PROBABILISTIC LISTENER: A CASE OF REFLEXIVE *ZIJI "SELF"* AMBIGUITY RESOLUTION IN MANDARIN

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C.Psyd Presentation
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AN EXAMPLE TO KICK OFF

The postman met the streetsweeper before he went home.

AN EXAMPLE TO KICK OFF

The postman met the streetsweeper before he went home.

Ambiguous!

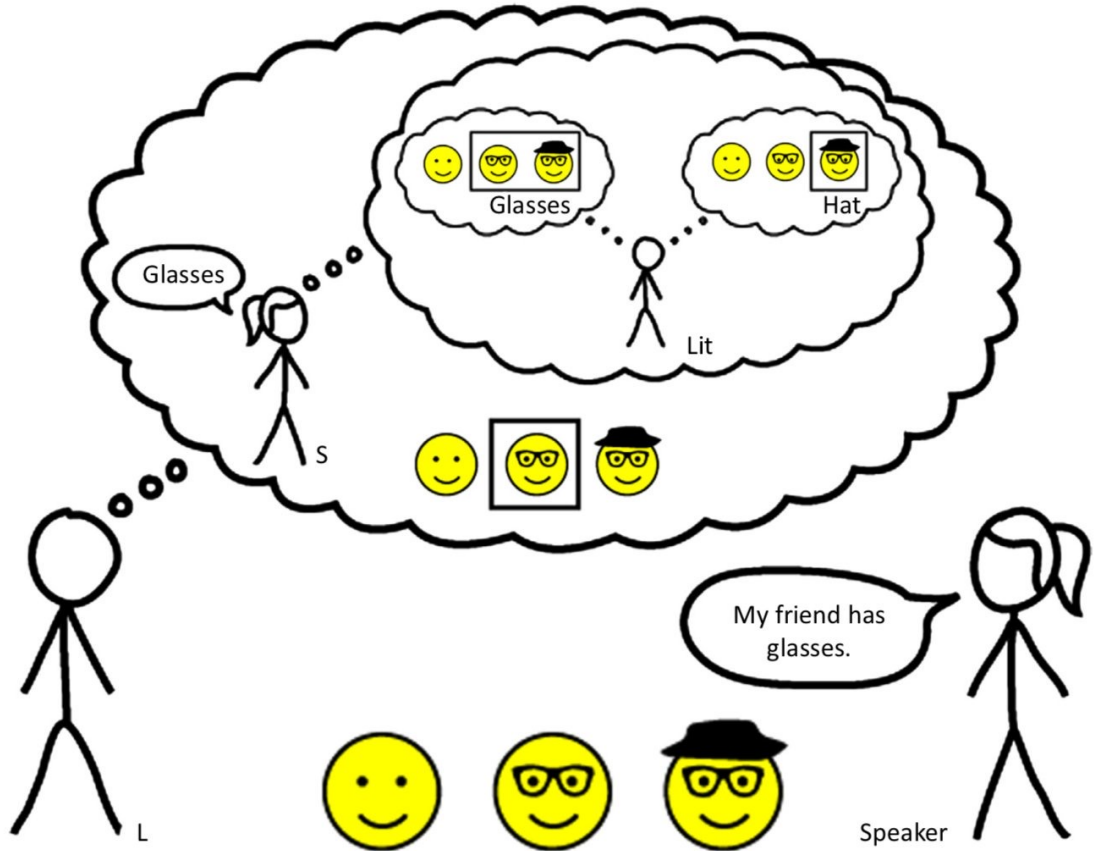
- **How can people decide the referent among all alternatives?**
- **What rules does the brain use to do so?**

RATIONAL SPEECH ACT MODEL (RSA)

1. The listener assumes the speaker has already chosen the best utterance to convey the world among all alternatives.

=> A Rational Listener assumes a Rational Speaker.

RATIONAL SPEECH ACT MODEL (RSA)

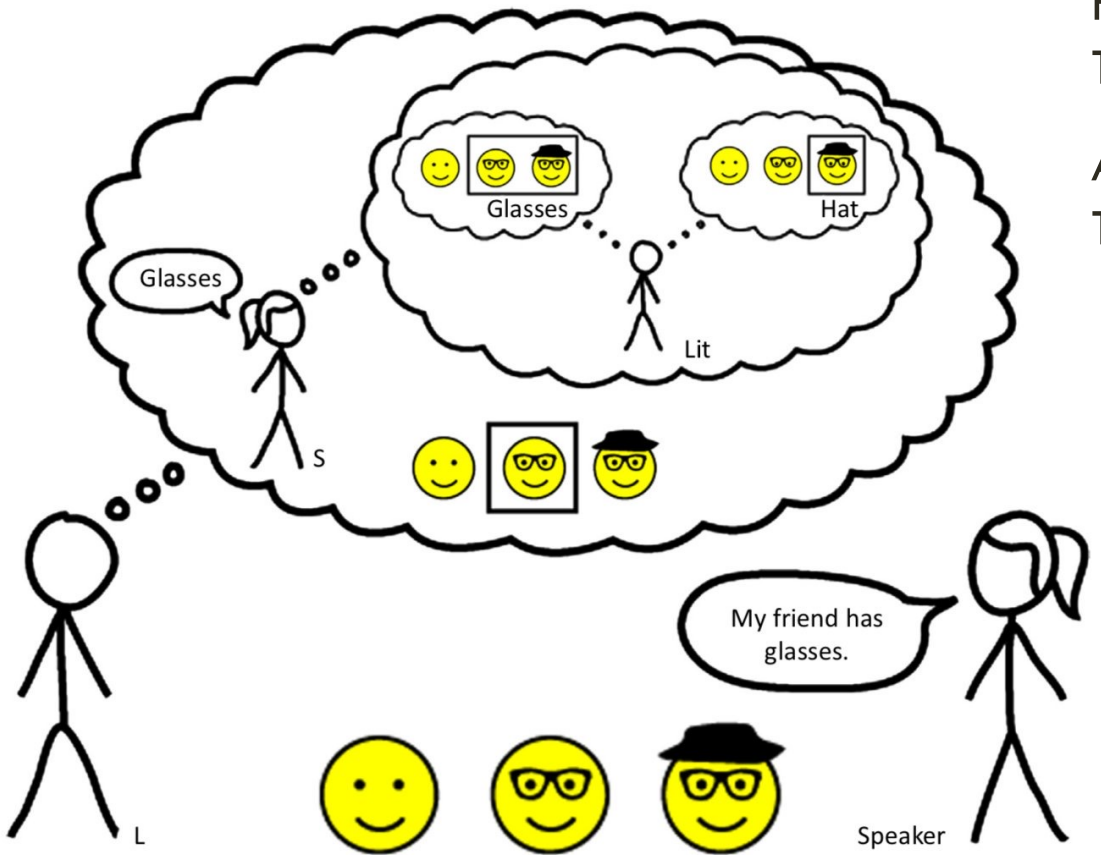


Listener

Speaker

(Goodman & Frank, 2016)

