Linguistic experience in our theories of language

An attitude verb perspective

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Asian Junior Linguists Conference, Dec 2022

Linguistic experience shapes grammatical knowledge and language processing

Grammar

Grow up with English:
learn English grammatical rules.

Grow up with Japanese:
learn Japanese grammatical rules.

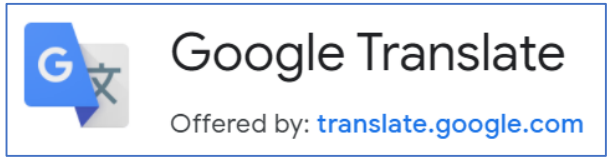
Word recognition

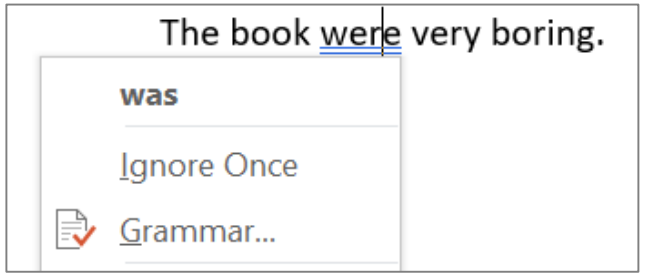
belief
Recognized quickly
High frequency

frenzy
Recognized slowly
Low frequency

Brysbaert et al. 2017; among others

Supported by recent advances in computational modeling





Language models / recurrent neural networks:

- Discover statistical regularities of words in a corpus (their "linguistic experience")
- Impressive performance in natural language processing domains, e.g. machine translation, auto-completion

Can capture various psycholinguistic / grammatical phenomena:

- Acceptability ratings
- Long-distance subject-verb agreement
- Some aspects of meaning

Lau et al. 2017, Gulordova et al. 2018, Linzen et al. 2016, Marvin & Linzen 2018, Wilcox et al. 2018; Landauer et al. 1998; Mikolov et al. 2013, among many others; but see Ettinger 2020, Chaves et al. 2019, Sprouse et al. 2018 etc.

This talk

Picture so far: a lot of linguistic knowledge and behavior seem to be modeled by the statistics of our everyday linguistic experience ("**language statistics**").

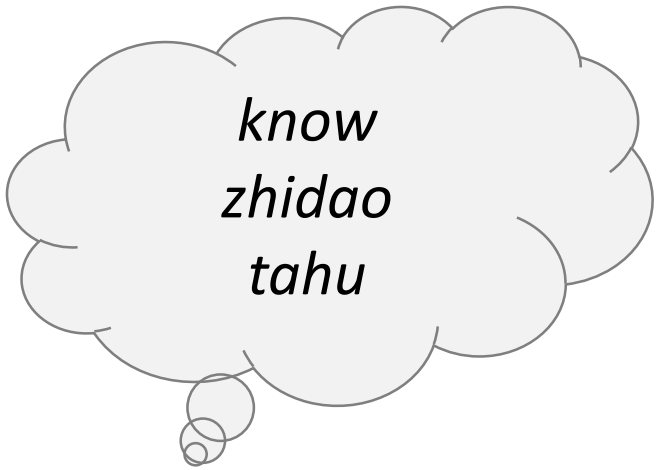
- Informal observations, lab experiments, computational models

Today: figuring out the limits of this approach.

1. In what cases does the "language statistics" approach run into limits?
2. How should we think about these cases?

Two case studies involving attitude verbs

- Verbs that typically describe mental states and communication.
- Appear with complement clauses: *They **think** it's snowing*.



Case study 1: “Bridge effects”

1. *What did Kim think/say/believe that Jo received _?*
2. *??What did Kim resent/shout/hate that Jo received _?*

think: bridge verb
resent: non-bridge

Call this variation in acceptability “**bridge effects**”.

Why do bridge effects exist?

Case study 2: how do children learn what these verbs mean?

"Belief" verbs

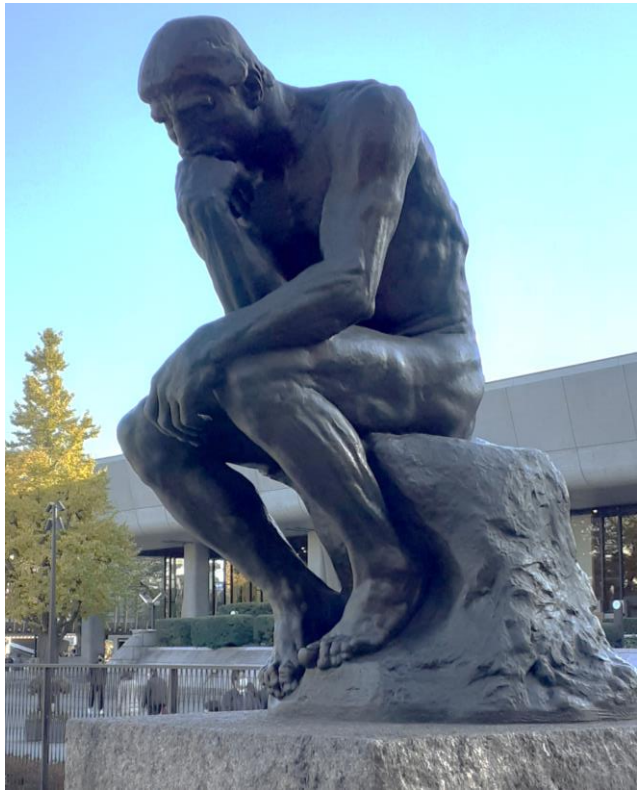
think

know

believe

guess

say



"Desire" verbs

want

prefer

love

like

Sneak preview

Language statistics play **at best an indirect role (although still an important one)** in these case studies.

These case studies serve as **a reminder of the importance** of other aspects of language, e.g. learning biases, syntax, pragmatics, …

Case study 1: Bridge effects

Joint work with Diogo Almeida & Jon Sprouse

Diogo Almeida

Jon Sprouse

Bridge effects and rules on forming wh-questions

Island constraints: structural restrictions on fronting wh-words/wh-question formation.

Bridge effects – yet another set of restrictions.

How should these be restrictions be explained?
Syntax? Pragmatics? Psycholinguistics?
How do we draw the line? Implications for theories of syntax, pragmatics, psycholinguistics, …?

Ross 1967, among many others

Overview

- Outline of existing theories
- Large scale experiments to evaluate these theories
- Upshot: **we need better theories.**

Theory 1. Frame frequency

Bridge effects track how often a **verb** takes a finite complement clause.

