Limited involvement of Mandarin Chinese tone sandhi in prediction during language comprehension

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Comprehenders make predictions on the fly:
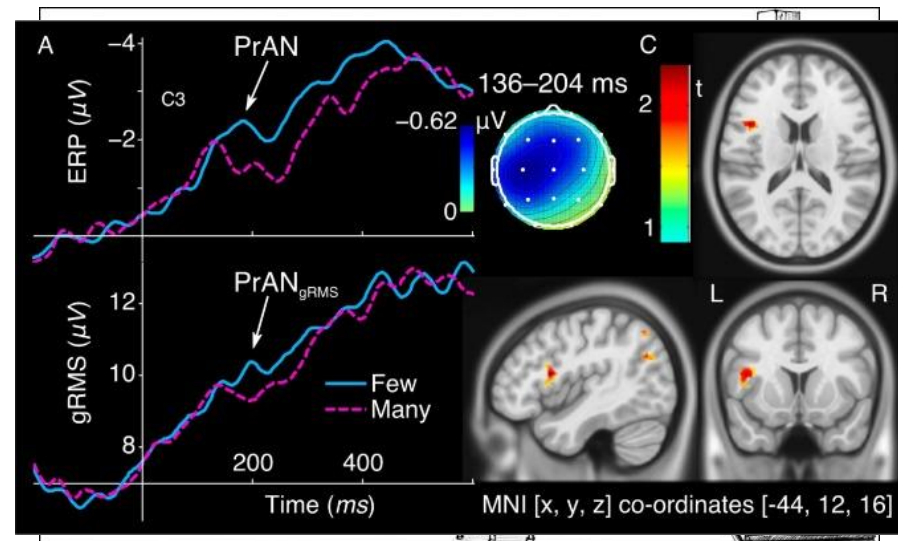
"I went to Starbucks to buy… coffee"

Using phonological information to predict

Ito & Speer (2008)
- Listeners use contrastive pitch accent to predict upcoming nouns
- "Find the blue ball. Now, find the …" "green ball" vs. "GREEN ball"

Roll et al. (2013, 2017)
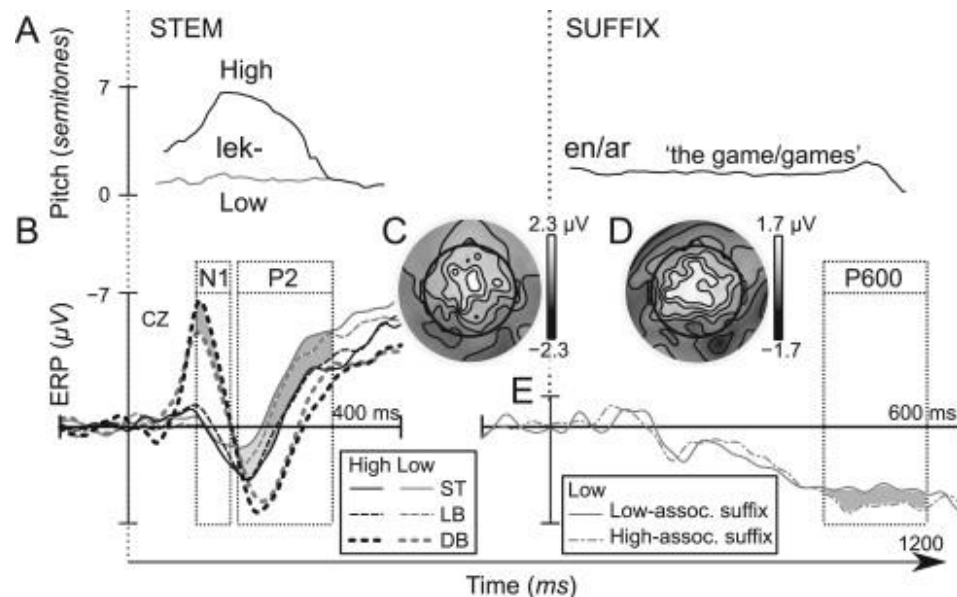- Swedish word-stem tones are used to predict suffixes and select candidates during word recognition

Predicting phonological form

Roll et al. (2010, 2013, 2015)
- P600 effect elicited by mismatching Swedish word-stem tones and suffixes

Delong et al. (2005)
- N400 effect elicited by mismatching English indefinite article (a/an) and the most predictable word's form

Using Mandarin Chinese tone sandhi as a test case

- Lexical tone: pitch contours that encode meaning
- *Ma1ma1 ma4 ma3*, mother scold horse, "Mother scolds the horse".

Xu (1997)

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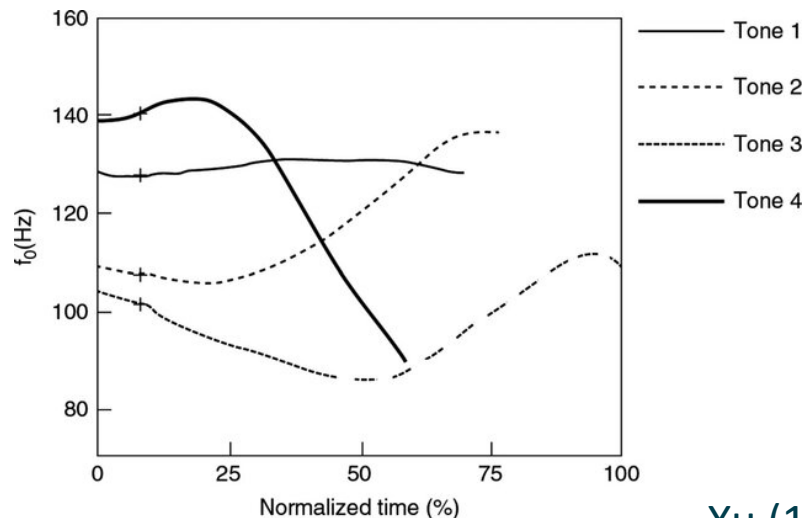
Tone sandhi: lexical tone can undergo change, triggered by neighbouring linguistic environment.