RATIONAL SPEECH ACT MODEL (RSA)



Listener N G HG Speaker

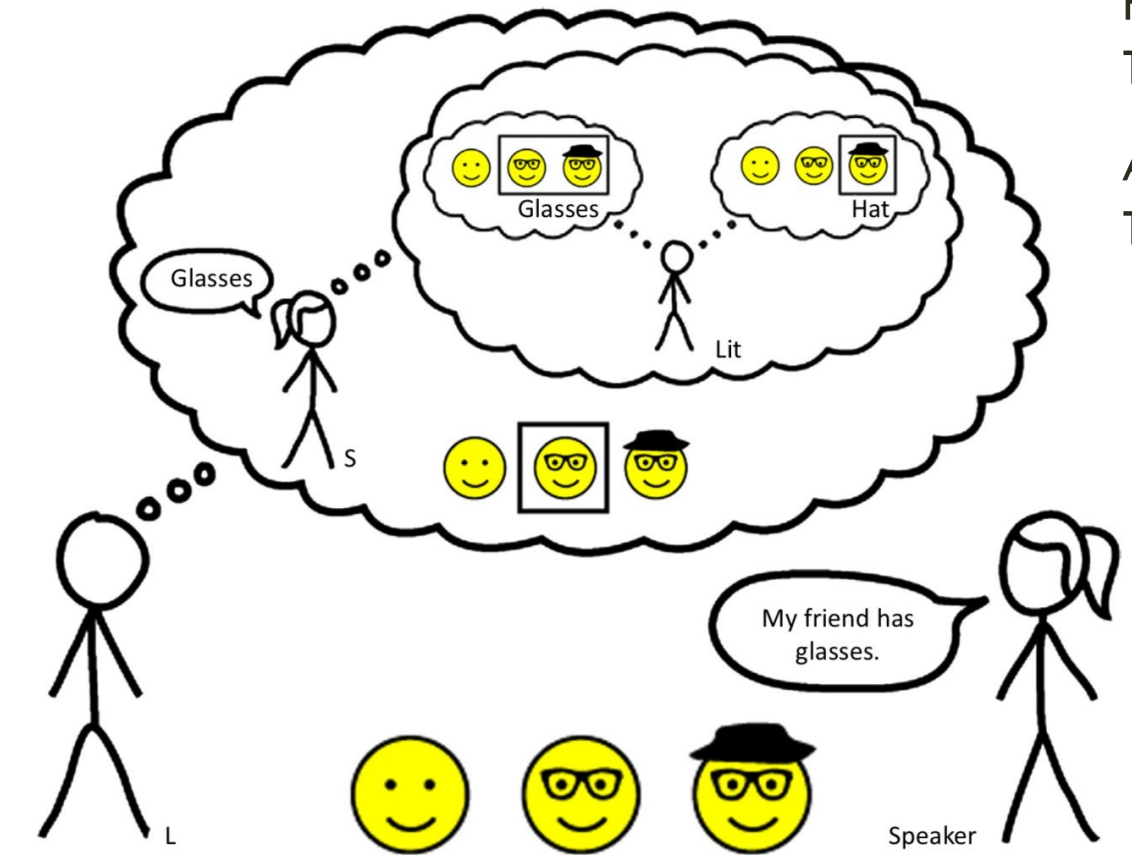
Heard:
The postman met the streetsweeper before he went home.

Alternative:
The postman met the streetsweeper before going home.

RSA component 1 will predict:
… before streetsweeper went home.

(Goodman & Frank, 2016)

RATIONAL SPEECH ACT MODEL (RSA)



Listener N G HG Speaker

Heard:
The postman met the streetsweeper before he went home.

Alternative:
The postman met the streetsweeper before going home.

RSA component 1 will predict:
… before streetsweeper went home.

Cost of the utterance ?
Prior World Knowledge ?

(Goodman & Frank, 2016)

RATIONAL SPEECH ACT MODEL (RSA)

1. The listener assumes the speaker has already chosen the best utterance to convey the world among all alternatives.

⇒ A Rational Listener assumes a Rational Speaker.

2. Prior Knowledge of the world

The postman met the streetsweeper before he went home.

RATIONAL SPEECH ACT MODEL (RSA)

Rational Listener $\propto$ World Knowledge $\times$ Rational Speaker

(Frank & Goodman, 2012)

RATIONAL SPEECH ACT MODEL (RSA)

Rational Listener $\propto$ World Knowledge $\times$ **Rational Speaker**

Rational Speaker:

- Speaker utility：
  - Frequency of the utterance （pronoun）
  - Grammar rules
- Speaker's resource limitation

(Frank & Goodman, 2012)

(Frank & Goodman, 2012)

RSA: A PROBABILISTIC MODEL

The mathematical formulars:

(r: Referent, u: Utterance)

Rational Listener Interpretation

$$P_L(r|u) \propto P(r) \times P_s(u|r)$$

Speaker Probability (Likelihood)

$$P_s(u|r) \propto exp(\alpha \times U_s(u, r))$$

Speaker Utility

$$U_s(u, r) = ln(P_{LL}(r|u)) - Cost(u)$$

Literal Listener (normalize)