1. *What did Kim **think** that Jo received?* — *think*+clause frequent
2. *??What did Kim **resent** that Jo received?* — *resent*+clause rare

Independent psycholinguistic evidence that low-frequency structures create processing difficulties. (e.g. Hale 2001; Levy 2008)

Kothari 2008, but see Liu et al. 2019; Richter & Chaves 2020

Theory 2. Template-based theory

Wh-questions with *say* or *think* are very frequent, e.g.:

*What did you **say** they will do?*
*Where do you **think** they went?*

For language processing purposes, we create "templates" based on frequently-encountered (prototypical) questions.

Say template: WH *do you say* CLAUSE*?*

Think template: WH *do you think* CLAUSE*?*

(Replace [ ] with suitable material.)

Dąbrowska 2008, 2013; Verhagen 2005: see also Ambridge & Goldberg 2008

Theory 2. Template-based theory

1. *What did Kim **think** that Jo received?*

   → Use the *think* template.

2. ??*What did Kim **resent** that Jo received?*

   → No *resent* template; modify existing templates instead.

   → Weirdness reflects cost of modifying a template, which **increases** with **semantic distance** from *say* / *think*.

Dąbrowska 2008, 2013; Verhagen 2005: see also Ambridge & Goldberg 2008

Theory 3. Information structure

- "No fronting from **backgrounded** clauses" (Ambridge & Goldberg 2008)
- "No fronting from **focused** constituents." (e.g. Erteschik-Shir 2017, also 1973)

3. *Kim **thought** that Jo received the prize.*

Verbs like *think* foreground/focus the embedded clause.

4. *Kim **resented** that Jo received the prize.*

Resent draws attention to the emotional state;
the clause is backgrounded.

Problem #1: No clear consensus from prior experiments testing these theories

E.g.

- Ambridge & Goldberg 2008, Dąbrowska 2013: experimental results **supporting information structure theory**.
- Liu et al. 2021: **failed to replicate results**.

Problem #2: data quality

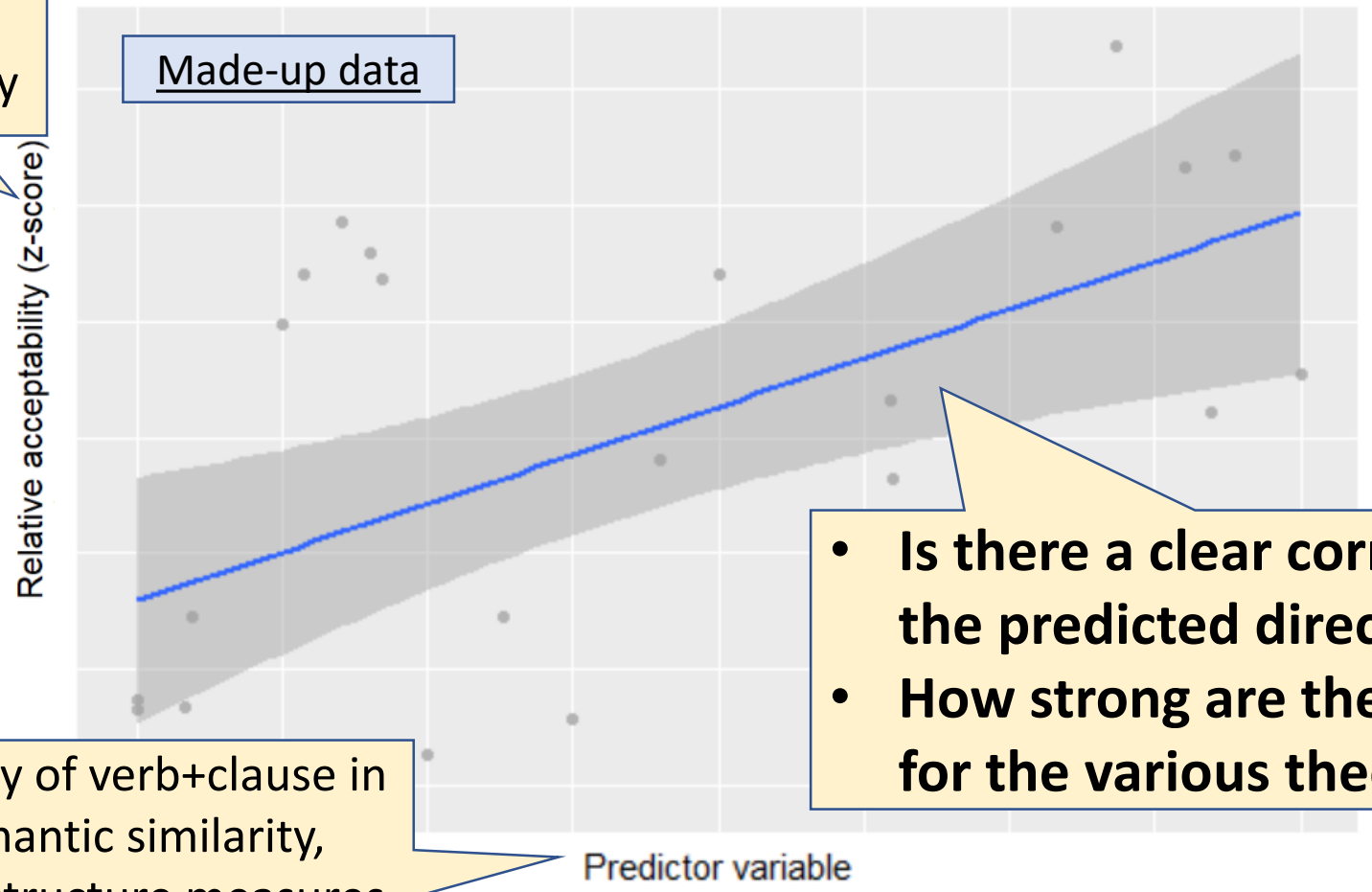
English has hundreds of attitude verbs that appear with finite clauses.

Current generalizations / experiments have small samples (~12-75 verbs).

Are these findings robust?