- The T3 sandhi:
  xiao3gou3 → *xiao2gou3* "small dog"

- The *yi* sandhi: numeral / indefinite article *yi1* "one"
  yi4tian1, *yi4tiao2*, *yi4ba3*, *yi2ge4*

- Both patterns are right-dominant and can potentially be used in prediction

Initial evidence suggests listeners may use the *yi* sandhi to predict (Liu et al., 2023, preprint)

Experiment 1: (Huo & Chow, 2023, preprint)
Can listeners use tone sandhi in a numeral to predict an upcoming classifier and noun?
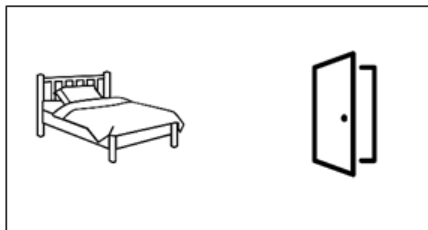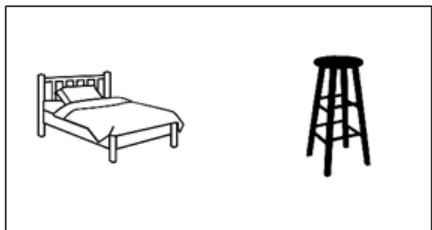
T3 sandhi ("liang")

"李 叔叔 看到 两 张 床。"
"Li3 shu1shu kan4-dao4 liang3 zhang1 chuang2."
 Li uncle see-PAST two CL_zhang bed
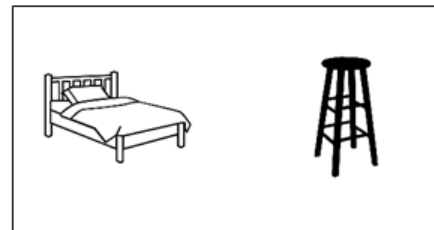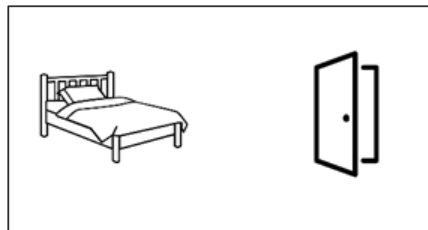"Uncle Li saw two beds."

Yi sandhi ("yi")

"李 叔叔 看到 一 张 床。"
"Li3 shu1shu kan4-dao4 yi4 zhang1 chuang2."
 Li uncle see-PAST one CL_zhang bed
"Uncle Li saw one bed."

Condition

Different Tones   **Same Tones**

两 张 床   两 把 凳子
liang3 zhang1 chuang2   liang2 ba3 deng4zi
two CL_zhang bed   two CL_ba stool

两 张 床   两 扇 门
liang3 zhang1 chuang2   liang3 shan4 men2
two CL_zhang bed   two CL_shan door

Condition

Different Tones   **Same Tones**

一 张 床   一 扇 门
yi4 zhang1 chuang2   yi2 shan4 men2
one CL_zhang bed   one CL_shan door

一 张 床   一 把 凳子
yi4 zhang1 chuang2   yi4 ba3 deng4zi
one CL_zhang bed   one CL_ba stool

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Results: Experiment 1A, eye-tracking
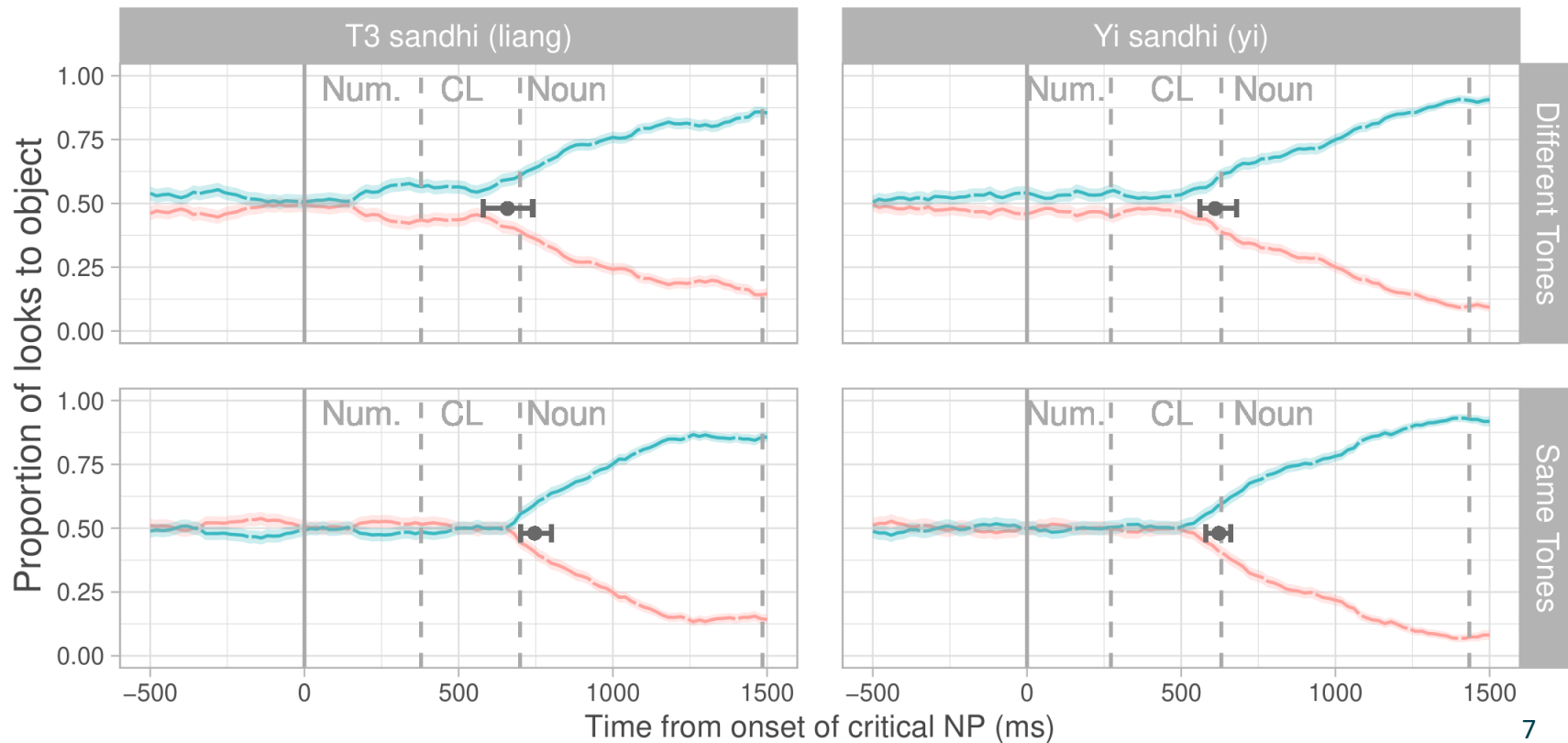
Follow-up:
Sensitivity to tone sandhi violations, acceptability judgment task

一个

consistent
🔈 "Yi2 ge4"
**violating**
🔈 "Yi4 ge4"

- Listeners were highly sensitive to tone sandhi
  - Both the T3 sandhi and the *yi* sandhi
  - A larger individual difference in sensitivity to T3 sandhi

- Listeners' inability to predict is not because of an insensitivity to its violations
  - i.e. they know that *yi4* is not compatible with *ge4*