Let R be set of all grammatical referents, {r1, r2, ...}, for utterence u,

$$P_{LL}(r|u) = \frac{P(r)}{\sum_{i \in R} P(i)}$$

Prior probability for each world state

$$P(r)$$

Message Cost

$$Cost(u) = -log(P(u))$$

(Frank & Goodman, 2012)

RSA: A PROBABILISTIC MODEL

The mathematical formulars:

(r: Referent, u: Utterance)

Rational Listener Interpretation

$$P_L(r|u) \propto P(r) \times P_s(u|r)$$

Speaker Probability (Likelihood)

$$P_s(u|r) \propto exp(\alpha \times U_s(u,r))$$

Speaker's resource limitation (0.93)

Speaker Utility

$$U_s(u,r) = ln(P_{LL}(r|u)) - Cost(u)$$

Literal Listener (normalize)

Let R be set of all grammatical referents, {r1, r2, ...}, for utterence u,

$$P_{LL}(r|u) = \frac{P(r)}{\sum_{i \in R} P(i)}$$

Grammatical rules (binding)

Prior probability for each world state

$$P(r)$$

Prior world knowledge

Message Cost

$$Cost(u) = -log(P(u))$$

Frequency of the pronoun

ziji – self

taziji – himself

ta – him

A TEST CASE IN MANDARIN CHINESE

WHY MANDARIN CHINESE?

- Mandarin has **more pronouns** than English does for different meanings.
- The process of pronoun resolution is more complicated with the interaction between pronouns, especially for the reflexive *ziji*.

- Would the additional choices the speaker has impact listener preferences?
- Is RSA model capable in a more complicated system?

THERE ARE MORE PRONOUNS IN MANDARIN

Non-local NP		**Local NP**		***Pronoun***
[张伟]$_i$	说	[小明]$_j$	把	*[自己]*$_{i/j}$ 弄糊涂了。
[Zhang Wei]$_i$	says	[Xiao Ming]$_j$	BA	*[ziji]*$_{i/j}$ confused.

[Zhang Wei]$_i$ says that [Xiao Ming]$_j$ confused *[self]*$_{i/j}$.

THERE ARE MORE PRONOUNS IN MANDARIN

(the non-local NP) (the local NP)

Speaker **Clause Subject** ***Pronoun***

[张伟]$_i$ 说 [小明]$_j$ 把 *[他自己]*$_{i*/j}$ 弄糊涂了。

[Zhang Wei]$_i$ says [Xiao Ming]$_j$ BA *[taziji]*$_{i*/j}$ confused.

[Zhang Wei]$_i$ says that [Xiao Ming]$_j$ confused *[himself]*$_{i*/j}$.

THERE ARE MORE PRONOUNS IN MANDARIN

(the non-local NP) (the local NP)

Speaker **Clause Subject** ***Pronoun***

[张伟]$_i$ 说 [小明]$_j$ 把 *[他]*$_{i/j?/k}$ 弄糊涂了。

[Zhang Wei]$_i$ says [Xiao Ming]$_j$ BA *[ta]*$_{i/j?/k}$ confused.

[Zhang Wei]$_i$ says that [Xiao Ming]$_j$ confused *[him]*$_{i/j?/k}$.

ALL ALTERNATIVES

Utterances = [*ziji (self)*, *taziji (himself)*, *ta (him)*]

Referents = [Non-local NP, Local NP, Others]

Grammatical Pairs = {*ziji* : Non-local NP, Local NP

taziji : Local NP

ta : Non-local NP, Local NP, Others}

RESEARCH QUESTIONS

- Can the **Rational Speech Act model** explain **pronoun resolution** process in **Mandarin Chinese?**

Experiment 1: Pronoun Interpretation Task => Rational Listener

Corpus Study => Rational Speaker

Experiment 2: World Knowledge Bias Task => World Knowledge

Rational Listener $\propto$ World Knowledge $\times$ Rational Speaker

ONLINE EXPERIMENTS

Stimuli:

- ([Non-local NP] says that [Local NP] [VERB] [PRONOUN].)
- **30 root stimuli** with similar structure were designed which were used in both experiments.
- 15 are in **co-argument** condition (ex. self, himself, him).
- The other 15 are in **possessor** condition (ex. self's, himself's, him's).

