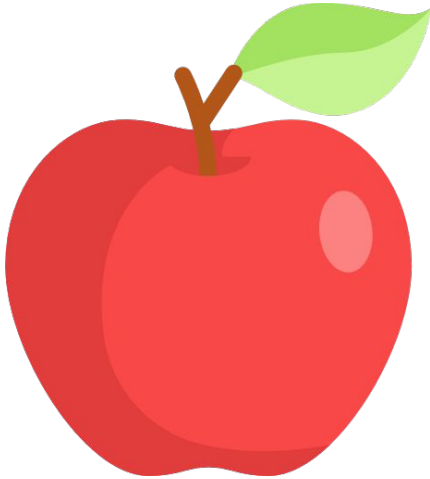


Figure 3: forest plot

**Verb learning is challenging for young children across many languages.**

Verbs refer to actions



Nouns refer to objects



Syntactic bootstrapping is a prominent theory of verb learning in early childhood.

“The duck is gorping the bunny.”



Naigles (1990), source:  
<https://nyu.databrary.org/volume/44>

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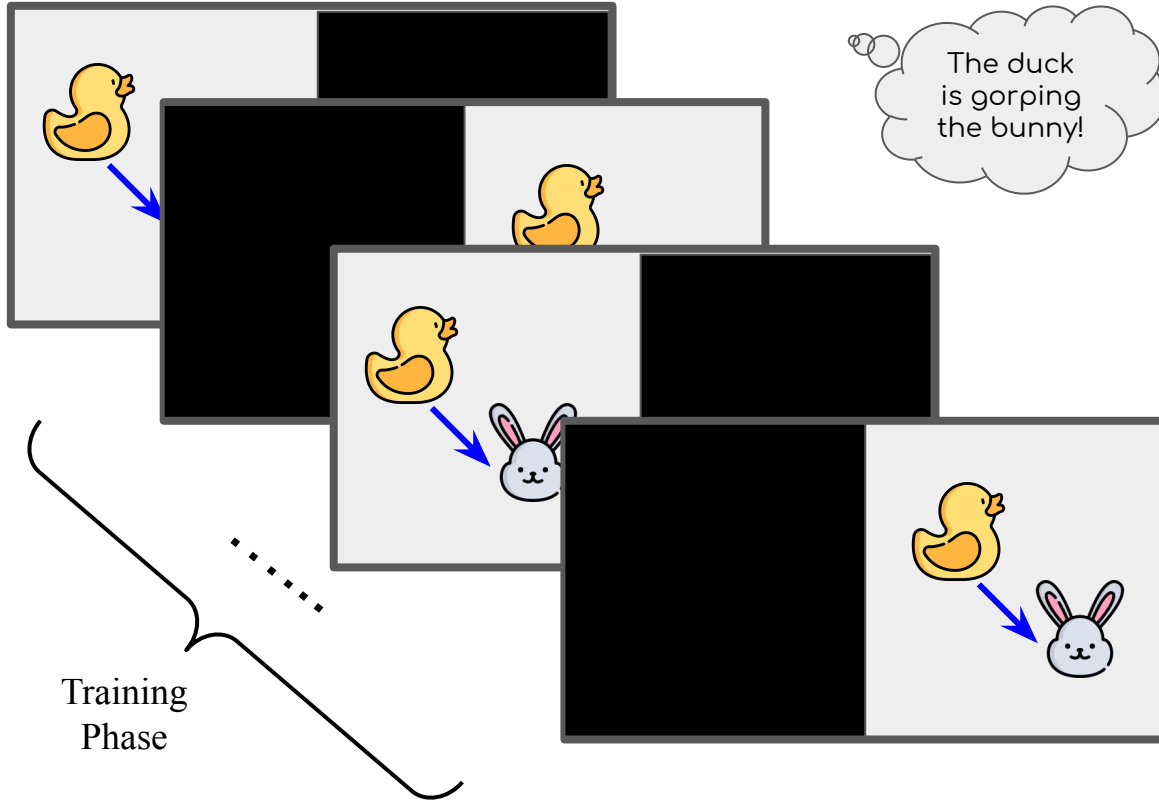
Syntactic bootstrapping is a prominent theory of verb learning in early childhood.

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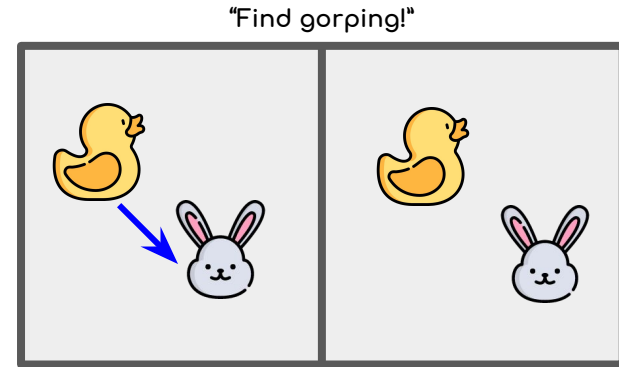


Naigles (1990), source:  
<https://nyu.databrary.org/volume/44>

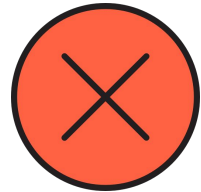
# This phenomenon is often tested with Two Alternative Forced Choice (2AFC) paradigm



The duck is gorging the bunny!

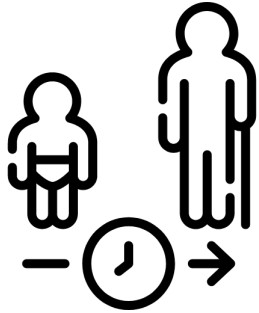


Testing Phase

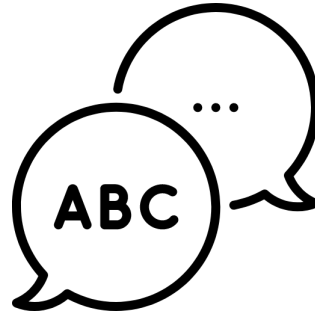




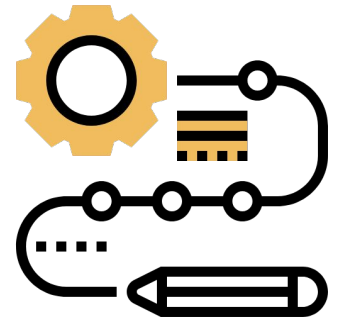
However, there are many open questions associated with syntactic bootstrapping.



Developmental trajectories



Sentence structure



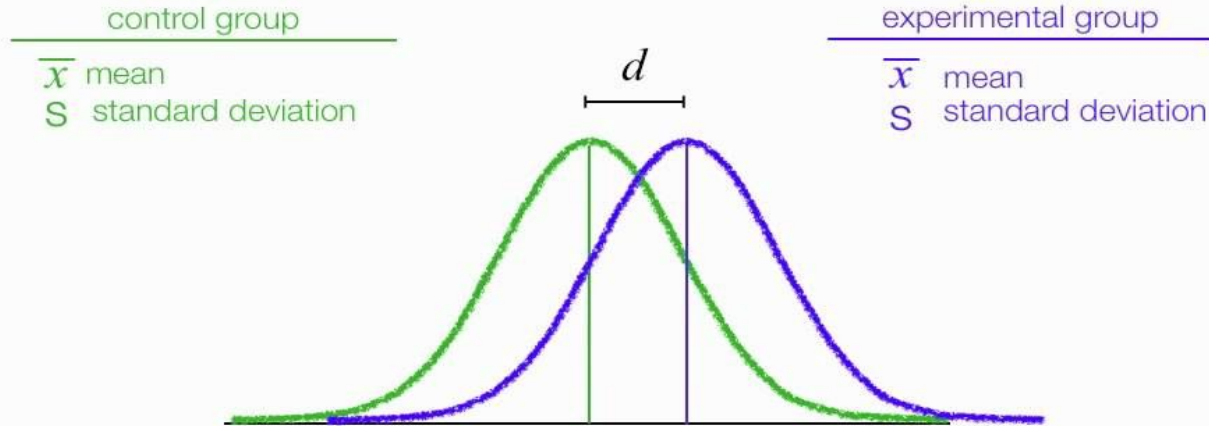
Different methodologies

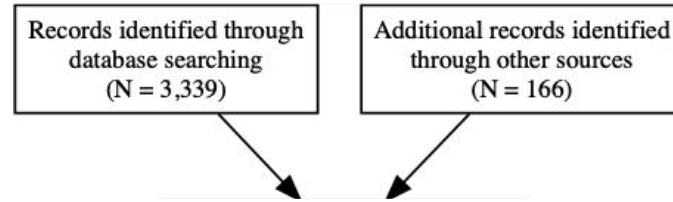
Individual experiment often lacks the power and variability to address these questions.