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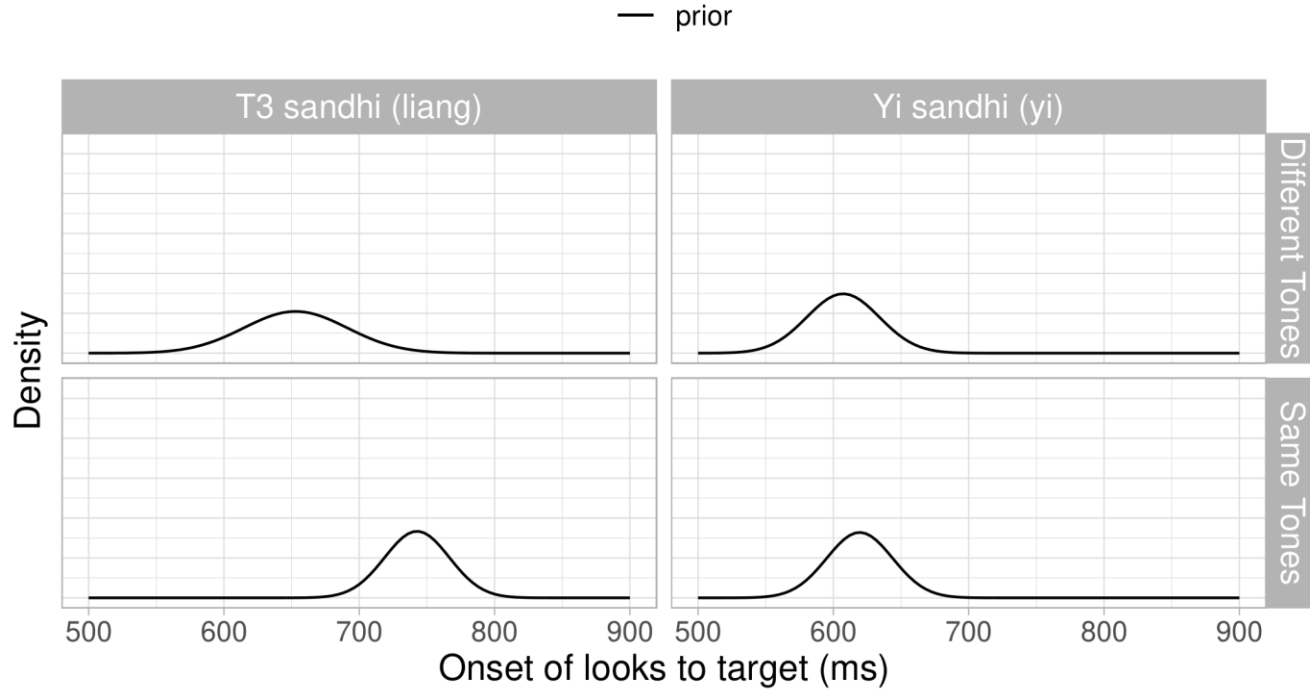# Results: Experiment 1B, direct replication of 1A + follow-up
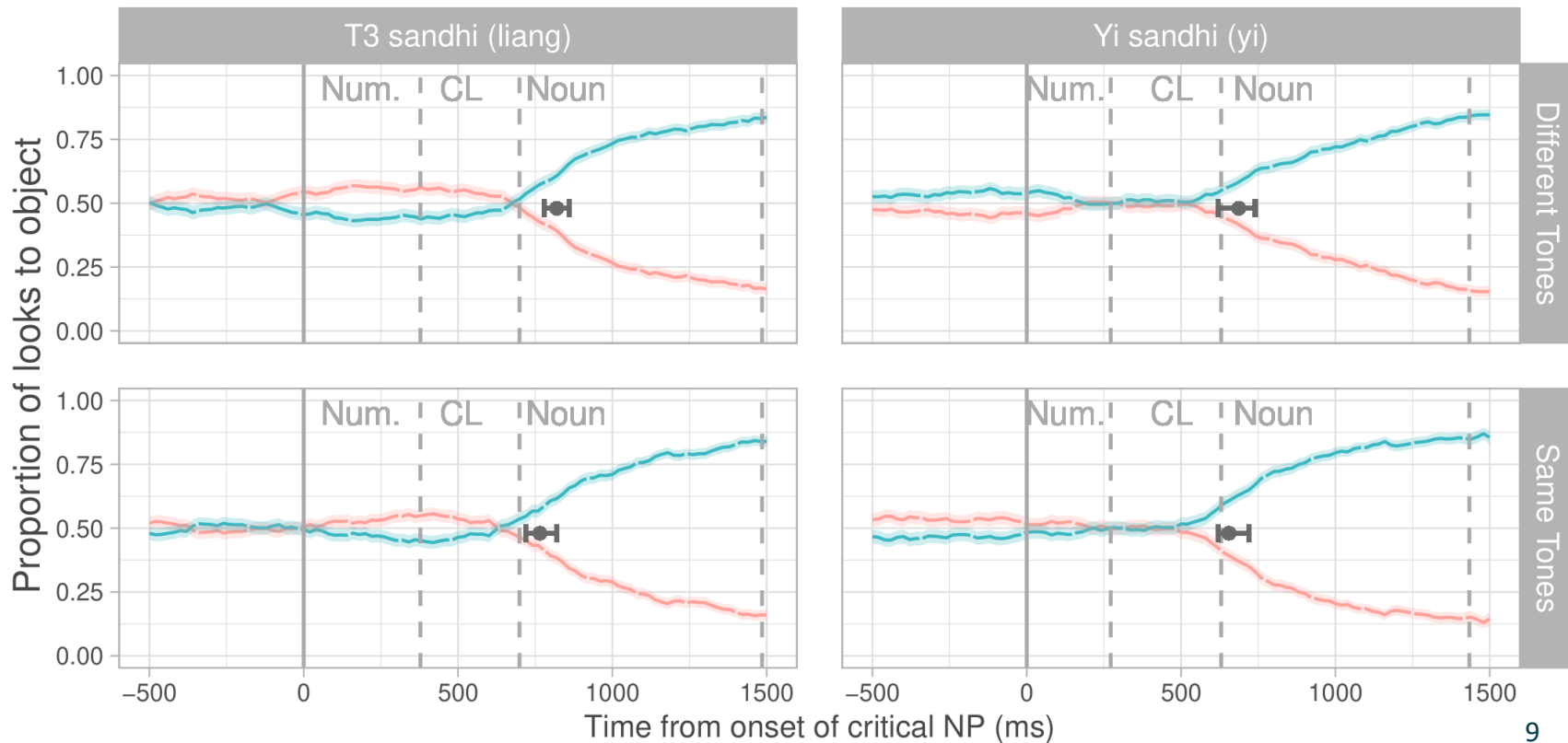