EXPERIMENT 1 - PRONOUN INTERPRETATION TASK

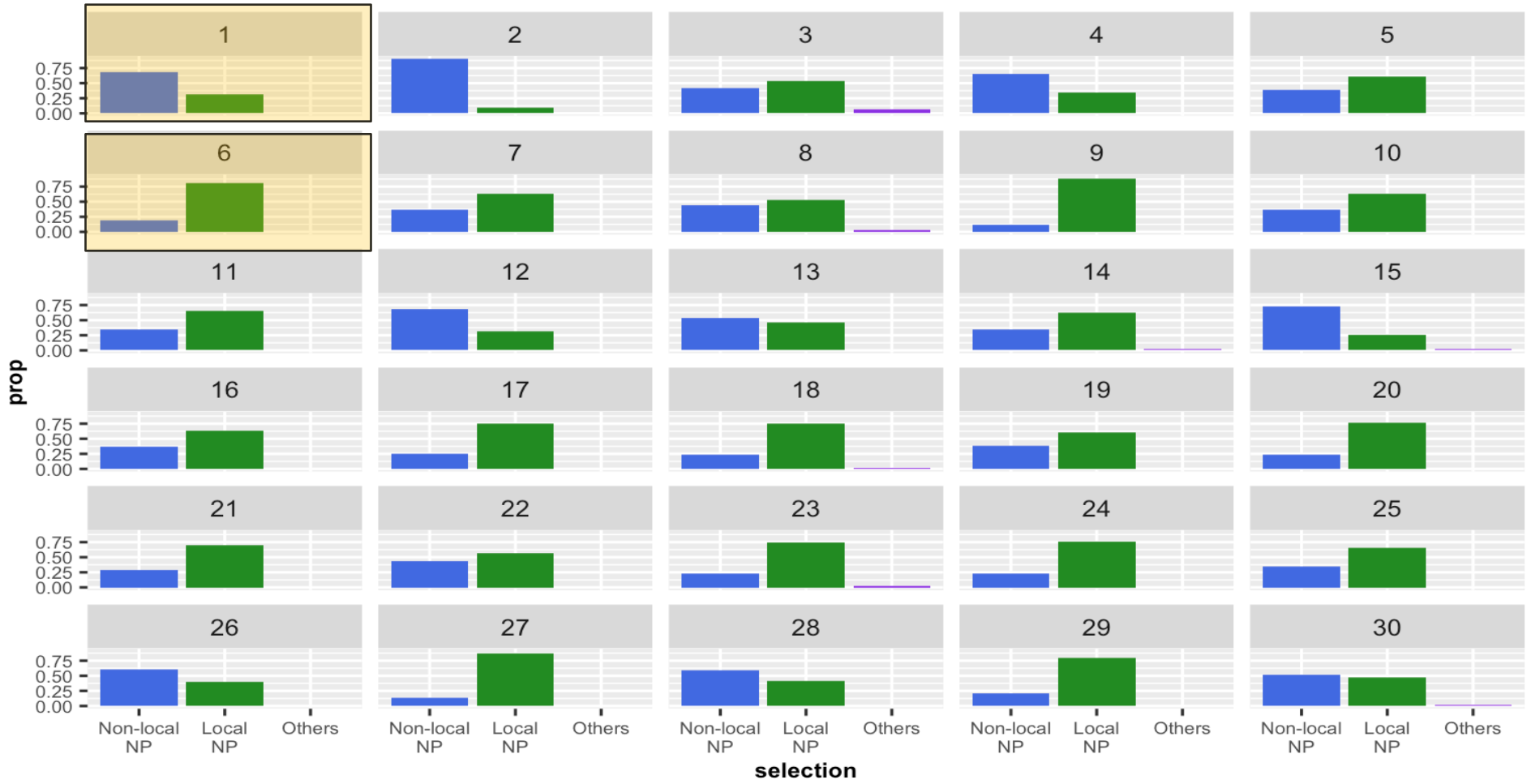
- Goal: To find out how people interpret different pronouns in Mandarin.
- Task: Given a **complete sentence** with a pronoun, participants were asked to choose who the pronoun refers to by clicking the picture of the character.
- 30 items for 3 conditions

  [*ziji*, *taziji*, *ta*]
- 135 valid participants.
- (About 45 participants per condition)

Wang said Zhang held *ziji's* child in arms.
王刚说张伟把自己的孩子搂在了怀里。

问题：谁的孩子被搂在了怀里?
Q: Whose child was held in arms?

RESULTS - PRONOUN INTERPRETATION TASK: *ZIJI*



CORPUS STUDY

Source: **Corpus of the Chinese Web** 2017 (zhTenTen17)

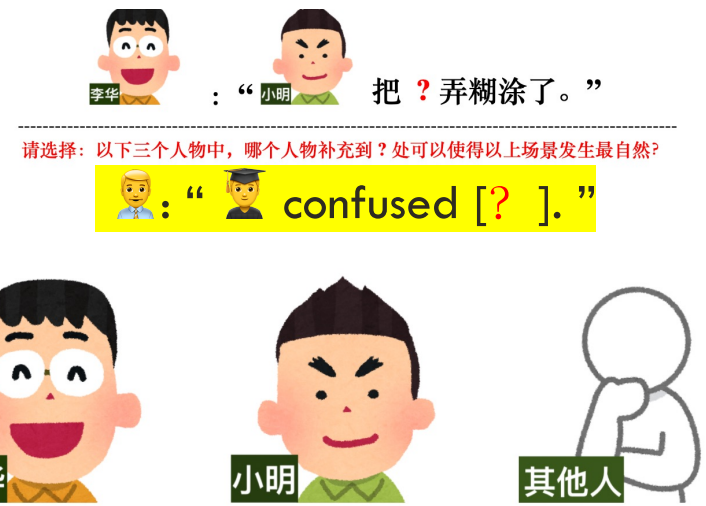
- is a Chinese corpus made up of texts collected from the Internet.
- 16,593,146,196 (16.5 billion tokens)
- 13,531,331,169 (13.5 billion words)

Results:

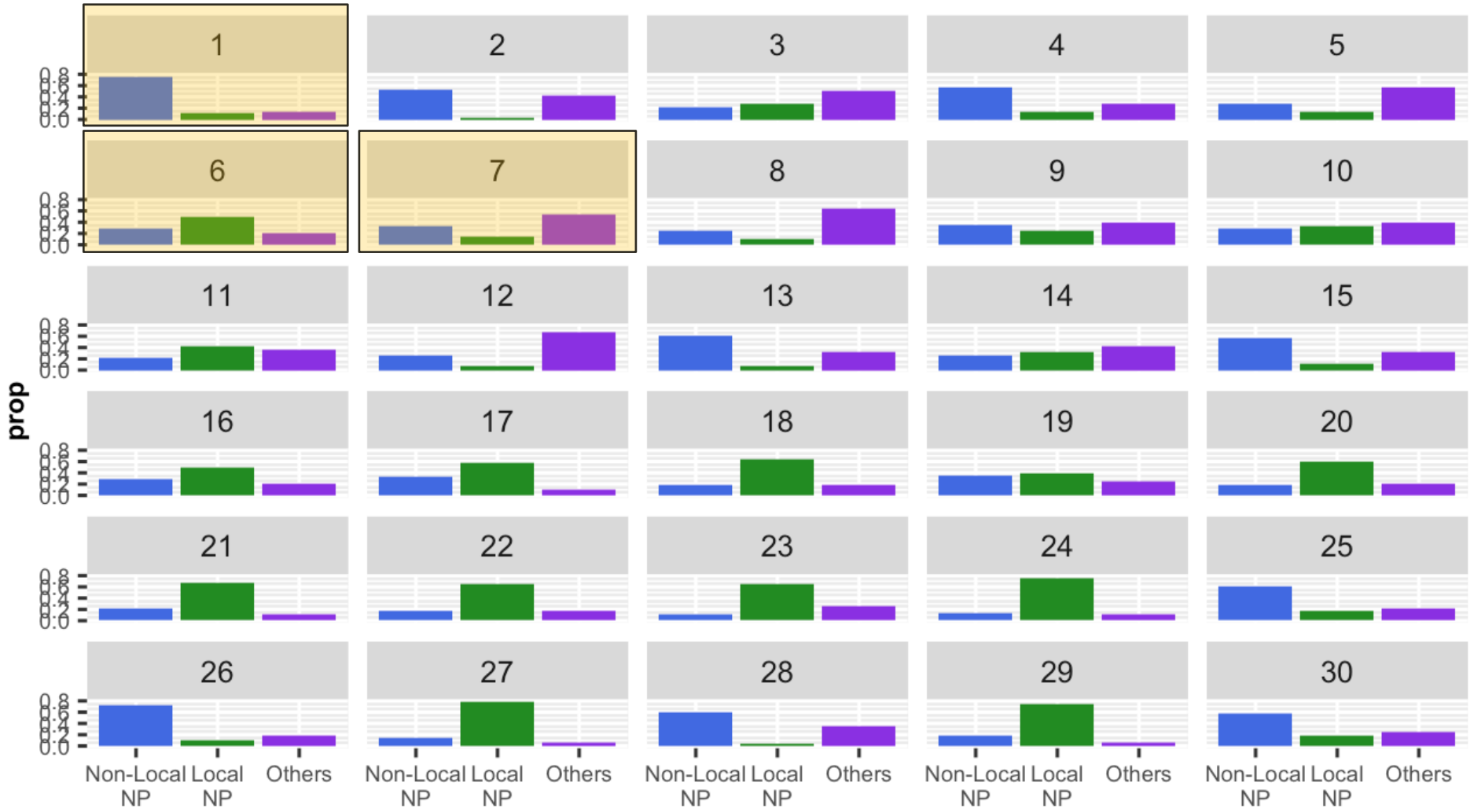
Pronoun	Coargument	Possessor
ziji	29.54%	**71.29%**
ta	**70.31%**	28.45%
taziji	0.15%	0.26%