# Meta-analysis a quantitative method to aggregate data from the literature.

## Effect size

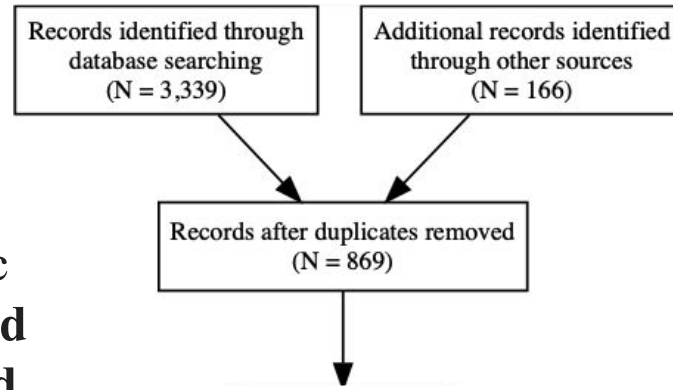
$$d = \frac{\bar{x} - \bar{x}}{S}$$



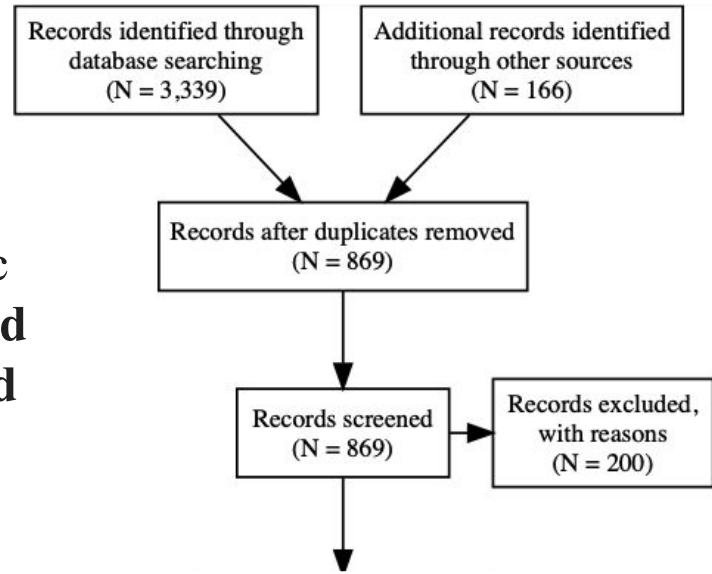


We conducted a meta-analysis on the syntactic bootstrapping literature following the **Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)** protocol

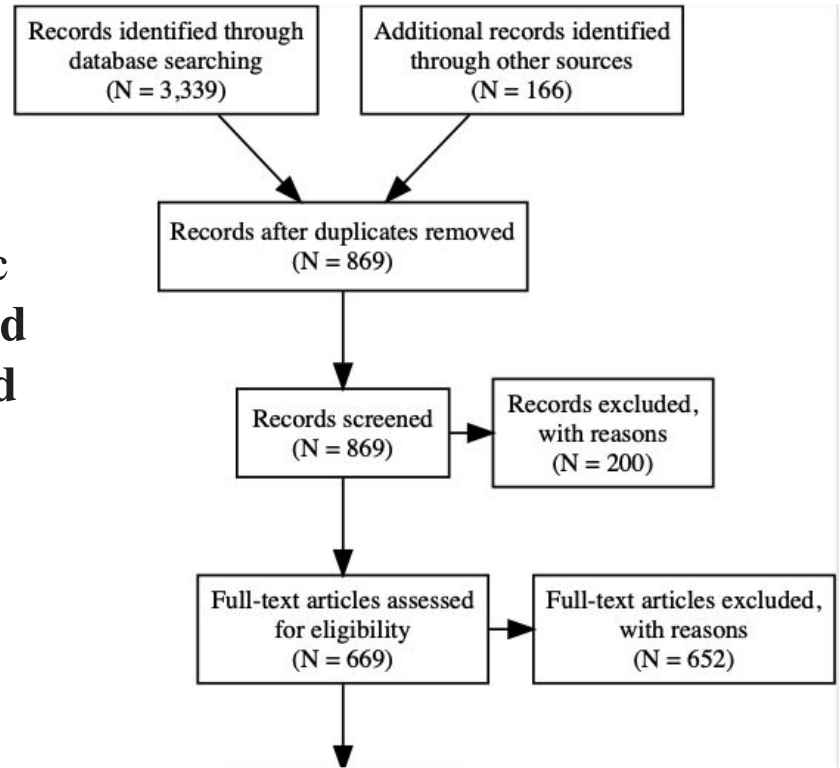
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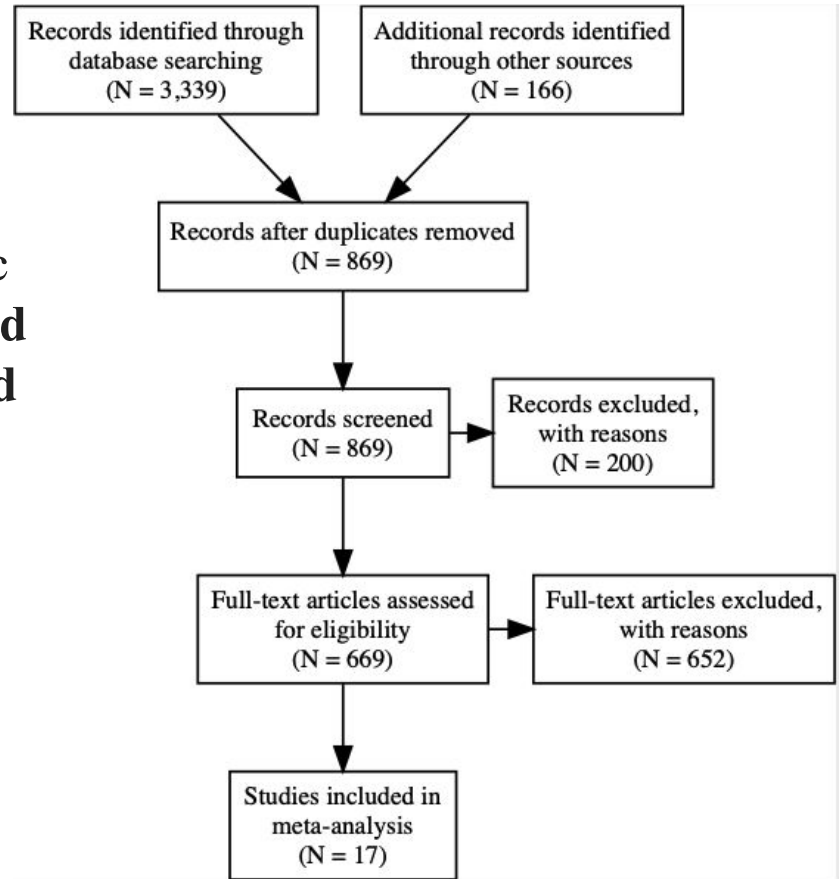
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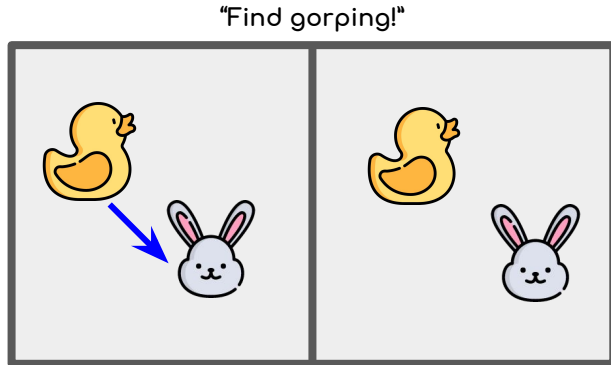
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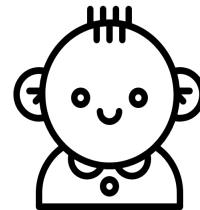
- **Participants:** Monolingual, typically-developing, English-speaking children