No correlation between listeners' T3 sandhi sensitivity and their ability to use T3 sandhi to predict
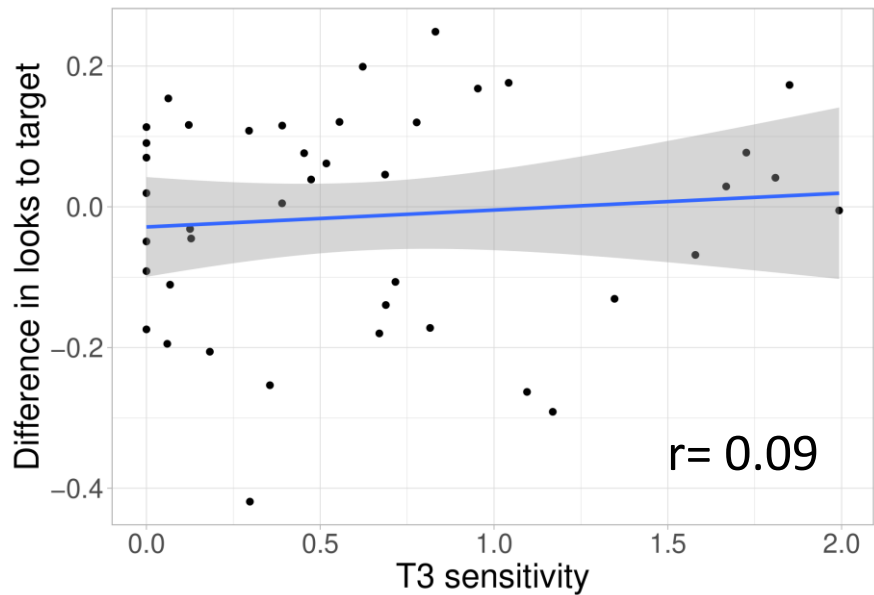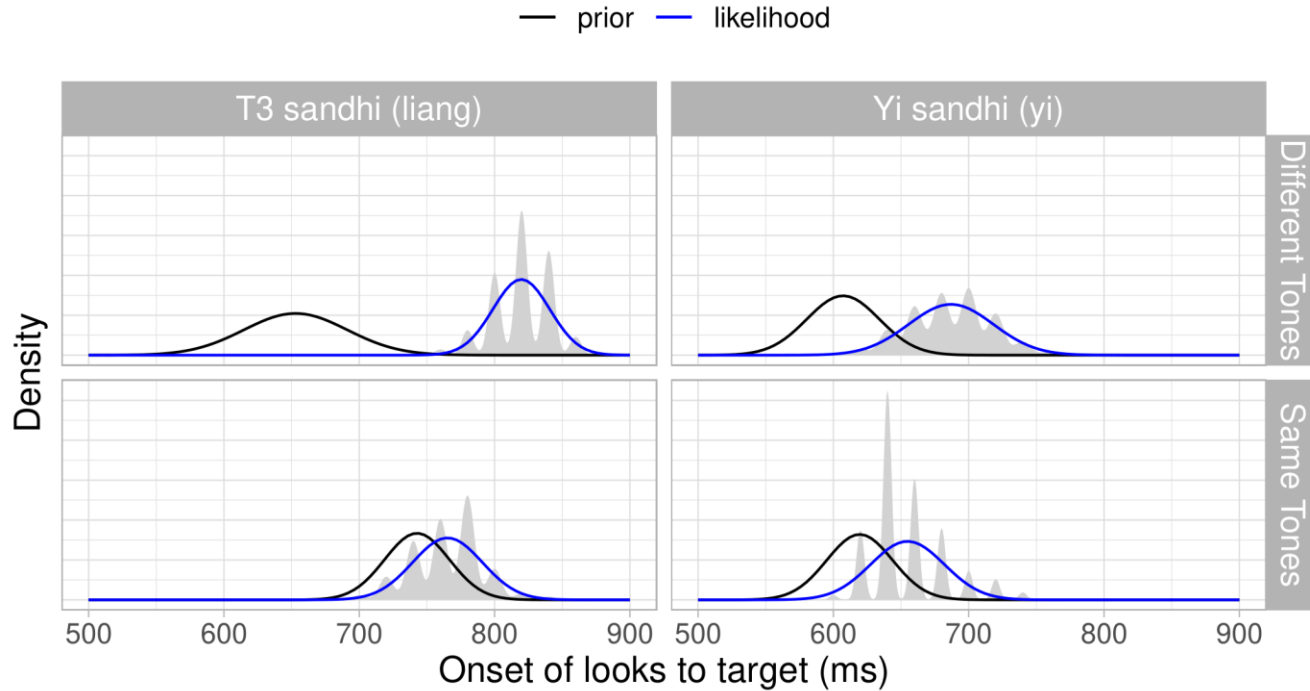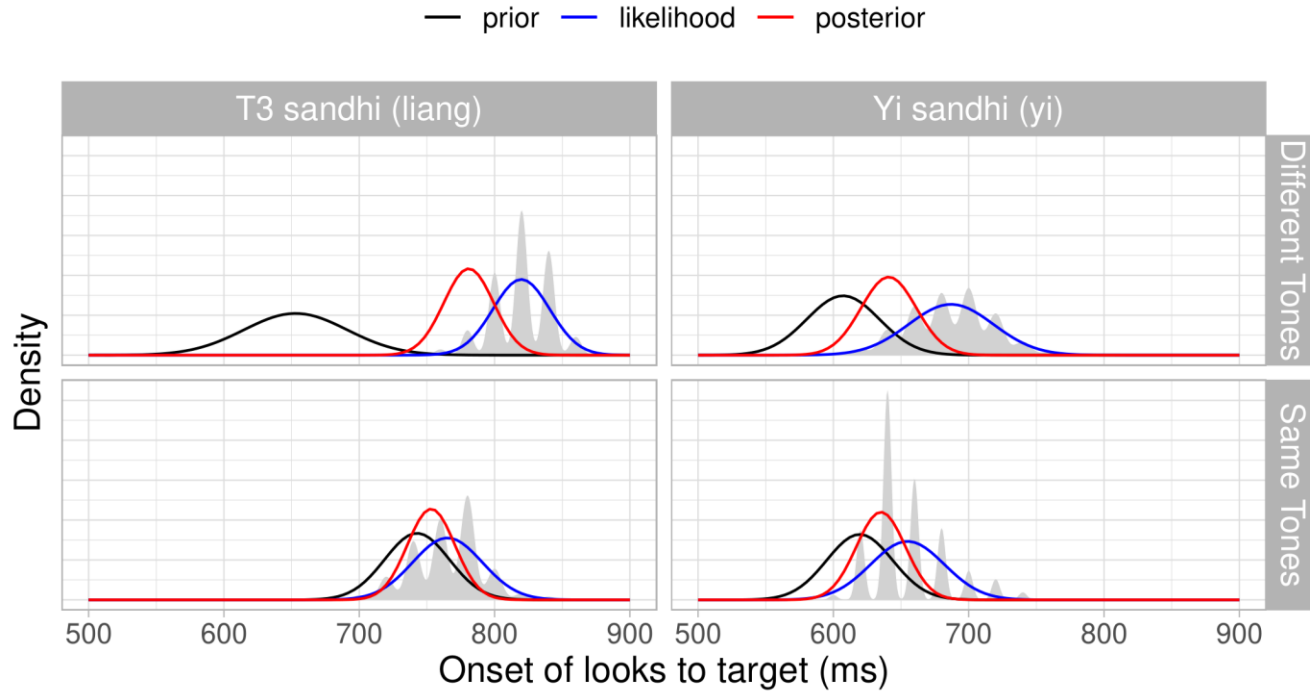