EXPERIMENT 2 - WORLD KNOWLEDGE BIAS TEST

- Goal: To find out people's knowledge about the world. Who is more likely to be the theme/experiencer of an action, Non-local NP or Local NP or Others?
- Task: Given a **real-world situation** with a **question mark** in the target position, participants need to choose a character to fill the question mark based on their world knowledge.
- 30 item same as Exp. 1
- 28 valid participants



EXPERIMENT 2 - WORLD KNOWLEDGE BIAS RESULT



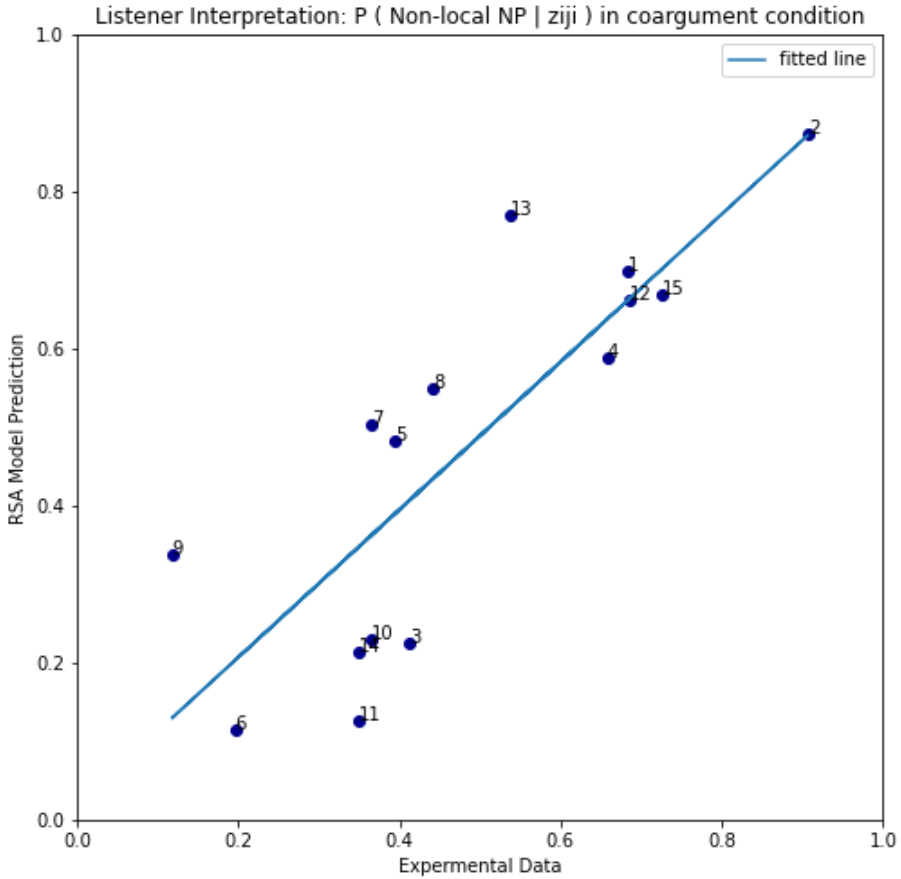
RSA MODEL RESULTS

Rational Listener $\propto$ World Knowledge $\times$ Rational Speaker

RSA MODEL RESULTS

(RATIONAL LISTENER ∝ WORLD KNOWLEDGE × RATIONAL SPEAKER)

RSA model does a good job in **all** ***ziji*** *(self)* condition.