- **Method:** Two alternative forced choice (2AFC) experiment

- **Effect size:** 
$$d = \frac{M_1 - M_2}{SD_{pooled}}$$

N = 60

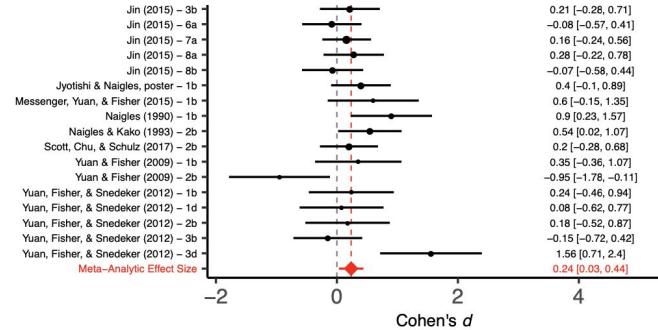
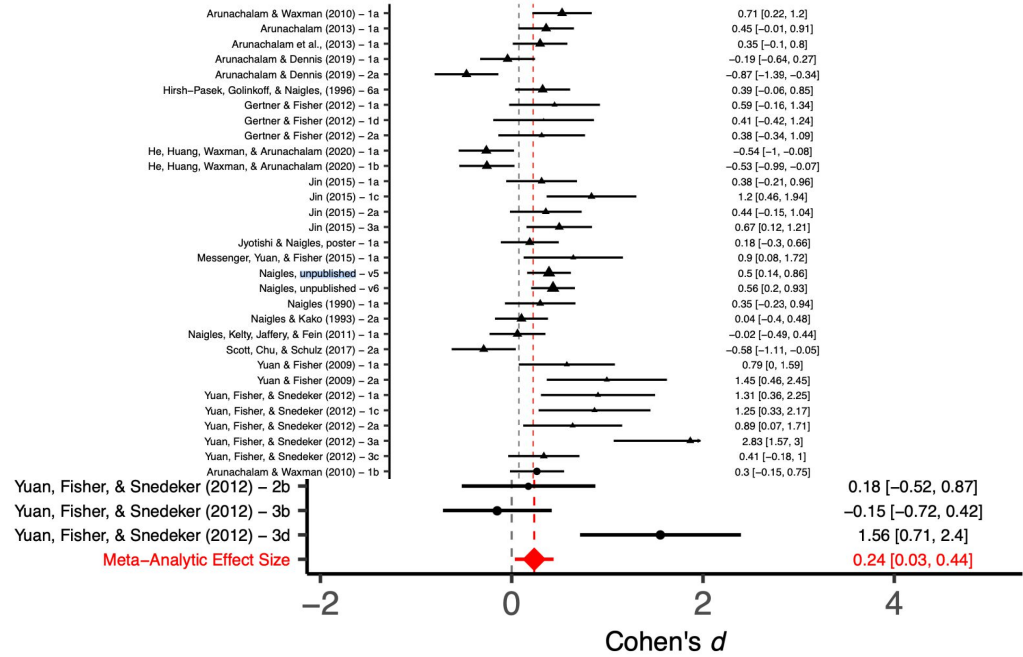
N = 849