r= 0.09

Applying Bayesian principles to Experiments 1A and 1B
(following Stone, 2021)

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(following Stone, 2021)

Experiment 1:

Can listeners use tone sandhi in a numeral to predict an upcoming classifier and noun?

> **Perhaps not.**
>
> Listeners are highly sensitive to tone sandhi patterns (at the numeral position).
>
> However, we cannot find robust evidence that they can predict an upcoming noun based on tone sandhi in a numeral.
>
> …we also have converging results from mouse cursor tracking.

Experiment 2: (Huo & Chow, in prep)

Can listeners use the tone of a numeral to detect that their noun prediction is wrong (and update it accordingly)?

🔊 "安妮在星巴克买了一块蛋糕/一瓶水。"
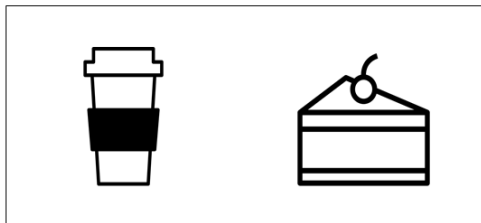(At Starbucks, Anne bought a piece of cake/a bottle of water)

Different Tones	**Same Tones**
"一 块 蛋糕"	"一 瓶 水"
yi2 kuai4 dan4gao1	yi4 ping2 shui3
one CL$_{piece}$ cake	one CL$_{bottle}$ water
a piece of cake	a bottle of water