Our contribution: exhaustive experimental evaluation of these theories

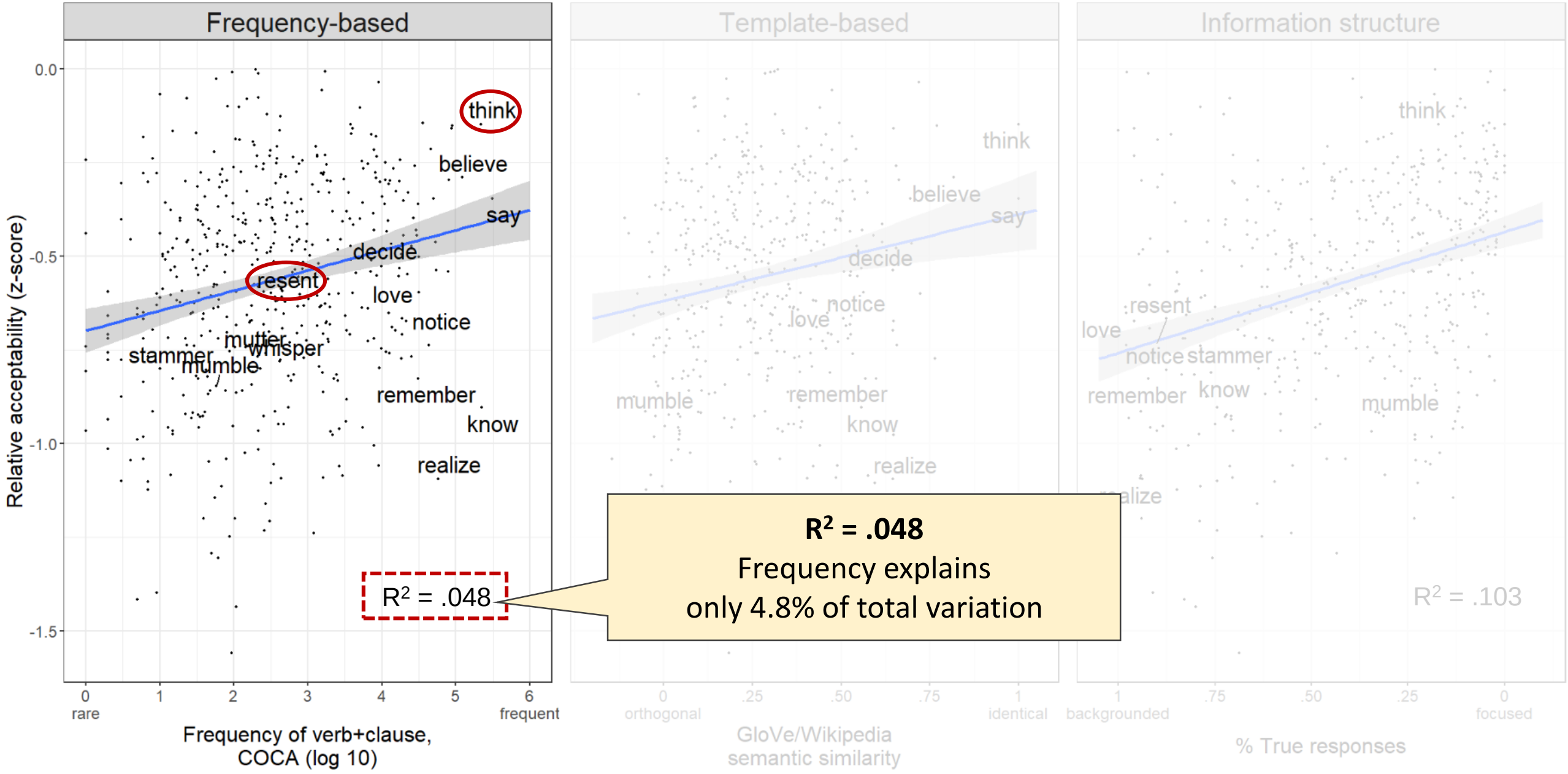
Bridge effects / relative acceptability



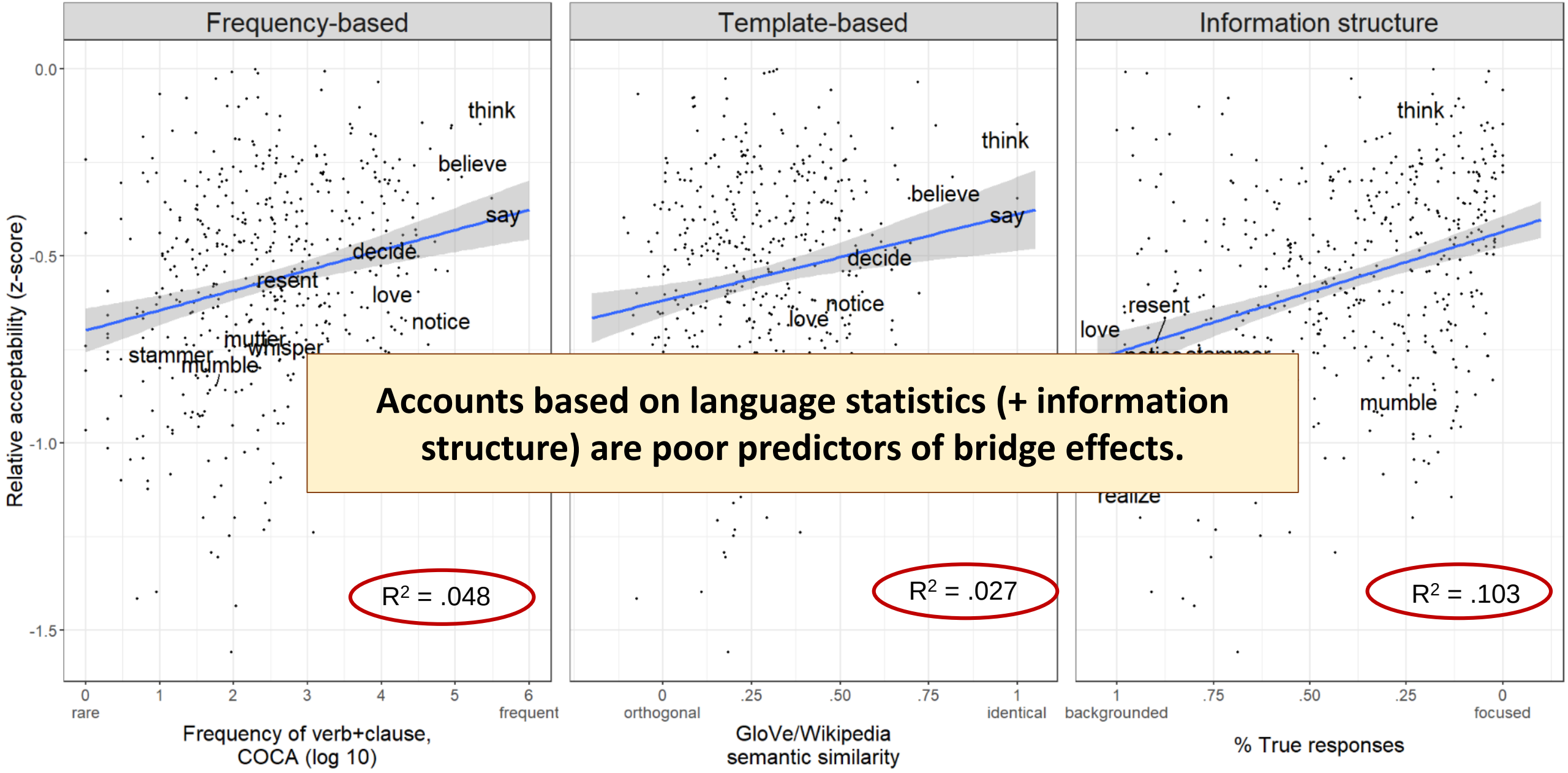
Exhaustive
640 verbs x 60 sets of ratings per verb on Amazon Mechanical Turk (~9,200 participants).