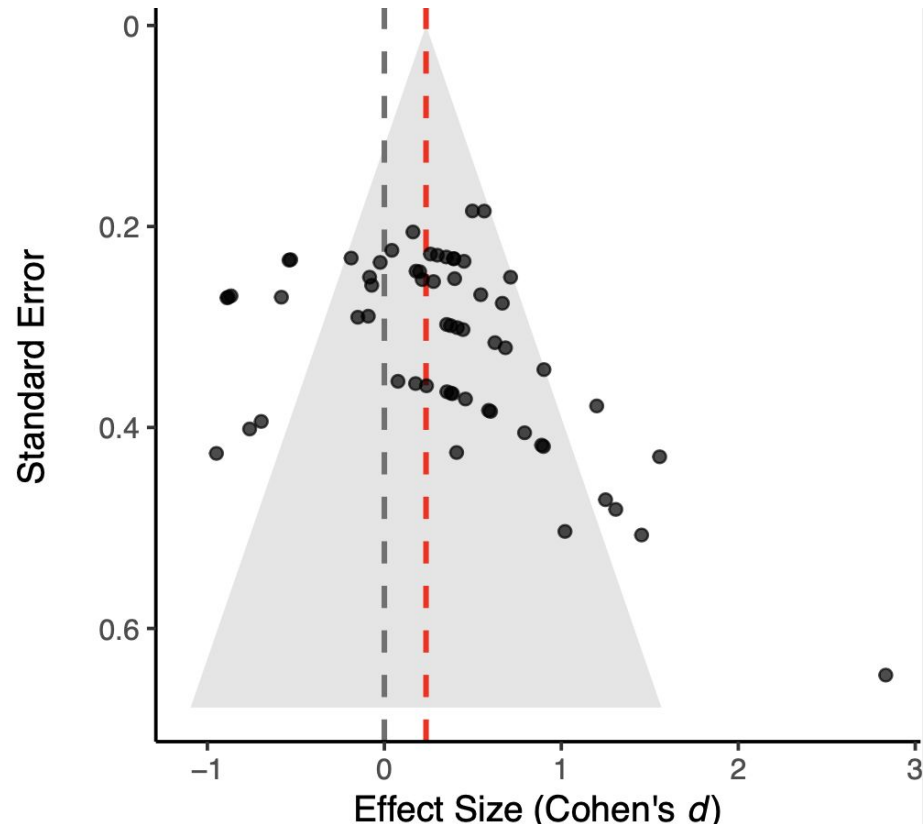
14 Months - 42 Month

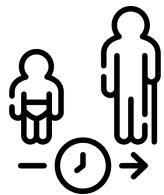


We found that the effect size is  
small:  
 $d = 0.24[0.03, 0.44]$



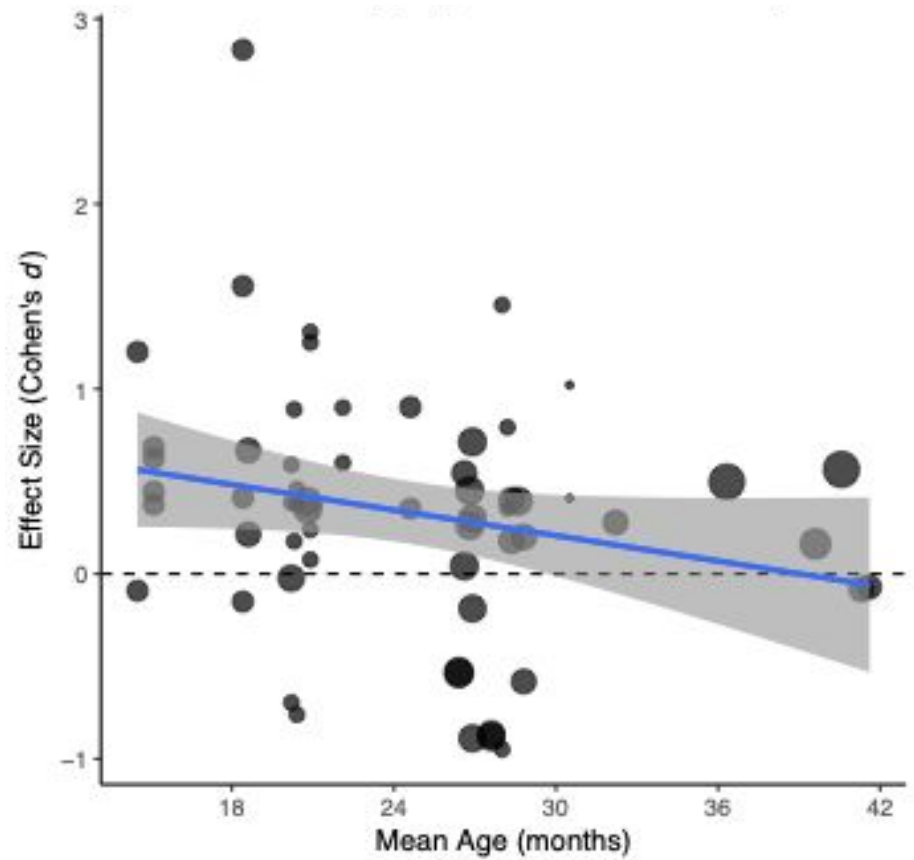
We found evidence for publication bias:  
(Egger's test:  $Z = 4.72$ ;  $p < .0001$ )

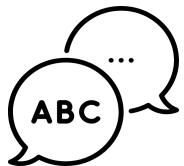




Syntactic bootstrapping effect does not strengthen with age.