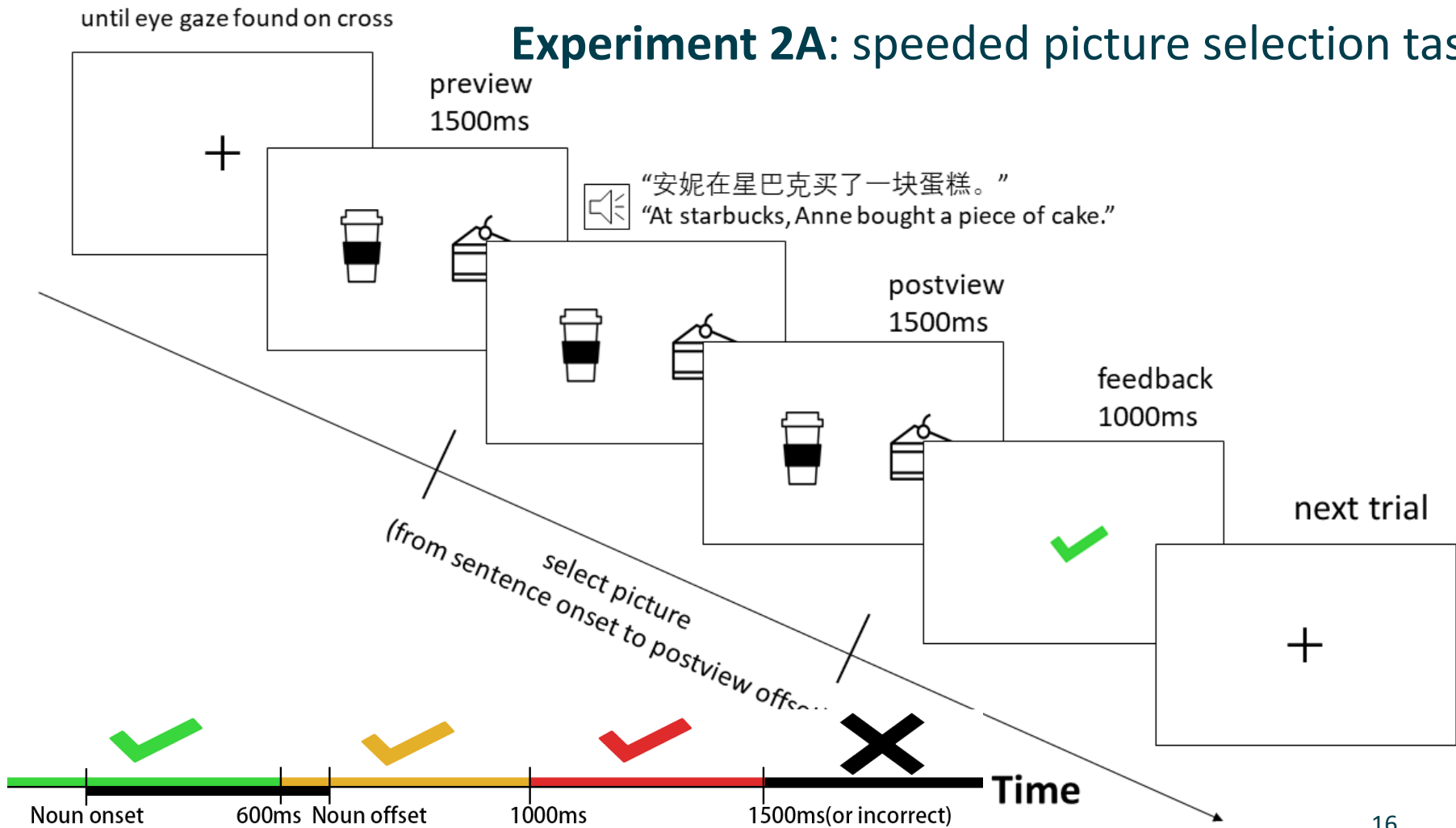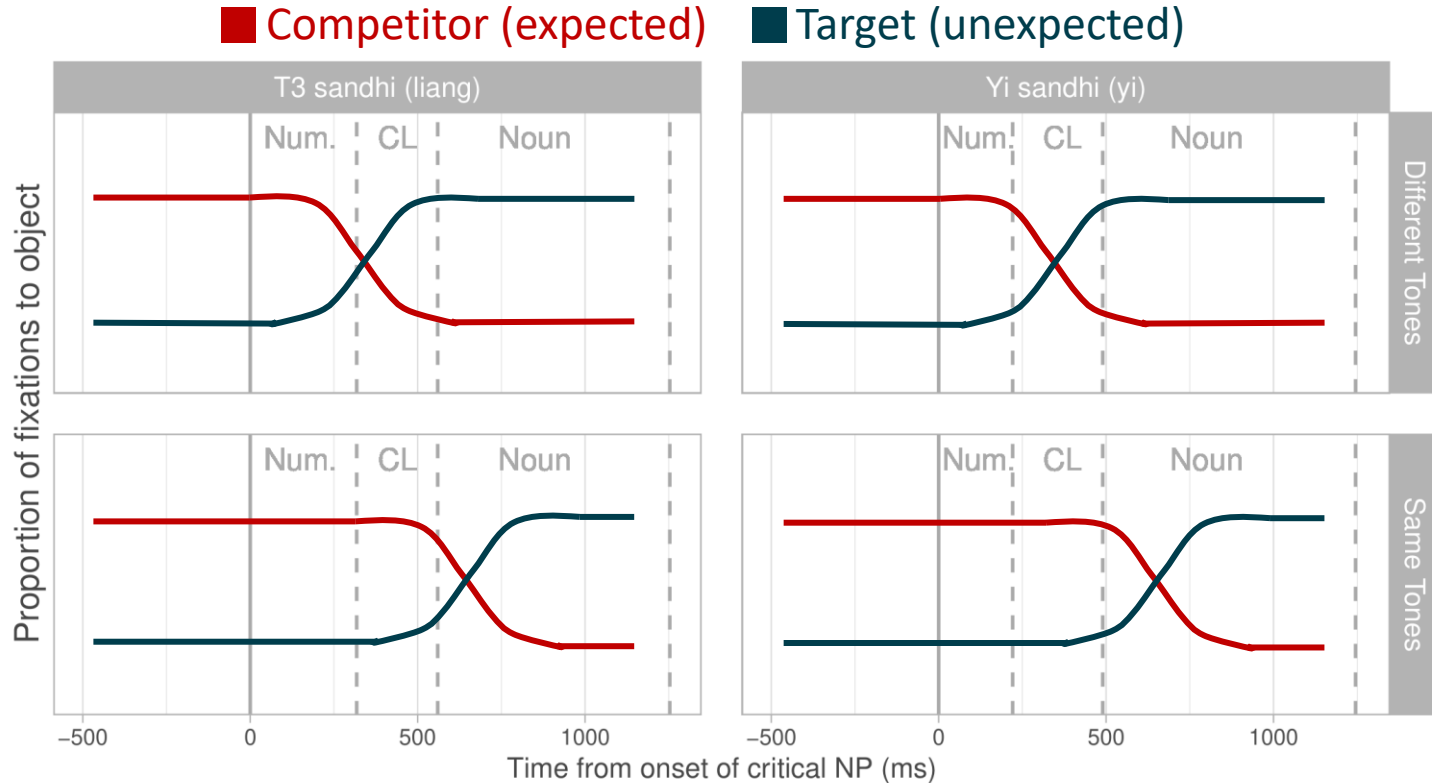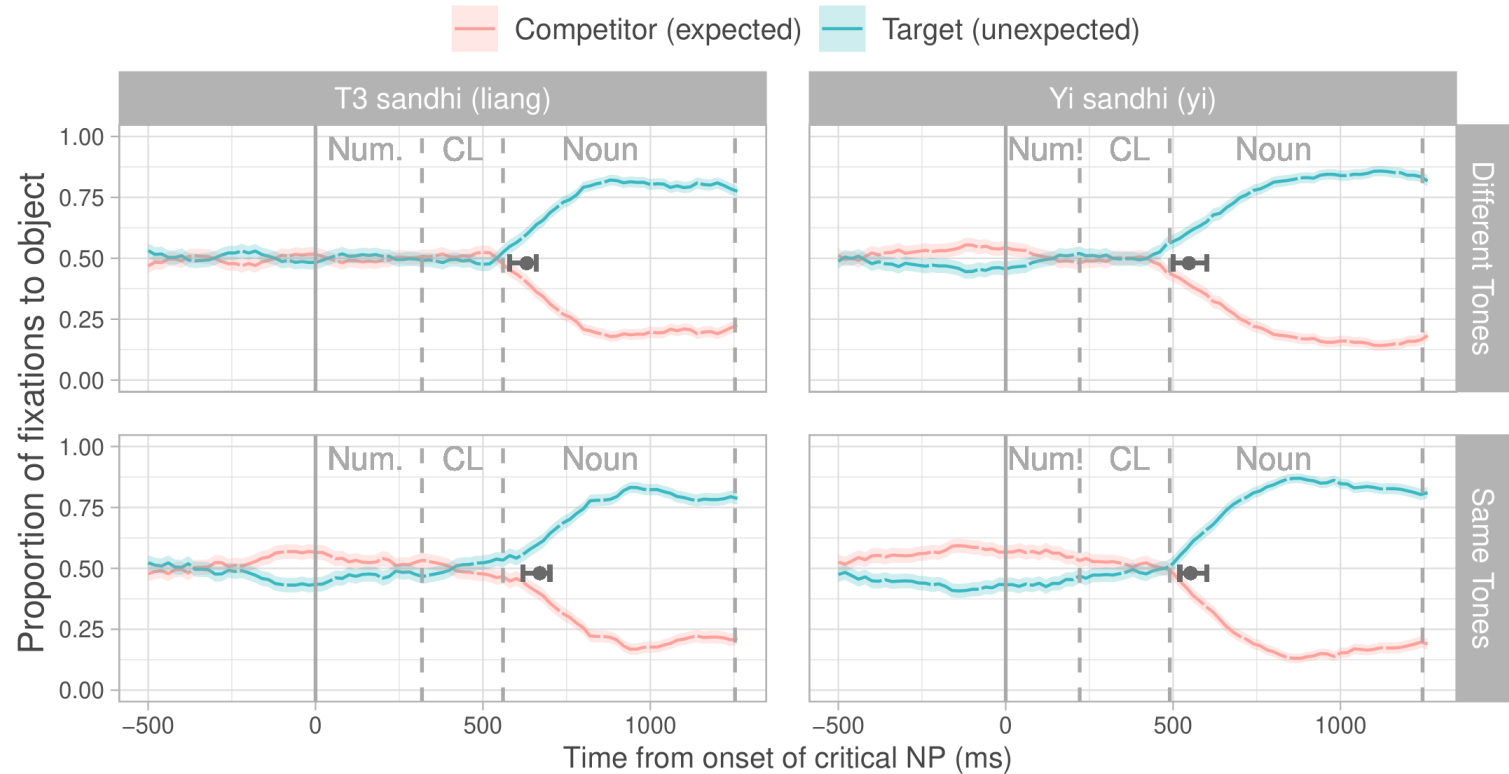| 一 杯 咖啡	一 块 蛋糕	一 杯 咖啡	一 瓶 水
yi4 bei1 ka1fei1	**yi2** kuai4 dan4gao1	yi4 bei1 ka1fei1	yi4 ping2 shui3
one CL$_{cup}$ coffee	one CL$_{piece}$ cake	one CL$_{cup}$ coffee	one CL$_{bottle}$ water

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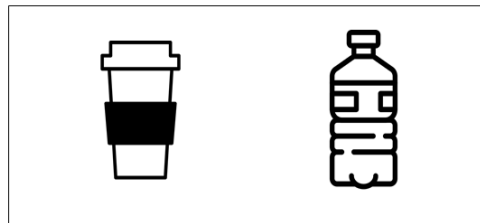
Experiment 2A: speeded picture selection task