Possibility of the listener to interpret ***ziji*** as **Non-local NP**

R-value = 0.821

P-value = 0.00017 < 0.05

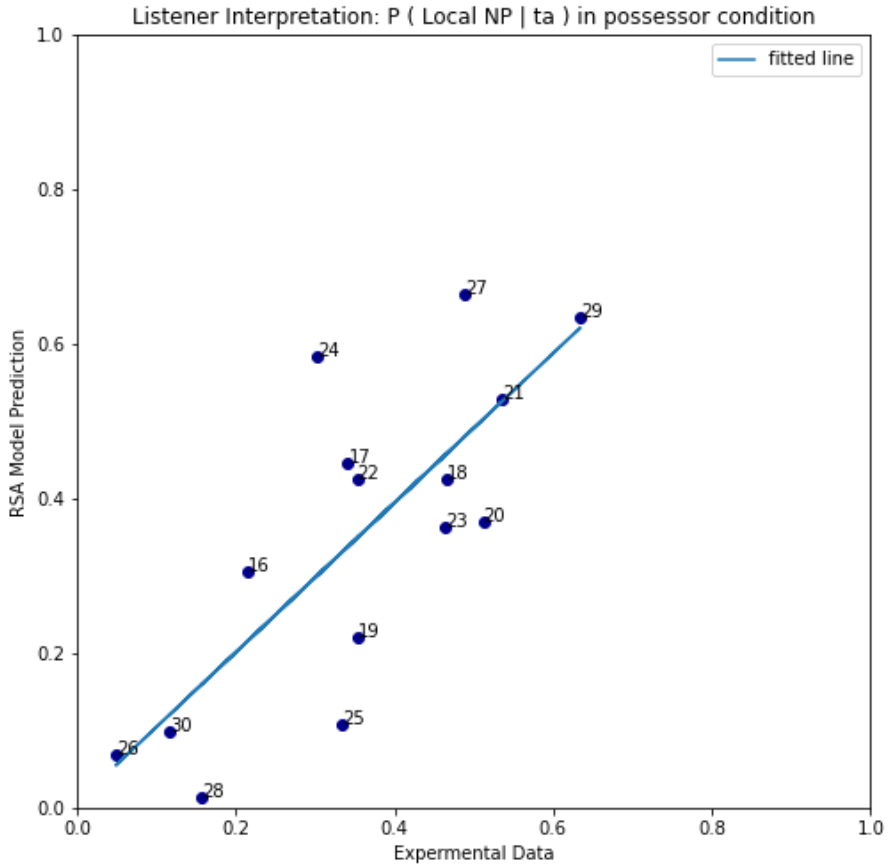
***

Grammatical Pairs = {
ziji **: Non-local NP, Local NP**
taziji **: Local NP**
ta **: Non-local NP, Local NP, Others}**

RSA MODEL RESULTS

(RATIONAL LISTENER ∝ WORLD KNOWLEDGE × RATIONAL SPEAKER)

RSA model performs well in **some** *ta* *(him)* condition.



Possibility of the listener to interpret ***ta*** as **Local NP**

R-value = 0.767

P-value = 0.0008 < 0.05

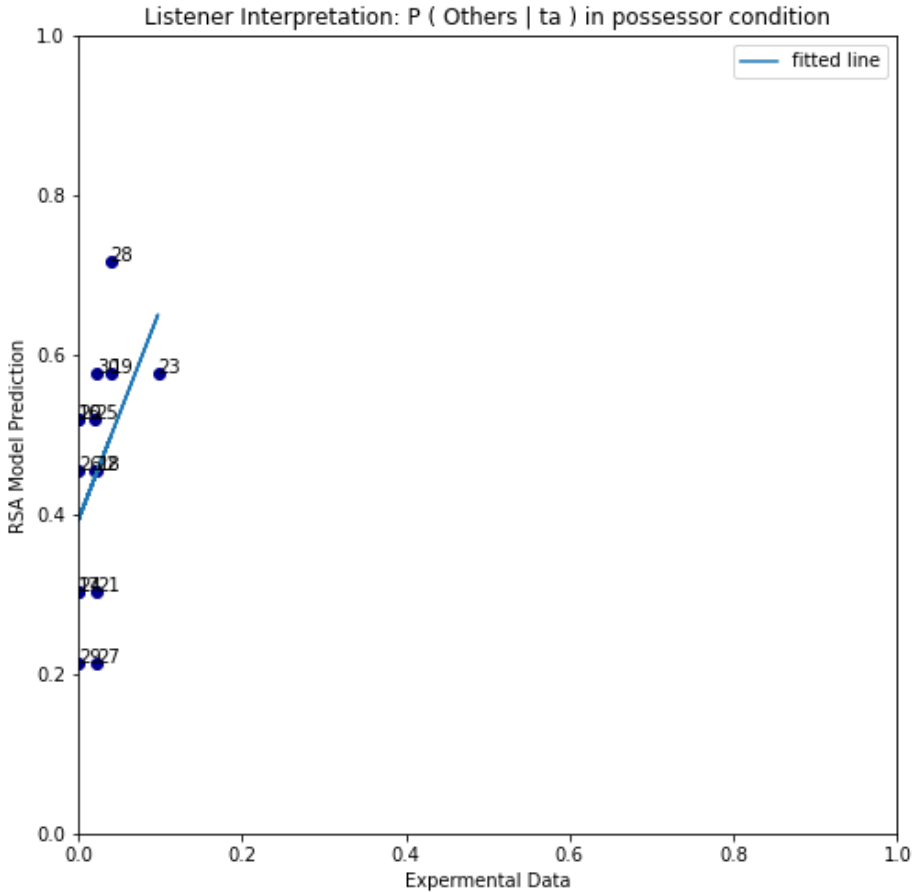
***

Grammatical Pairs = {
ziji **: Non-local NP, Local NP**
taziji **: Local NP**
ta **: Non-local NP, Local NP, Others}**

RSA MODEL RESULTS

(RATIONAL LISTENER ∝ WORLD KNOWLEDGE × RATIONAL SPEAKER)

RSA model performs well in **some** *ta* *(him)* condition.



Possibility of the listener to interpret ***ta*** as **Others**

R-value = 0.455

P-value = 0.088 > 0.05

X

Grammatical Pairs = {
***ziji* : Non-local NP, Local NP**
***taziji* : Local NP**
***ta* : Non-local NP, Local NP, Others}**

SUMMARY

The RSA model proposes that the listener imagines the speaker is choosing the message that can best communicate about the world and combines this with prior world knowledge to interpret ambiguous pronouns.