- **Is there a clear correlation in the predicted direction?**
- **How strong are the correlations for the various theories?**

e.g. frequency of verb+clause in a corpus, semantic similarity, information structure measures



R^2 = .048
Frequency explains
only 4.8% of total variation



Accounts based on language statistics (+ information structure) are poor predictors of bridge effects.

Summarising

Prior experimental studies likely to have verb sample issues.

With a full set of verbs:

- Existing theories are **empirically weak**.

Results call for better theories of bridge effects

Verb classes seem to matter: verbs allowing nonfinite clauses (*believe*/*expect* NP *to* VP; *claim to* VP) tend to have higher relative acceptability (point-biserial correlation = .40, $p<.01$).

Open questions:

1. Is the verb class fact due to verb **syntax**, **semantics**, **pragmatics**?
2. **Cross-linguistic variation** in bridge effects. Why?

See also prior discussion by Erteschik-Shir 1973; Ambridge & Goldberg 2008; Fodor 1992

Case study 2: Learning attitude verb meanings

Joint work with Aaron Steven White, Chia-Hsuan Liao, Valentine Hacquard, & Jeff Lidz


Aaron Steven White


Chia-Hsuan Liao


Valentine Hacquard


Jeffrey Lidz

Outline

- Belief and desire verbs and syntactic bootstrapping
- The problem posed by Mandarin Chinese (and many Asian languages)
- How serious is the problem? Corpus analysis and a computational model of syntactic bootstrapping

Belief and desire verbs

"Belief" verbs

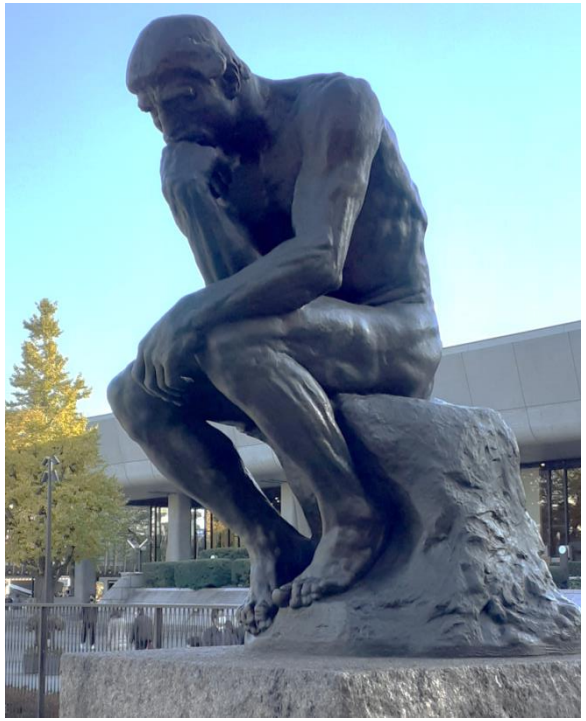
think

know

believe

guess

say



"Desire" verbs

want

prefer

love

like

*Dora **thinks** Kim went to bed.*

Express **commitment to truth** of "Kim went to bed"

*Dora **wants** Kim to go to bed.*

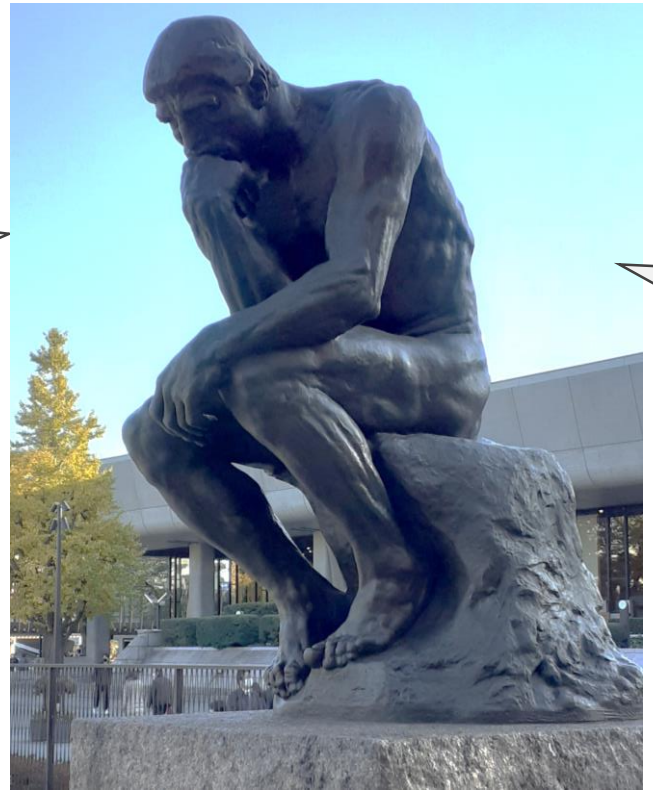
Express **preference** for "Kim goes to bed"

How might a child learn the meaning difference?

Many words have obvious physical correlates.

But belief and desire verbs describe hard-to-observe mental states.

Look at the ***statue***!



Is he ***thinking*** or ***wanting****?*

Gleitman 1990; Gillette et al. 1999

A solution: syntactic bootstrapping

Verb meanings can be tricky to observe, but syntax is relatively easy to observe.

→ Use syntax to learn semantics.