Prediction of results: Experiment 2A

If listeners can use tone sandhi in numerals to update predictions

Results: Experiment 2A, speeded picture selection task

until eye gaze found on cross

preview
1500ms

"安妮在星巴克买了一块蛋糕。"
"At starbucks, Anne bought a piece of cake."

postview
1500ms

(following some filler items)
comprehension question

安妮是去了星巴克吗?
Did Anne go to Starb

next trial

Experiment 2B: passive listening task (with comprehension questions)

Time

19
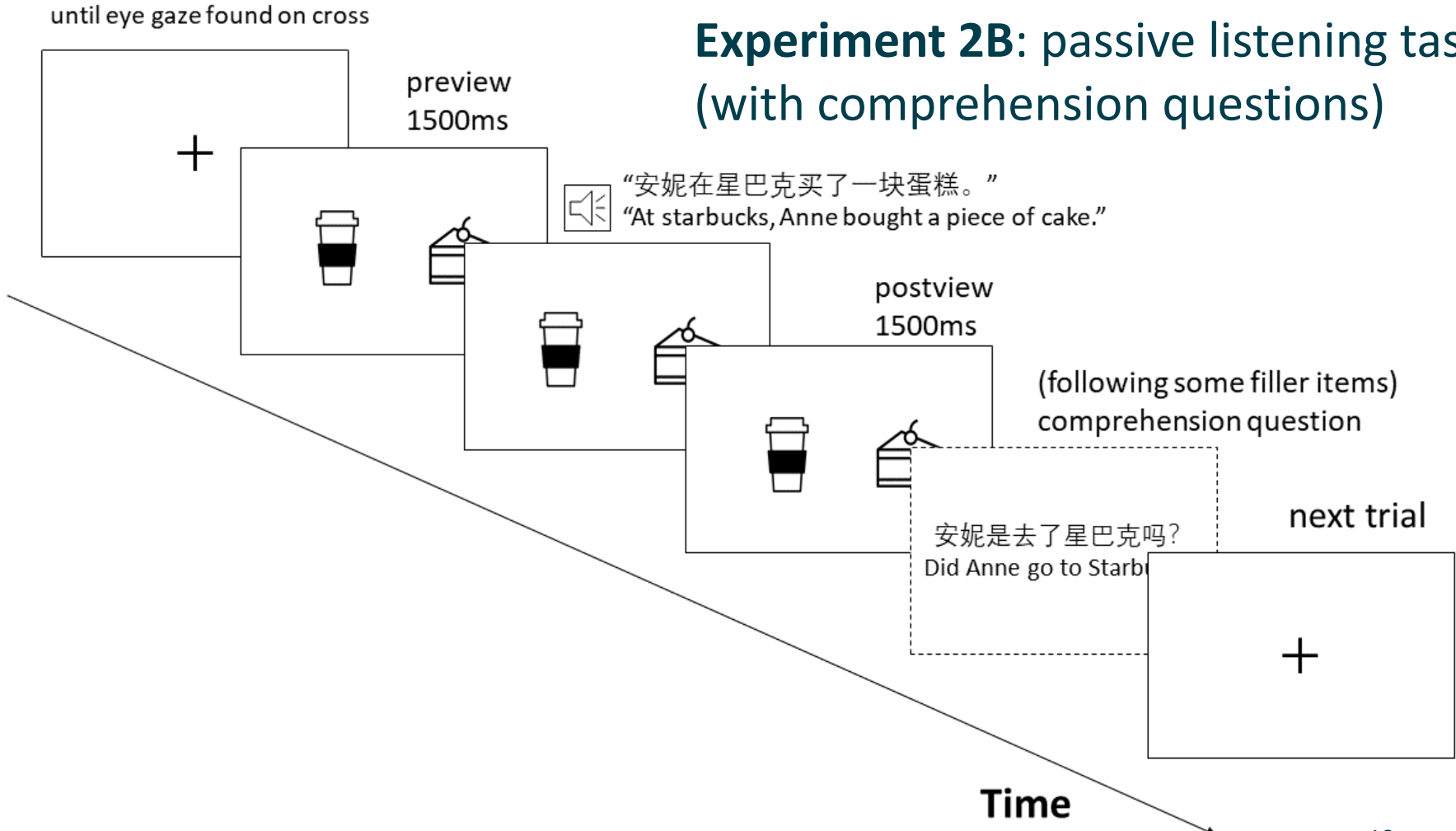
Results: Experiment 2B, passive listening task
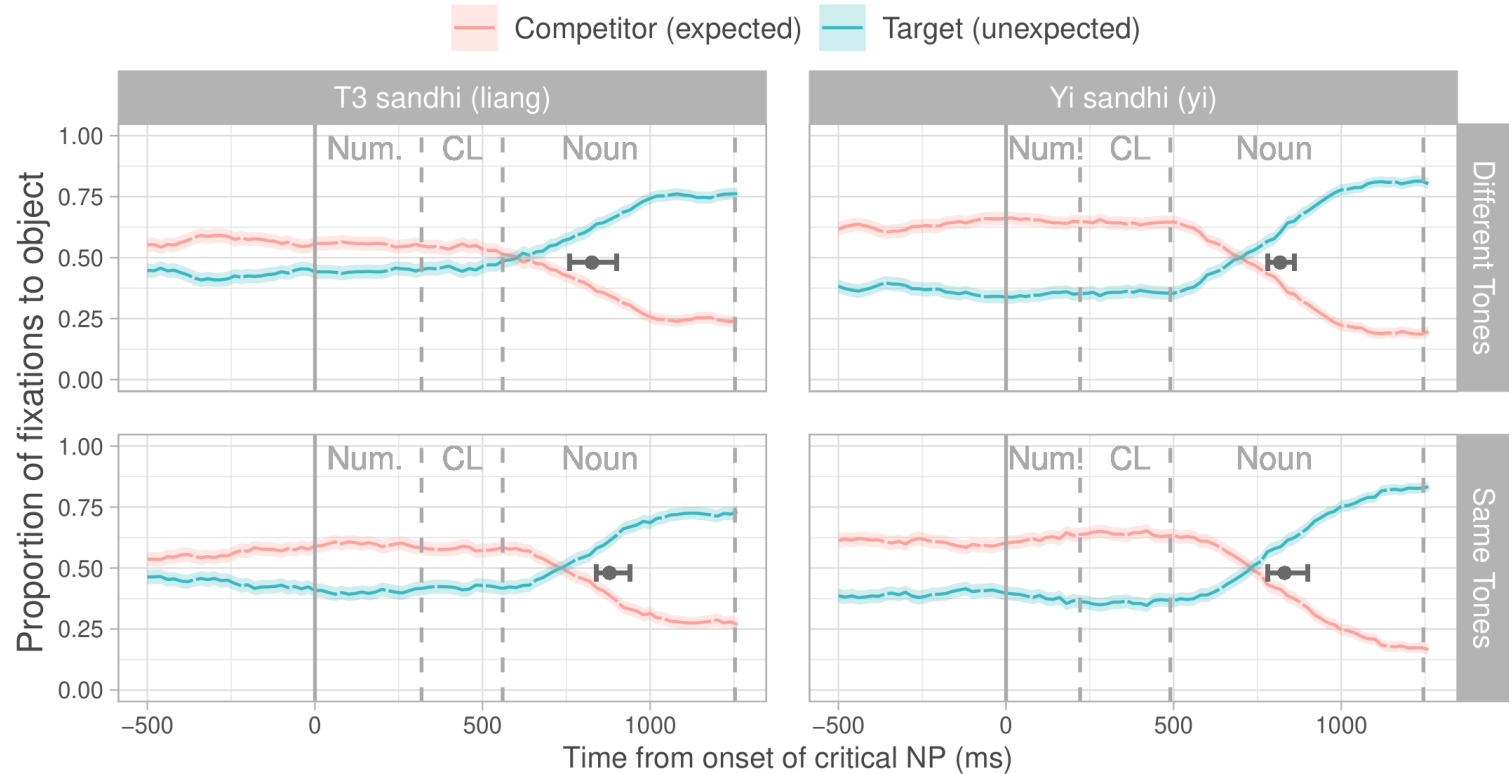
Experiment 2: Can listeners use the tone of a numeral to detect that their noun prediction is wrong (and update it accordingly)?