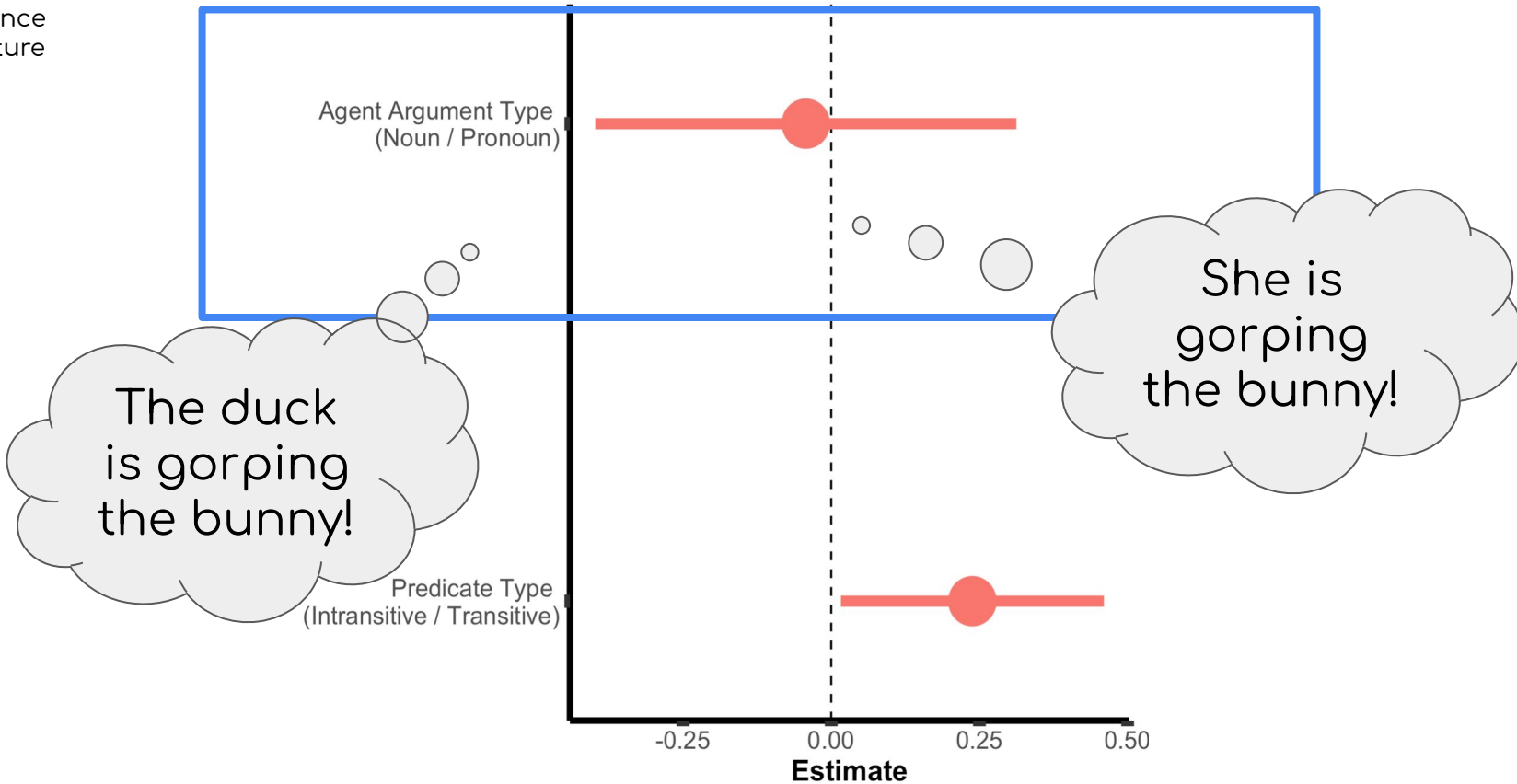
Developmental trajectories

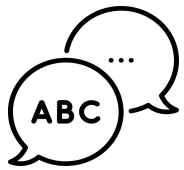




Sentence structure

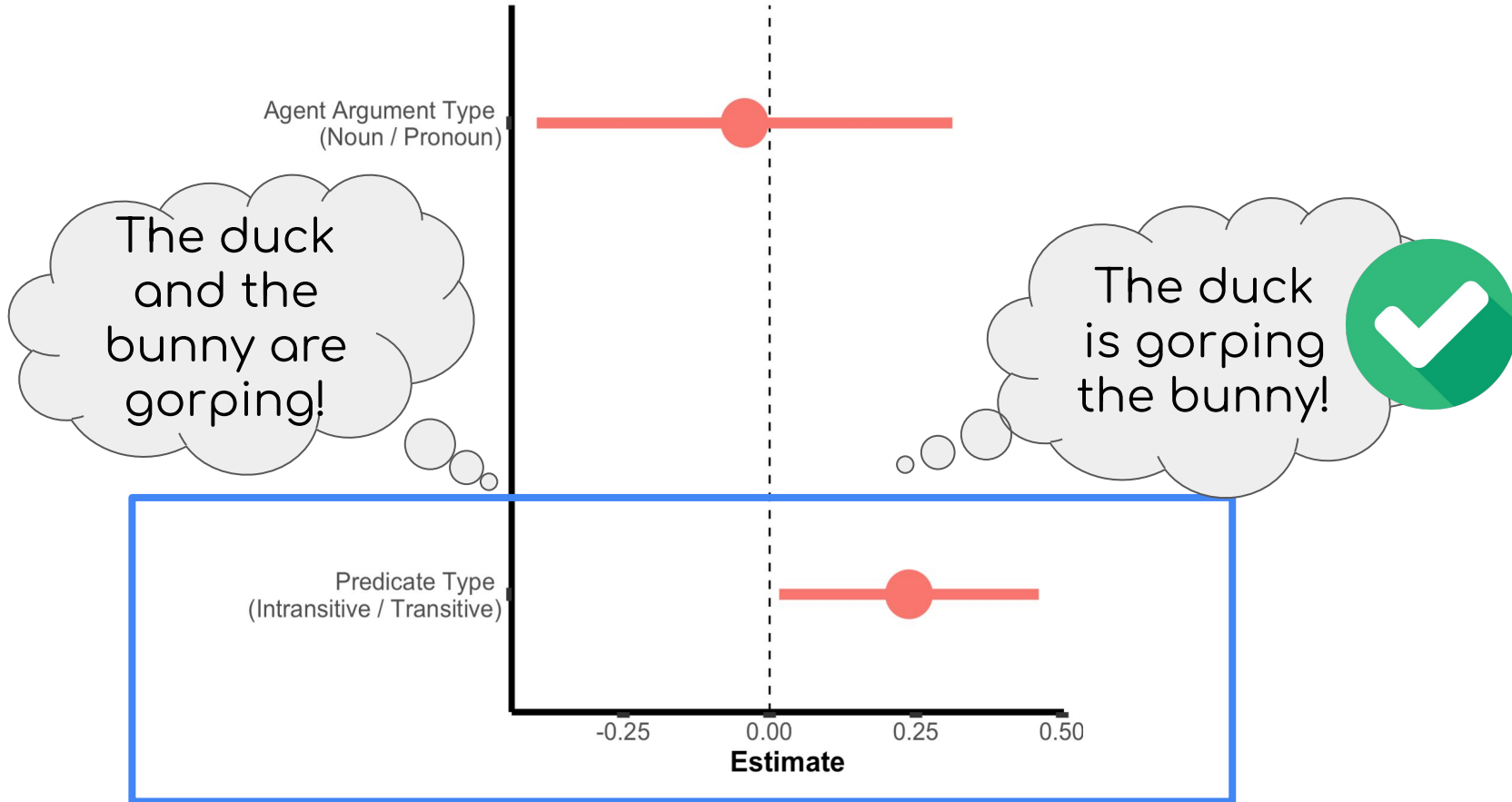
# Subject argument type does not have a significant impact on the effect size.

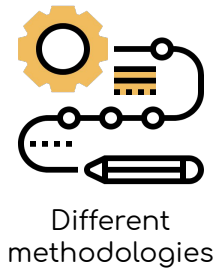




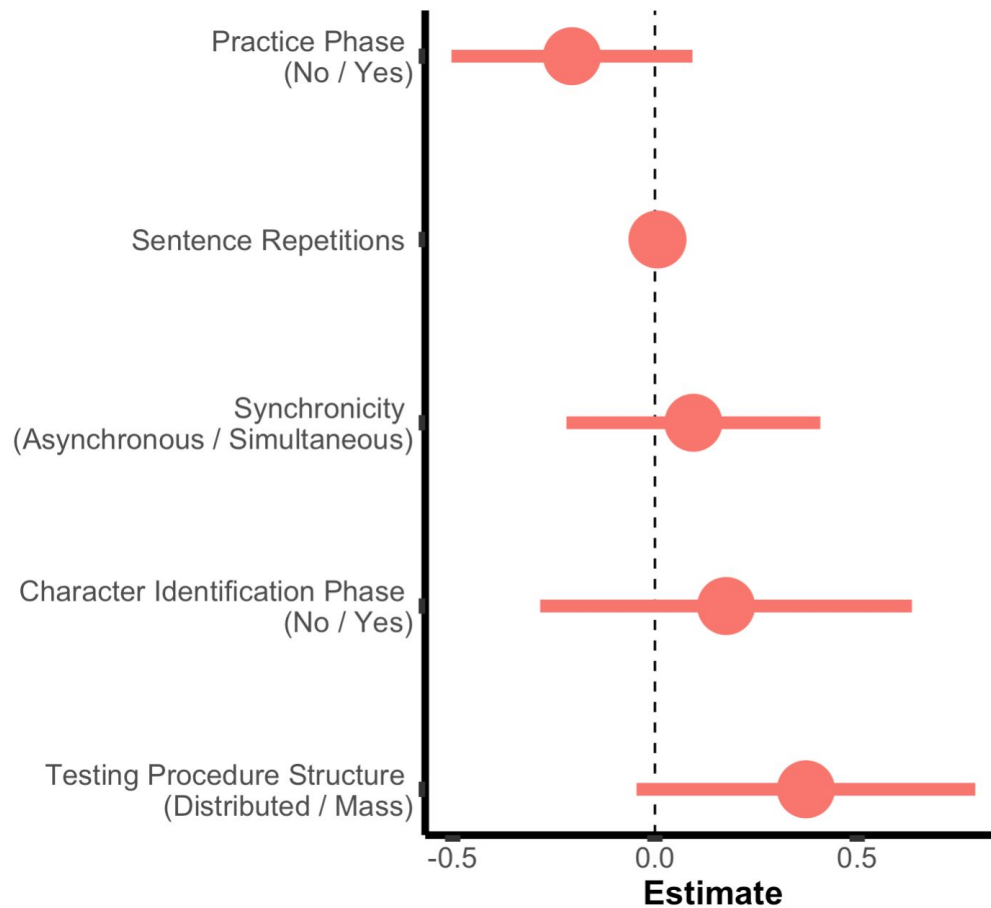
Sentence structure

# Predicate type is a significant predictor for effect size.





None of the methodological factor is a significant predictor.