The RSA model fits most of the experimental data well, and this result points us in a direction for understanding listeners' reasoning when resolving ambiguous pronouns => **Probabilistic Listener & Recursive Reasoning between the listener and the speaker.**

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THANK YOU

RSA VS SIMPLE BAYESIAN MODEL

RSA: Rational Listener $\propto$ World Knowledge $\times$ Rational Speaker

Simple Bayesian Model (SBM):

$P(\text{referent} \mid \text{utterence}) \propto P(\text{referent}) \times P(\text{utterance} \mid \text{referent})$

EXPERIMENT 3 - PRONOUN PRODUCTION TASK

- Goal: To find out how people choose pronoun to refer to a given referent
- Task: Given a sentence with a gap in the target position and given a character, participants were asked to select the most natural pronoun from a drop-down menu to convey the character information.
- 30 root stimuli over 2 conditions

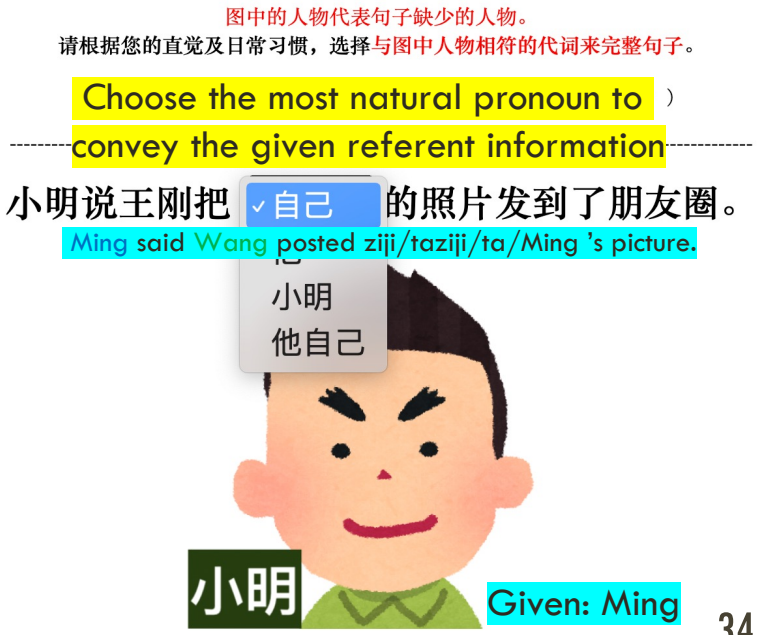
[Non-local NP, Local NP]

(since if we want to refer to Others,

the only possible pronoun is ta(him))

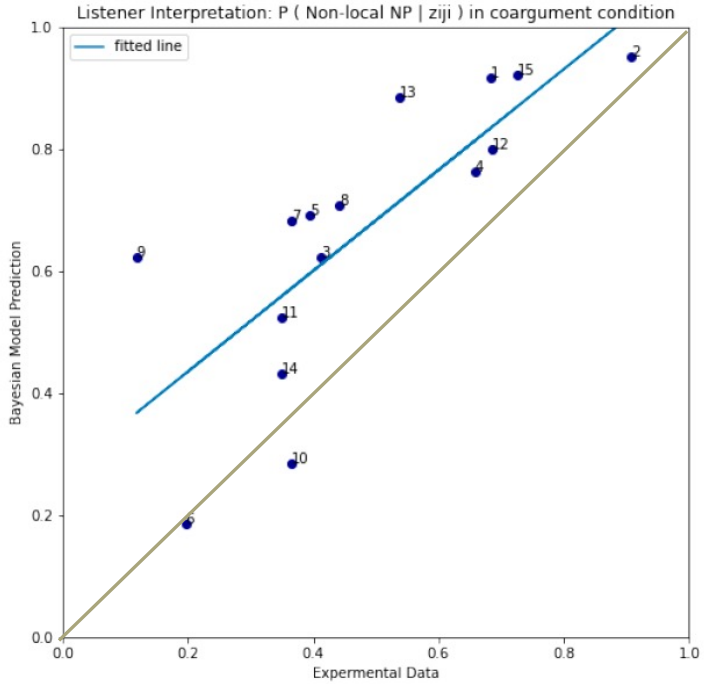
- 65 valid participants.

(Around 32 participants per condition)

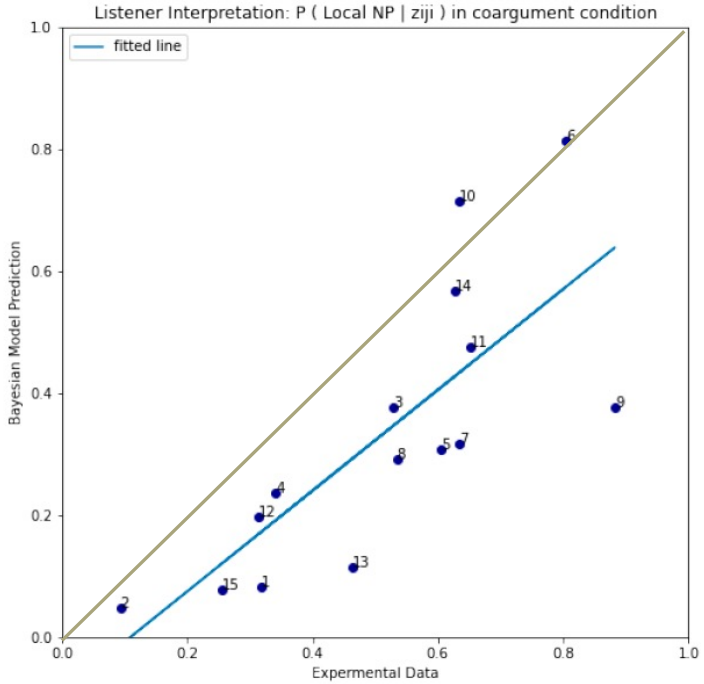


SBM: OVERFITTING AND UNDERFITTING ISSUE

Results for Bayesian Model (pronoun = ziji)