Perhaps not.
Looks to the unexpected target were not earlier in the Different Tones condition than in the Same Tones condition.
Again, this is surprising given that listeners are highly sensitive to these tone sandhi patterns.

The speeded picture selection task seemed to have inhibited listeners' initial prediction (Starbucks...coffee).

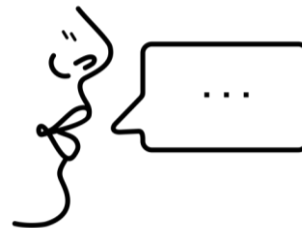Is tone sandhi not involved in predictive processing at all?

Experiment 3: (in prep)

Do speakers use tone sandhi in a numeral to predict in a sentence completion task?
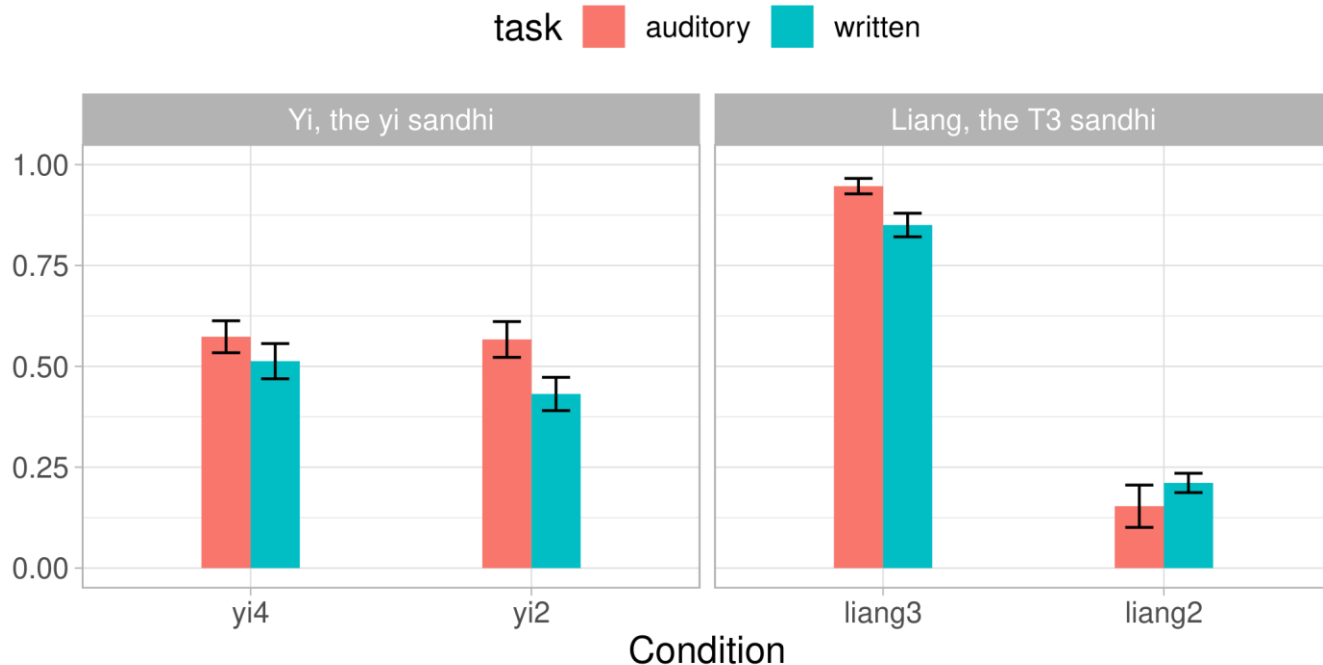
Neutral sentence context:

🔊 "As Wang entered the room, they saw that on the table there'd been *yi4/yi2/liang3/liang2...*"

Auditory cloze task vs. written cloze task (baseline, no tones)

Results Experiment 3: "As Wang entered the room, they saw that on the table there'd been one/two…"

Proportion of tone–consistent responses

Experiment 3:
Do speakers use tone sandhi in a numeral to predict in a sentence completion task?

Yes, but only to a small extent.

Having the tonal information in the auditory cloze task increased the proportion of tone-consistent responses.

However, participants' performance was far from perfect.

Summary

- Native listeners are perceptually highly sensitive to tone sandhi patterns.
- Tone sandhi information in numerals modulates cloze predictability (i.e. listeners show some sensitivity to tone sandhi in the cloze task).

- However, we found no eye-tracking evidence that listeners could use tone sandhi cues in numerals to predict an upcoming noun or update a previously made noun prediction.

Further steps:
- Tone sandhi in sentence completion: a forced choice task
- Effect of task on predictions made from the context

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Thank you!
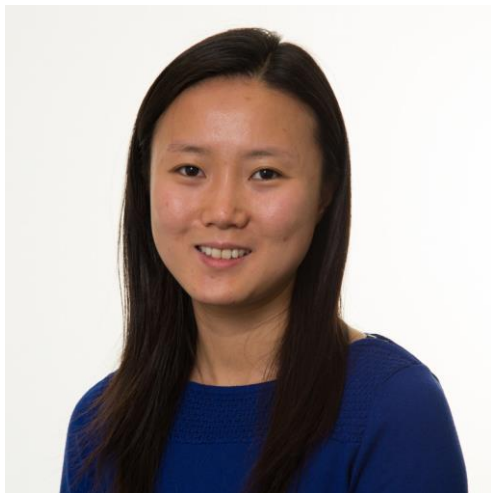
Dr. Wing-Yee Chow (PI)

Kayla Chen
(mouse cursor tracking
collaboration)

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