Gleitman & Landau 1985; Gleitman 1990; Gillette et al. 1999; Hacquard & Lidz 2019; Huang et al. 2018, 2022a,b; also Fisher 1996; Lee & Naigles 2008

Interesting points of connections with linguistic theory: Verb meanings are robustly correlated with syntax.

Zwicky 1971, Levin 1993, Villalta 2008, White & Rawlins 2015, etc.

Cross-linguistically, belief and desire verbs are differentiated morphosyntactically

*Dora **thinks** Kim **went** to bed.*

*Dora **wants** Kim **to go** to bed.*

	Complement clause of belief verbs	**Complement clause of desire verbs**
English	Finite	Non-finite

Hacquard & Lidz 2018, Bolinger 1968, Hooper 1975, a.o.

Belief clauses resemble declarative sentences

Declaratives

Dora ***thinks*** *Kim went to bed.*

Kim went to bed.

	Complement clause of belief verbs	**Complement clause of desire verbs**	**Declarative sentences**
English	Finite	Non-finite	Finite

Hacquard & Lidz 2018, Bolinger 1968, Hooper 1975, a.o.

Syntactic bootstrapping: Use syntax to learn semantics

- Observing morphosyntactic differences in one's linguistic experience is **helpful** ...
- But **not enough:** it doesn't tell learners what the verbs mean.

A learning proposal (a learning bias)

If a verb has an embedded clause that looks like a declarative sentence, that verb is a belief verb.

If not, it is a desire verb.

Huang, White, Liao, Hacquard, Lidz, to appear; Huang, Liao, Hacquard, & Lidz 2018; Hacquard & Lidz, 2019; Harrigan 2015; Papafragou et al., 2007; Lee & Naigles 2005; Gleitman 1990

Why? A role for pragmatics

“Dora thinks Kim went to bed.”

“Dora wants Kim to go to bed.”

“Kim went to bed.”

Direct assertion

Why? A role for pragmatics

“Dora thinks Kim went to bed.”

Indirect assertion of “Kim went to bed”

“Dora wants Kim to go to bed.”

“Kim went to bed.”

Why? A role for pragmatics

*"Dora **thinks** Kim went to bed."*

"Dora wants Kim to go to bed."

Indirect assertion of "Kim went to bed"

→ *Think* expresses truth judgments

"Kim went to bed."

A syntactic bootstrapping account requires belief and desire clauses to look distinct

Proposal

- If a verb has an complement clause that looks like a declarative sentence, that verb is a belief verb.
- If not, it is a desire verb.

The requirement is easily satisfied in languages with finiteness and mood morphology.

But what about a language that lacks such morphology, like Mandarin? (or Vietnamese, Thai, Malay, …)

Learners might draw the wrong semantic conclusions.

Hallmarks of Mandarin declarative sentences and belief clauses vs. desire clauses

	Complement of belief verbs	Complement of desire verbs	Declarative sentences
Overt subjects	Optional	%Not OK	Optional
Modals	Optional	Not OK	Optional
Aspect markers	Optional	Not OK	Optional

Problem: overt subjects, modals, and aspect markers are all optional – they can be omitted in the right context.

N. Huang 2018; accepted; Grano 2015; Li 1990; C.-T. J. Huang 1982, 2022; see also Zhang 2016

A good situation to be in

		Subject	Modal	Aspect	
Wo	**juede**	tamen	keneng	chi-guo	shuiguo.
I	feel/think	they	might	eat-EXP	fruit

"I **think** they might have eaten fruit." (Belief)

A less good situation

Wo	**juede**	chi	shuiguo.
I	feel/think	eat	fruit

"I **think** [they] eat fruit." (Belief verb)

Wo	**xihuan**	chi	shuiguo.
I	like	eat	fruit

"I **like** to eat fruit." (Desire verb)