(i) *P(Non-local NP | ziji) in coargument condition*

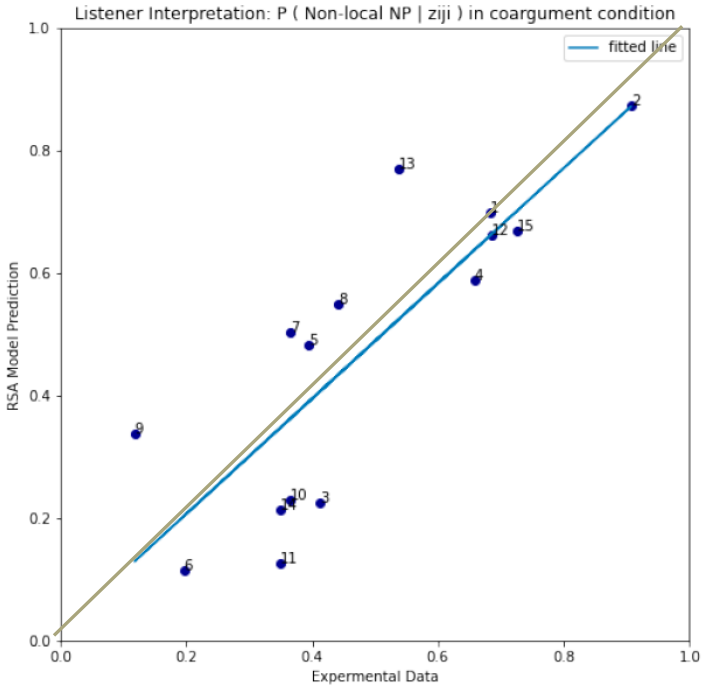


(ii) *P(Local NP | ziji) in coargument condition*

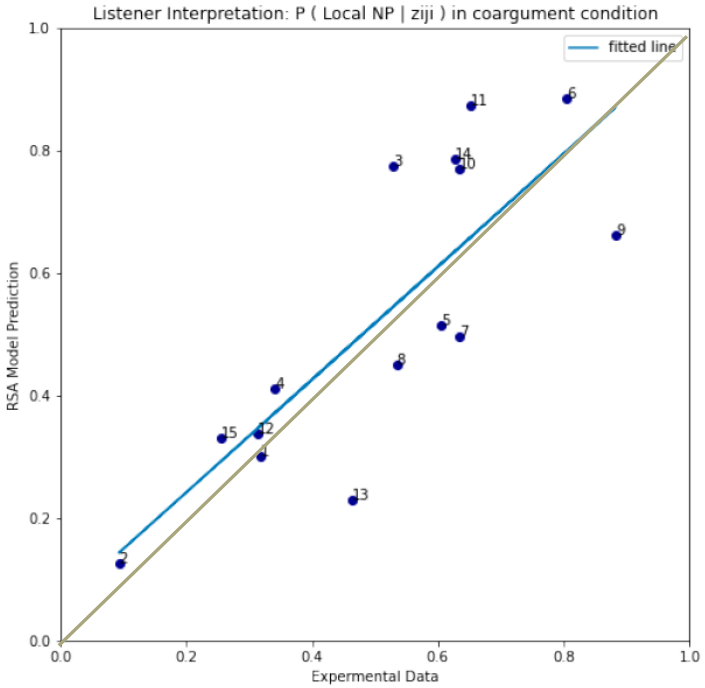
Dillon et al. (2016) shows a strong locality bias effect for *ziji* in self-paced reading measures. However this locality bias effect is not captured by simple Bayesian model.

RSA: MINOR OVERFITTING AND UNDERFITTING ISSUE

Results for RSA Model (pronoun = ziji)



(i) *P(Non-local NP | ziji) in coargument condition*



(ii) *P(Local NP | ziji) in coargument condition*

RSA model seems to include the locality bias.

STIMULI: CO-ARGUMENT

1. 把自己弄糊涂了。
2. 把自己出卖了。
3. 把自己照顾得很好。
4. 把自己当成小孩子了。
5. 把自己弄伤了。
6. 把自己想像成侦探了。
7. 把自己灌醉了。
8. 把自己绊倒了。
9. 把自己锁在教室里了。
10. 把自己逼得太紧了。
11. 把自己置于危险中。
12. 把自己气哭了。
13. 把自己吓坏了。
14. 把自己弄骨折了。
15. 把自己逗笑了。

1. confused ziji
2. betrayed ziji
3. took good care of ziji
4. treated ziji as a child
5. hurted ziji
6. imagined ziji as a policeman
7. got ziji drunk
8. tripped over ziji
9. locked ziji in the classroom
10. pushed ziji too hard
11. put ziji in danger
12. made ziji cry
13. scared ziji
14. broken ziji's bones
15. made ziji laugh

STIMULI: POSSESSOR

16. 把自己的照片发到了朋友圈。
17. 把自己的演讲稿修改了。
18. 把自己的想法忘记。
19. 把自己的作业遗漏了。
20. 把自己的遭遇讲给了别人听。
21. 把自己的工作做完了。
22. 把自己的想法表达出来了。
23. 把自己的孩子搂在了怀里。
24. 把自己的证件弄丢了。
25. 把自己的小狗找回来了。
26. 把自己的玩具模型弄坏了。
27. 把自己的房间打扫干净了。
28. 把自己的秘密告诉了别人。
29. 把自己的衣服捐掉了。
30. 把自己的文件删除了。

16. posted ziji's photos to social media
17. revised ziji‘s speech
18. forgot ziji‘s ideas
19. left out ziji‘s homework
20. told others ziji’s encounters
21. finished ziji's work
22. expressed ziji‘s idea
23. held ziji's child in arms
24. lost ziji's documents
25. found ziji's dog
26. broke ziji's toy model
27. cleaned ziji‘s room
28. told ziji's secret to others
29. donated all ziji's clothes
30. deleted ziji's documents

Formula 1. Simple Bayesian Model:

$$P(referent \mid utterance) \propto P(referent) \times P(utterance \mid referent)$$

Experiment 1 Experiment 2 Experiment 3

Formula 2. Rational Speech Act Model:

a. Rational Listener:

$$P(referent \mid utterance) \propto P(referent) \times Rational\ Speaker$$

Experiment 1 Experiment 2

b. Rational Speaker:

$$Rational\ Speaker = Literal\ listener - Cost(utterance)$$

Corpus study

c. Literal Listener:

$$Literal\ listener = Binding\ convention\ of\ the\ utterance \times P(referent)$$

Experiment 2