# Background

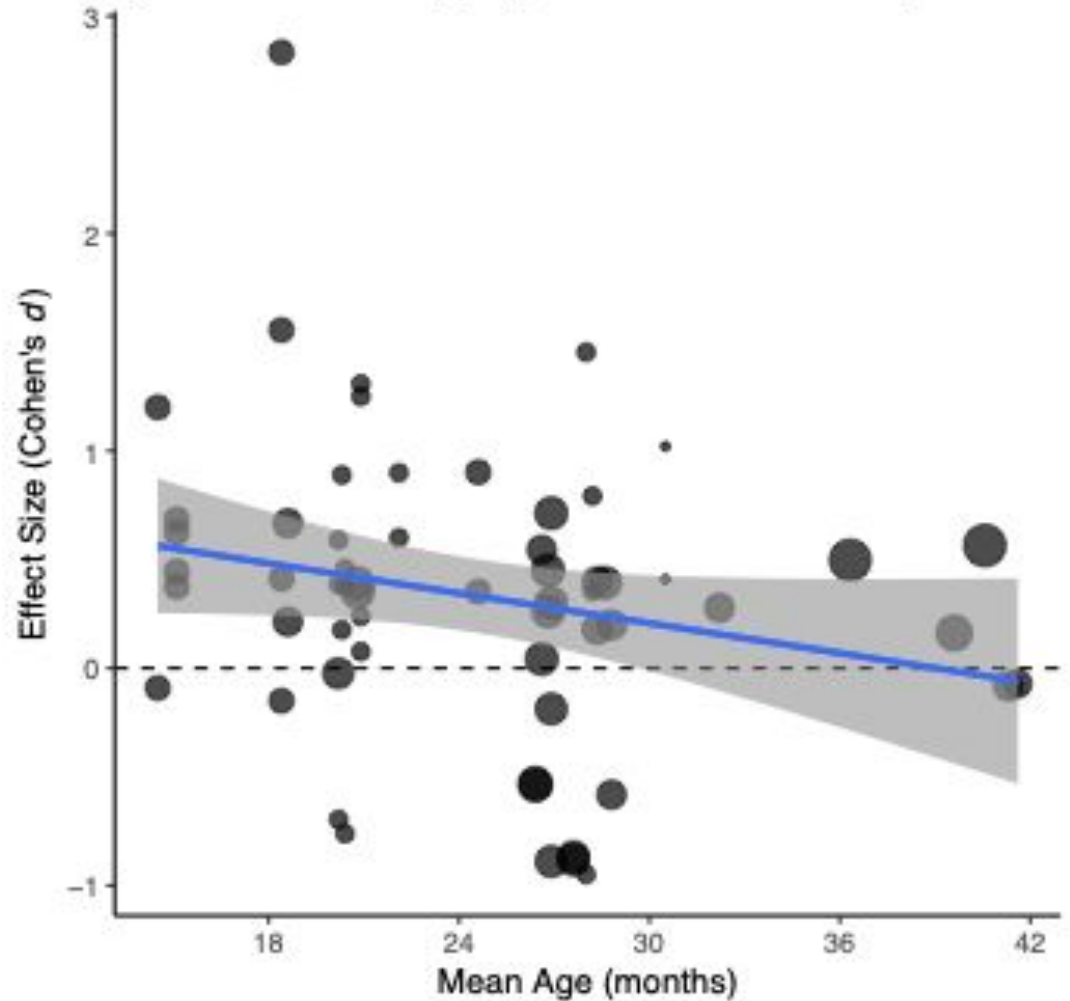
## Method

## Results

# Discussion

### The lack of developmental change

- Syntactic bootstrapping is an unlearned bias that experience has limited impact on (Fisher et al., 2020; Gleitman, 1990).
- The developmental change may happen later along with the “relational shift” (Gentner, 1988).
- Methodological adaptations mask the developmental change.





## Summary

- Some evidence for publication bias.

The duck  
is  
gorping  
the  
bunny!





## Summary

- Some evidence for publication bias.
- Overall effect size is small.

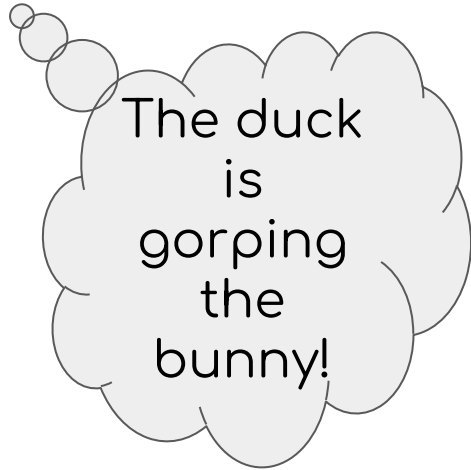
The duck  
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## Summary

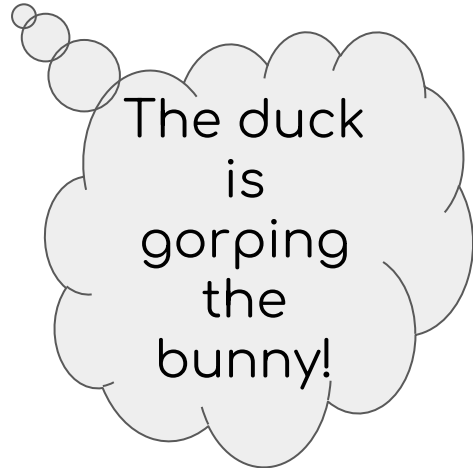
- Some evidence for publication bias.
- Overall effect size is small.
- Effect does not strengthen with age.

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## Summary

- Some evidence for publication bias.
- Overall effect size is small.
- Effect does not strengthen with age.
- The predicate type is a significant predictor for the effect size but not the word type of subjects.

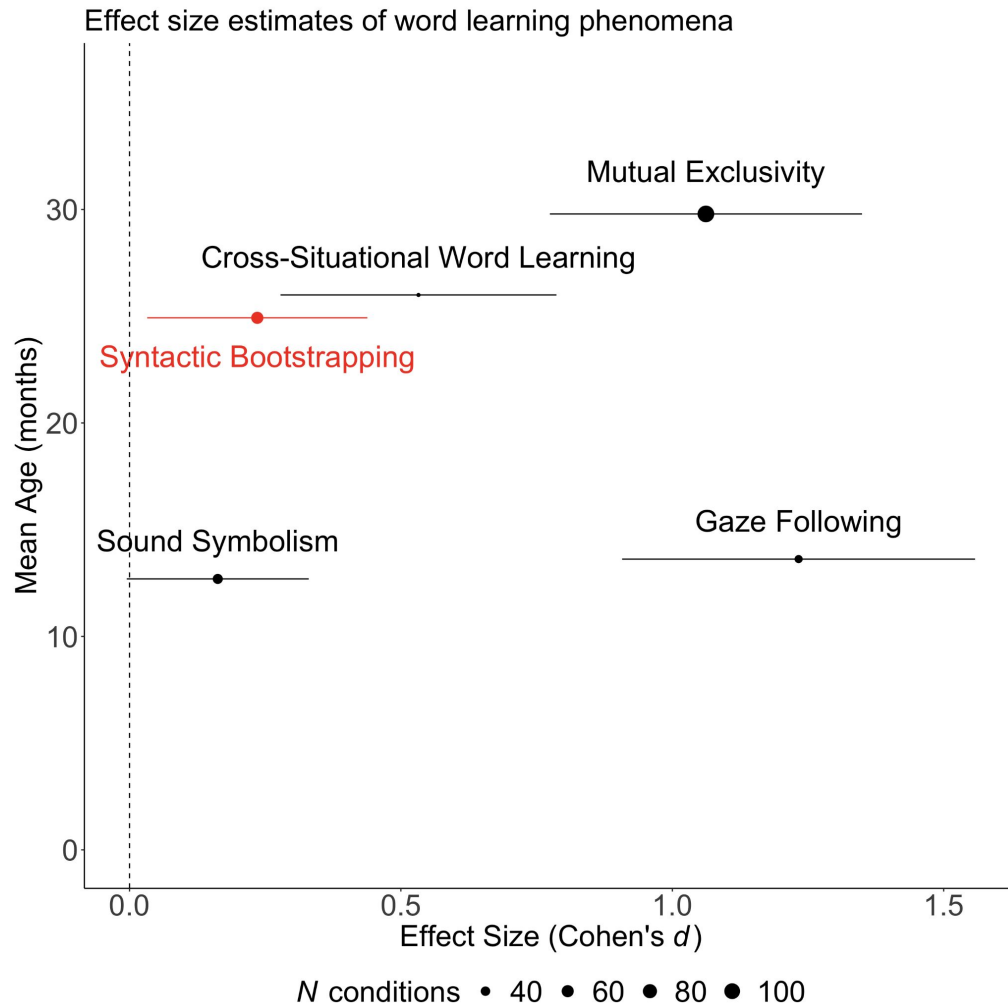


## Summary

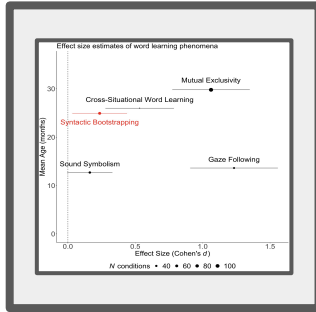
- Some evidence for publication bias.
- Overall effect size is small.
- Effect does not strengthen with age.
- The predicate type is a significant predictor for the effect size but not the word type of subjects.
- No methodological moderator is significant.