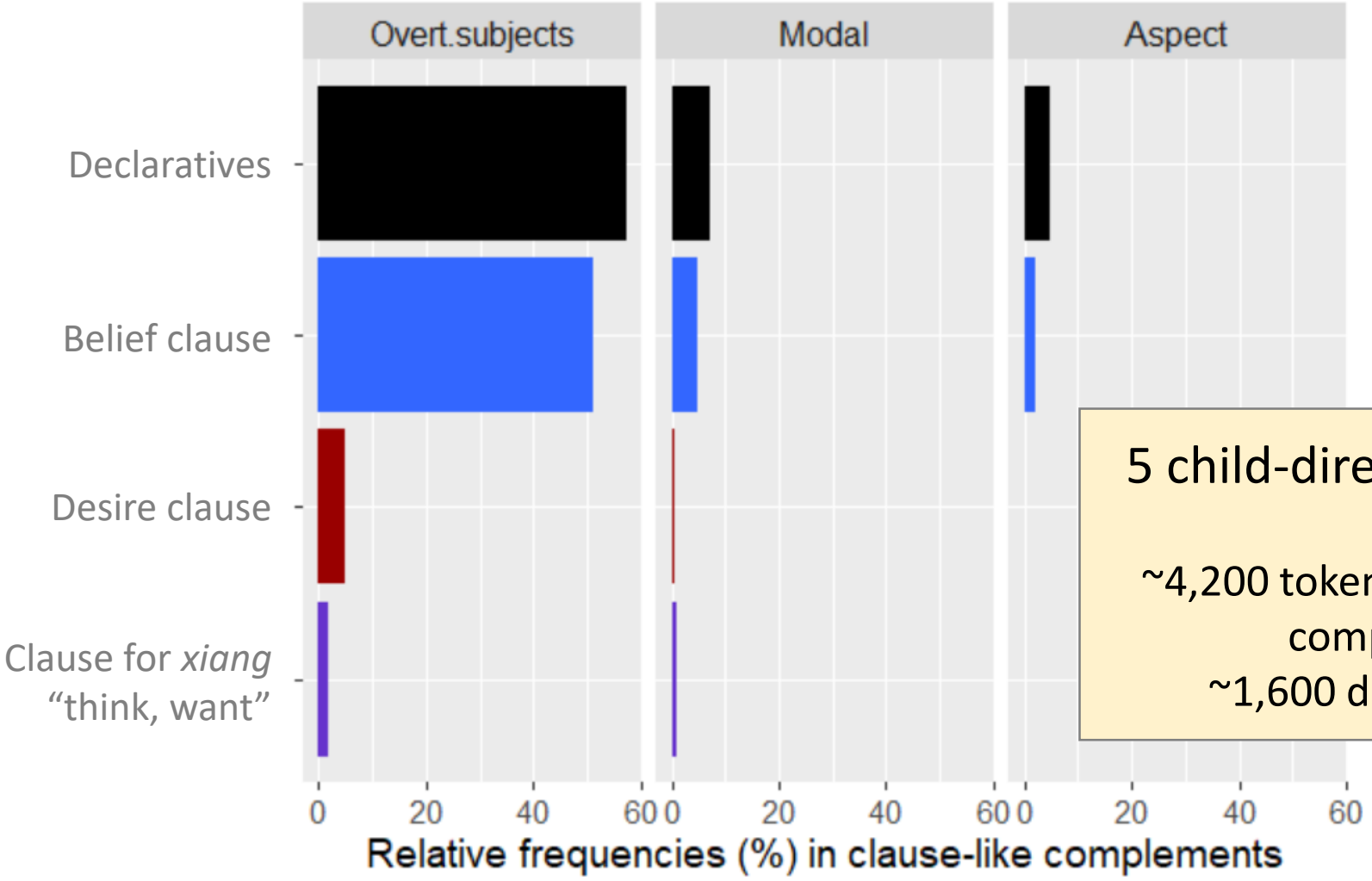
A way out of the problem

Learners can track the **overall distribution** of various morphosyntactic features in their linguistic experience.

Perhaps belief clauses and desire clauses **look different in aggregation**.

1. Is this the case?
2. If there is differentiation between belief and desire clauses, are the differences enough for the learner?

Q1: Are the clauses differentiated in the input?



5 child-directed speech corpora

~4,200 tokens of attitude verbs with complement clauses
~1,600 declarative sentences

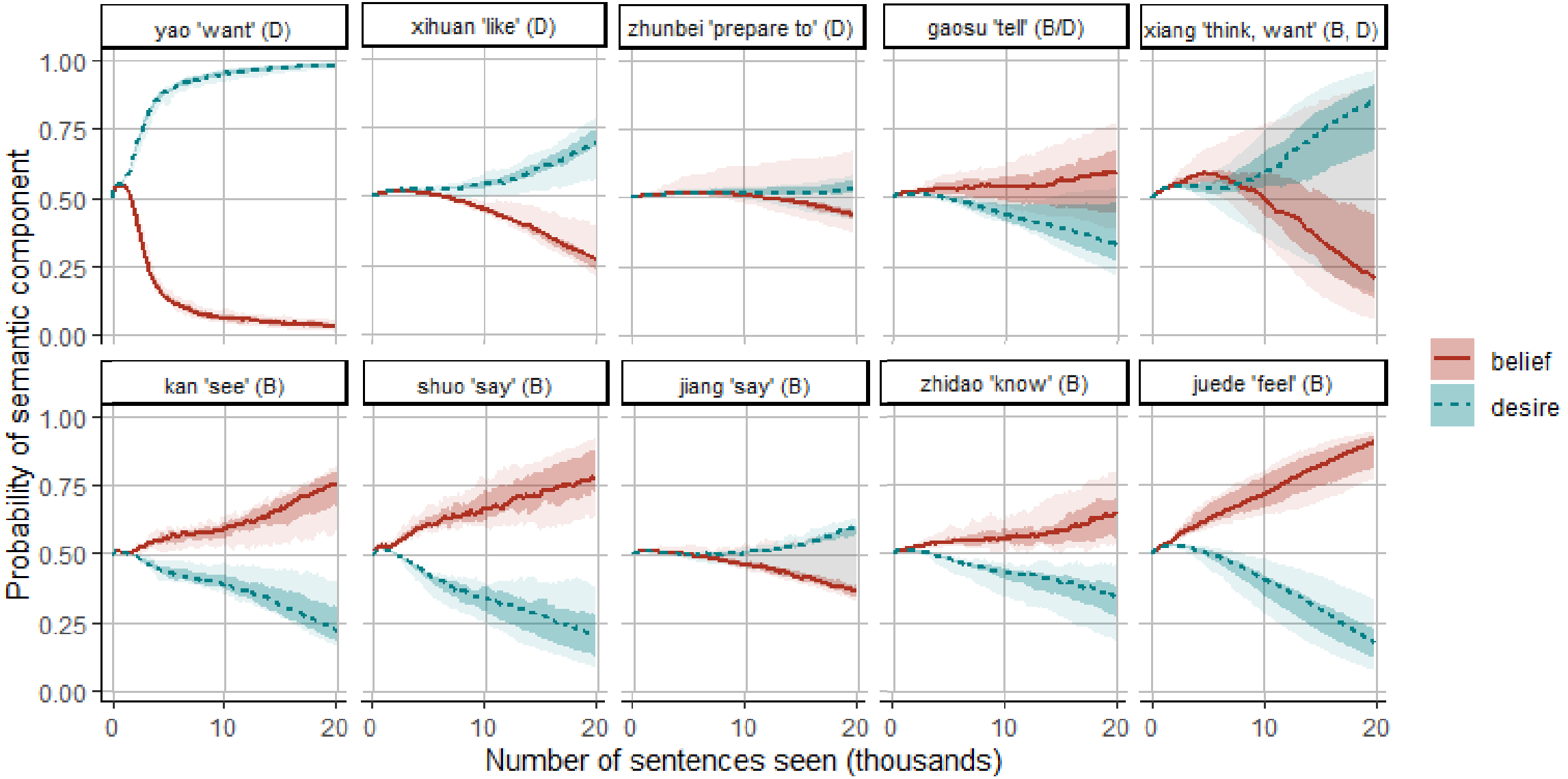
Q2: Do distributional differences guarantee successful learning of verb semantics?

Simulate a learner.

- Adapt a **computational model of syntactic bootstrapping** by White et al. 2018.
- **Model builds in a learning bias**: if the complement clause looks like a declarative, the verb is a belief verb; otherwise, the verb is a desire verb.
- Shown to model acquisition of English attitude verbs, using English child-directed speech data.

Does this "learner" succeed with Mandarin attitude verbs?

Mandarin results (10 CHILDES corpora)



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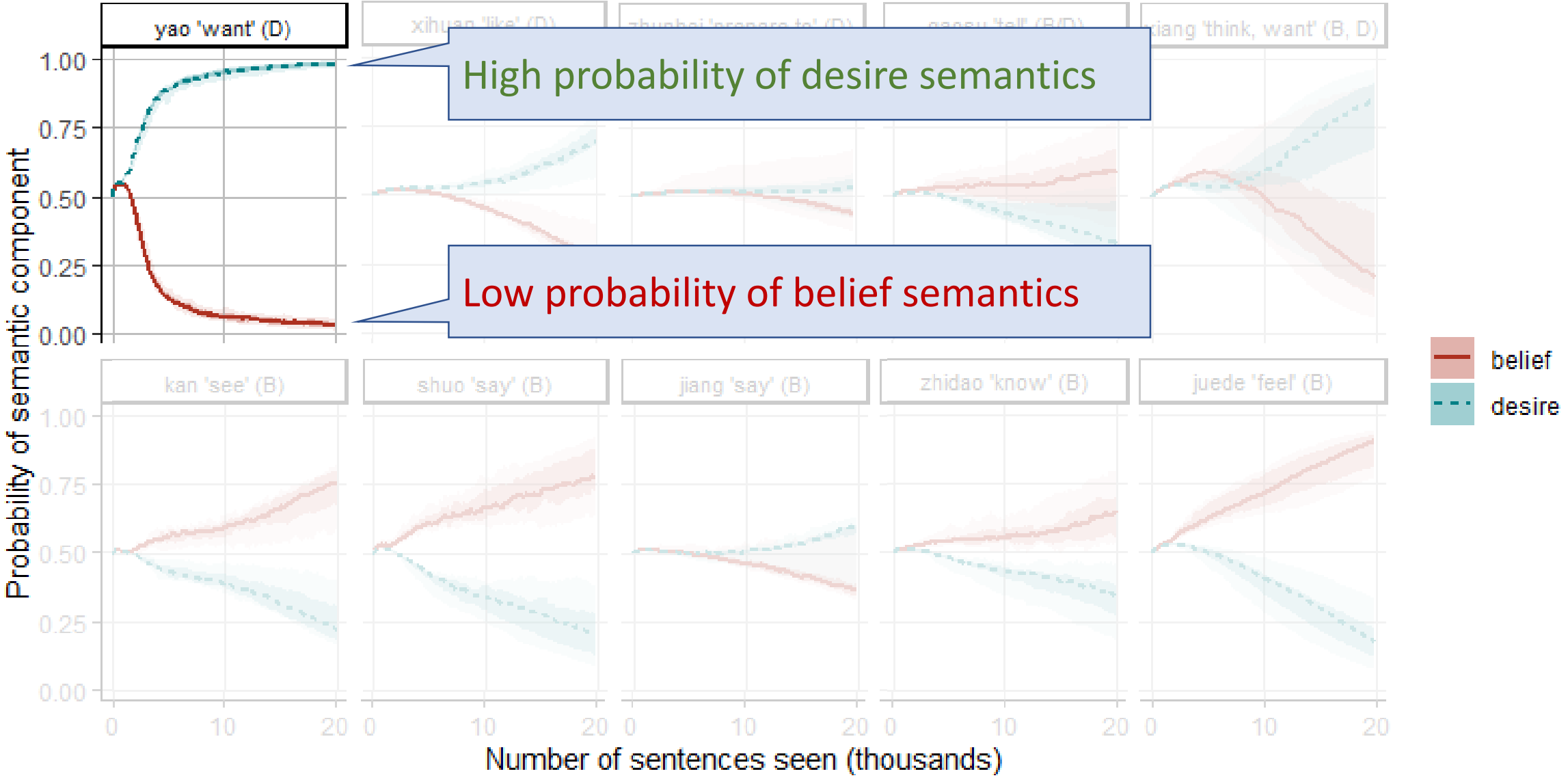