# How does syntactic bootstrapping relate to other word learning strategies?

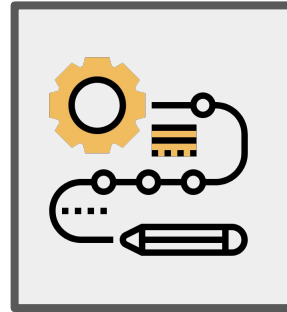
Bergmann et al., 2018



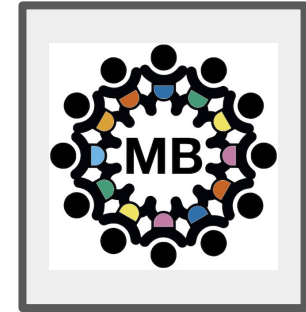
# Implications of our findings to verb learning theory



Other word learning strategies may supplement verb learning



The distinction between word learning phenomena and effects measured in the lab.



Large-scale direct replication is needed.

**Thank you so much for  
listening!**

**Paper preprint:**

<https://psyarxiv.com/x8ynm>

**Analysis script:**

<https://github.com/anjiecao/SyntacticBootstrappingMA>

**Dataset can be interactively explored at:**

<http://metalab.stanford.edu/dataset/synboot/>

Feel free to contact me with any questions or suggestions!

Twitter: @anjie\_cao

Email: [anjiecao@stanford.edu](mailto:anjiecao@stanford.edu)

# Conducting your own MA

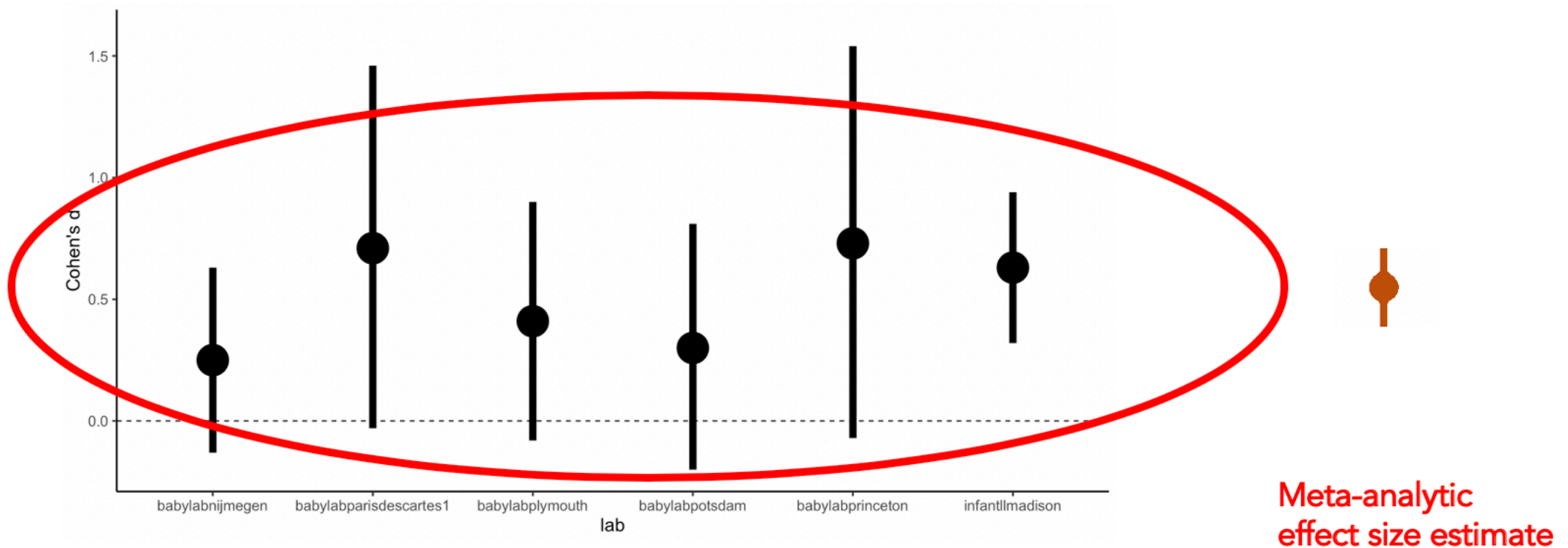
27 October 2021

*Modern Research Methods*



# Last time: Intro to meta-analysis

A quantitative approach to summarizing results across studies



# Cao and Lewis MA details

## Quantifying the syntactic bootstrapping effect in verb learning: A meta-analytic synthesis

AUTHORS

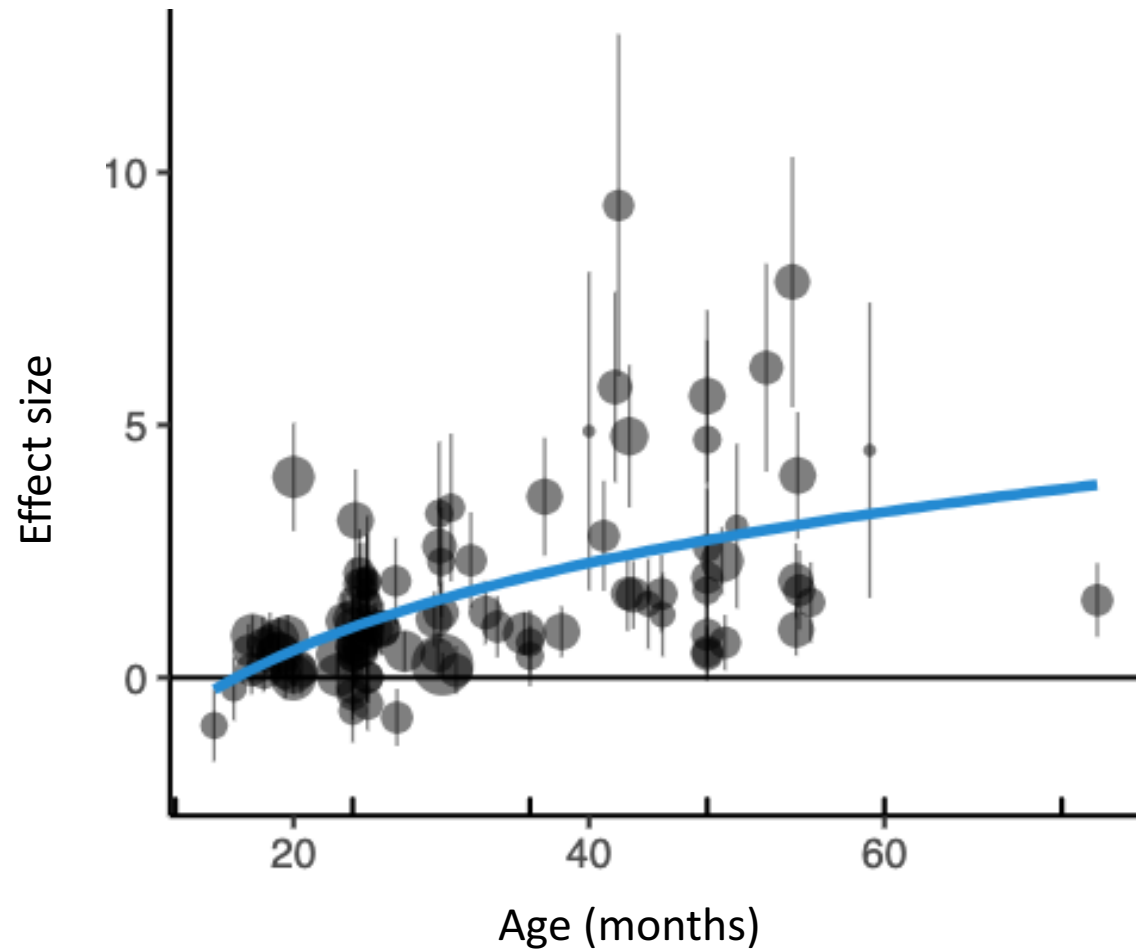
Anjie Cao, Molly Lewis

- Search strategy?
- Coding?
  - How many effect sizes total?
  - What else did we code for? (i.e. "moderators")
- Statistical approach?