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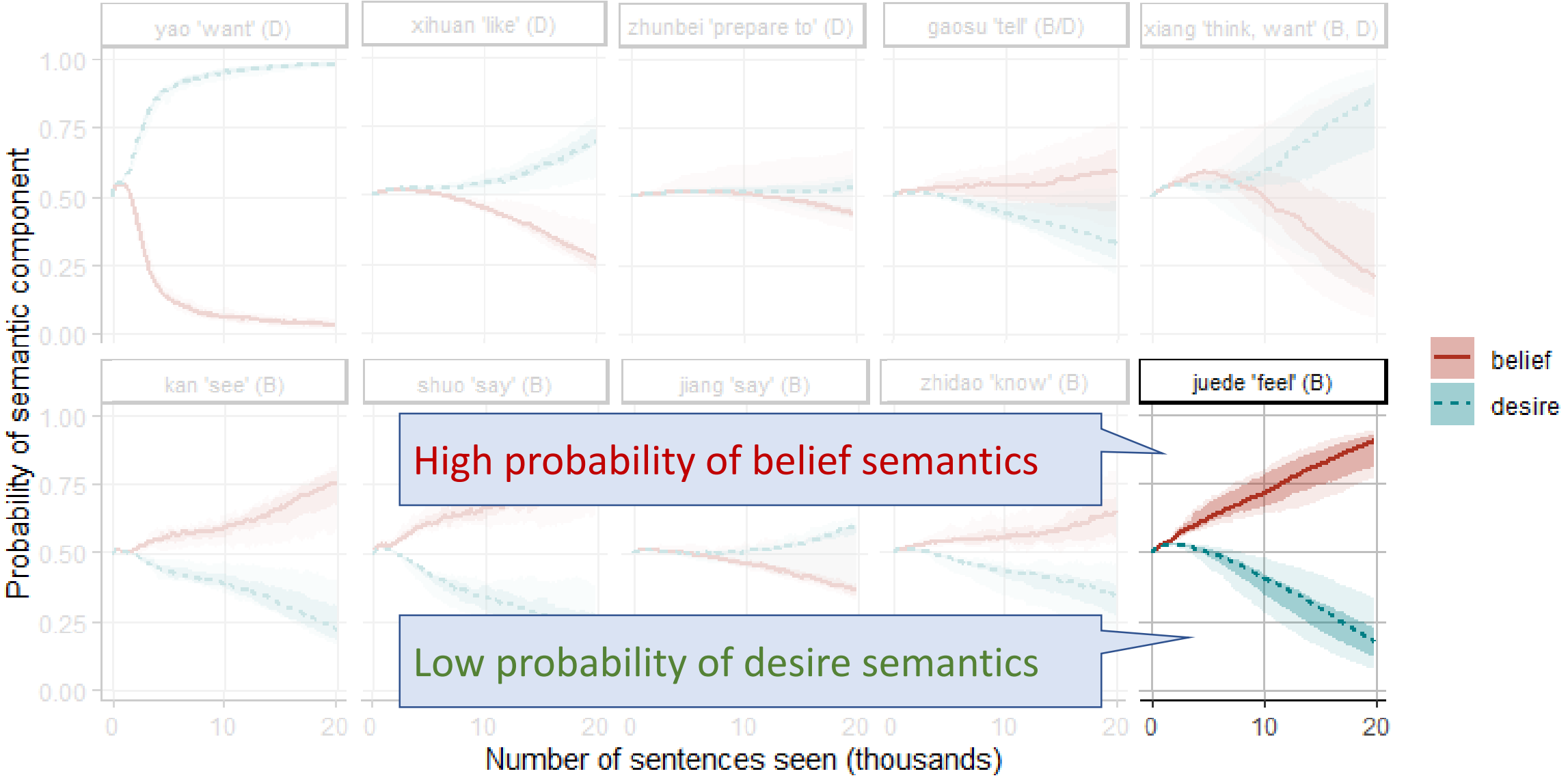
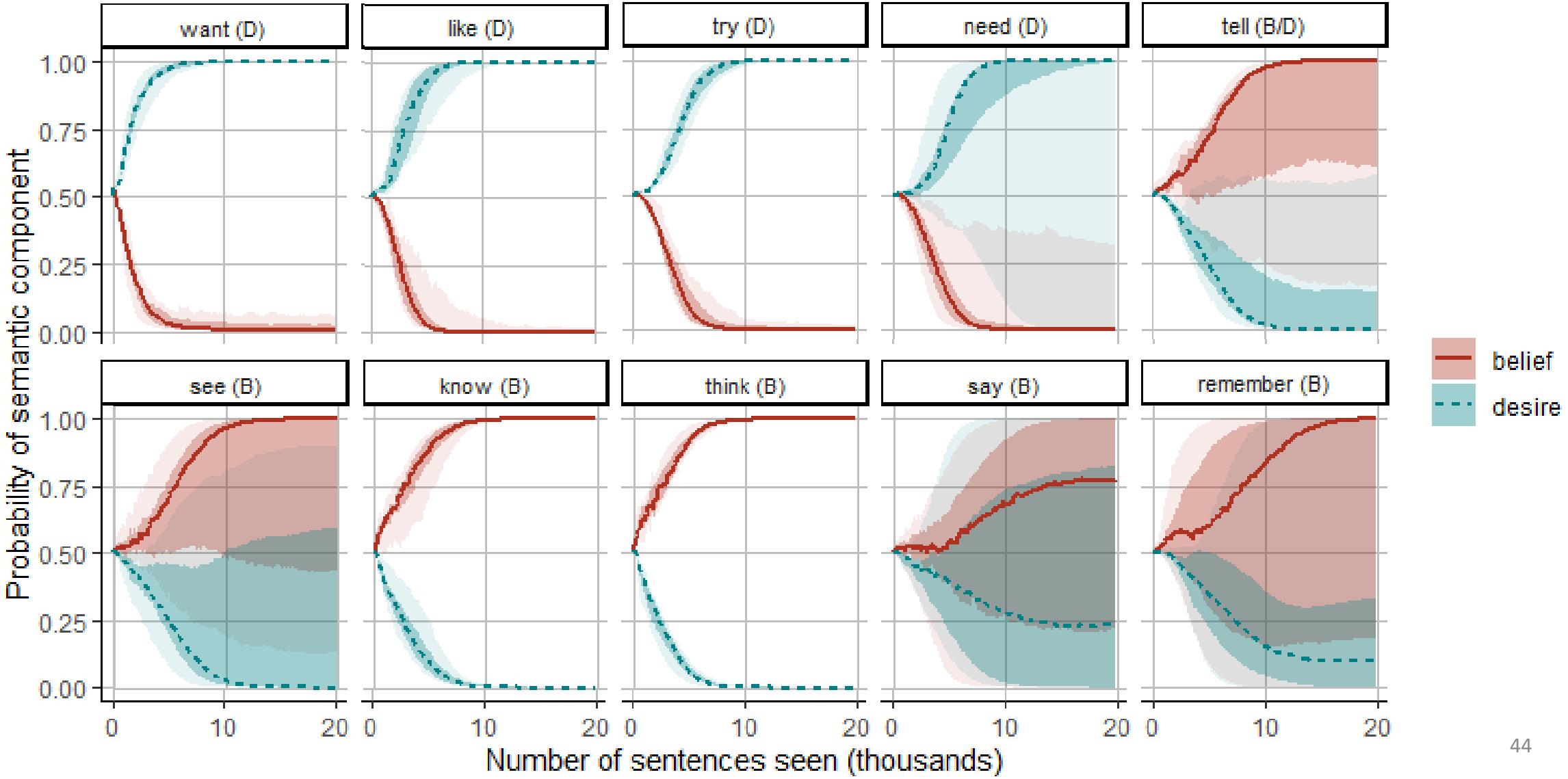


English results (replicating White et al. 2018)



Summing up this case study

- Belief and desire verbs are difficult to learn from observation of physical contexts → bootstrapping
- In Mandarin (+ many other Asian languages): belief and desire clauses can look alike: a problem for syntactic bootstrapping?
- Corpus analysis indicates that this is not the case.
- Computational model shows that morphosyntax + bias can help learners learn the right semantic contrasts in both Mandarin and English – **cross-linguistic support**.

Discussion and conclusion

The limits of linguistic experience

1. **Bridge effects**
2. **Learning attitude verb meanings**

Case study 1: Theories based on language statistics are unsatisfactory accounts of bridge effects.

- E.g. role of frequency is smaller or more indirect than previously theorized.
- (Same issue applies to other theories.)
- **Methodological point**: sample size and empirical verification

The limits of linguistic experience

1. Bridge effects
2. **Learning attitude verb meanings**

Case study 2: Belief and desire verbs have different profiles in a (Mandarin) learner's linguistic experience.

- But these differences in themselves cannot tell learners much about the actual meaning of verbs.
- Learning biases also necessary to help children acquire the right semantics.

Conclusion

Questions: How does linguistic experience shape the way we learn and process language? How useful is a statistical approach?

Findings from the case studies: Limitations of an approach that relies only on statistics in our linguistic experience (despite empirical successes elsewhere).

Value of theories that better delineate the roles of statistics, learning biases, syntax, pragmatics, processing mechanisms etc.

- An integrated approach to build a more nuanced, richer understanding of human language.

Thank you!

- Organisers of AJL.
- Special thanks to my collaborators and assistance by Yuhan (Claire) Zhang and Sandra Villata.

- Various aspects of this research was supported by NSF Grant #DGE-1449815, a NUS Postdoctoral Fellowship, and Singapore Ministry of Education Tier One grant #2021-FRC3-002, and NYU Abu Dhabi faculty research funds.