# Moderators

- = anything you think might influence the effect size
- Age
- Design
- Stimuli type
- # of languages spoken

# Exploring a moderator of effect size: Age



Each point is a study

# Design

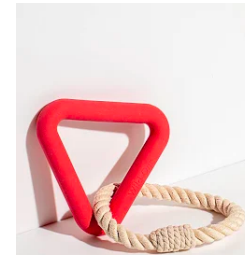
## Familiar-Novel Design

Can you find the “fep”?



## Novel - Novel Design

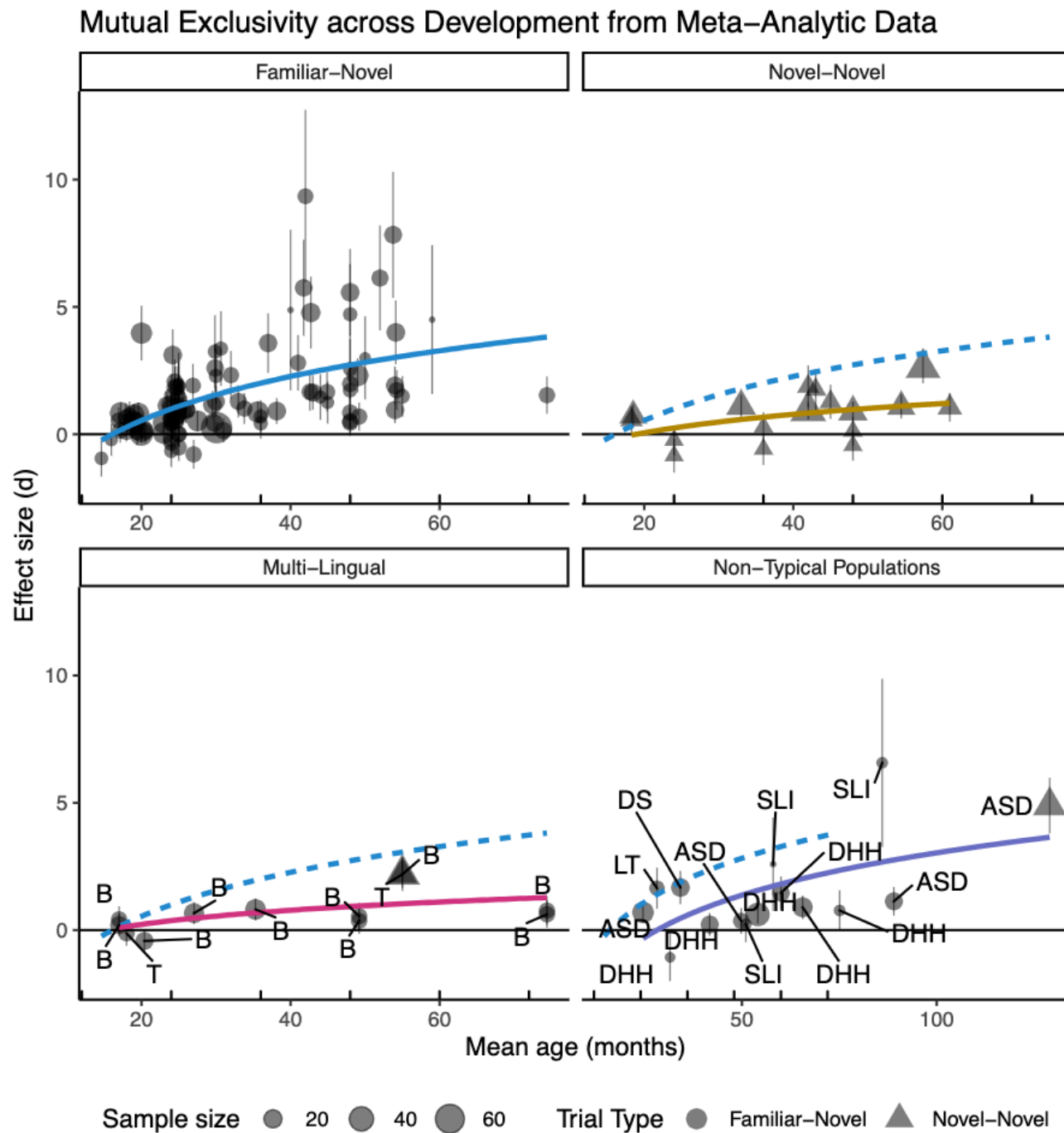
This is a “Dax”



Can you find the “fep”?



# Exploring other moderators



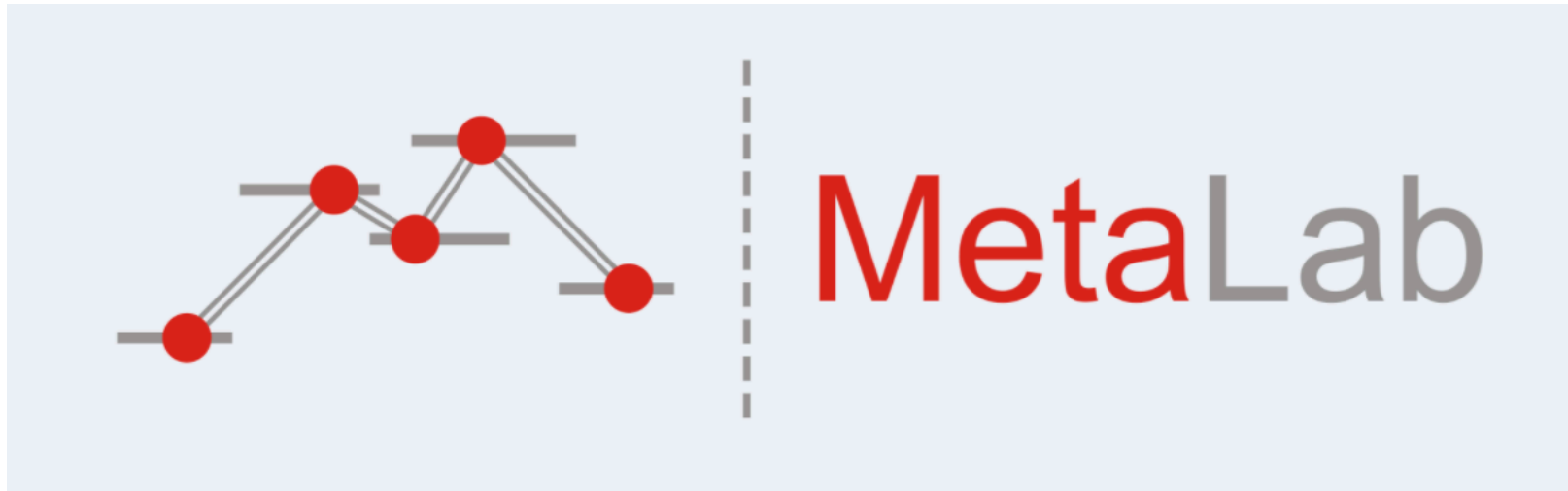
# Cao and Lewis MA details

Quantifying the syntactic bootstrapping effect in verb learning: A meta-analytic synthesis

AUTHORS

Anjie Cao, Molly Lewis

- Search strategy?
- Coding?
  - How many effect sizes total?
  - What else did we code for? (i.e. "moderators")
- Statistical approach?
- **Moderators?**



- Aggregate of meta-analyses of different phenomena in cognitive development (focus on language acquisition)
- Interactive visualizations
- <http://metalab.stanford.edu/>



# Next Time: Forming groups for final project

I'll have a number of topic suggestions.

If you have an idea for a phenomenon you'd like to do an MA for, come talk to me (should be related to cognitive/developmental/social psychology)