Tone Development and Change

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About me

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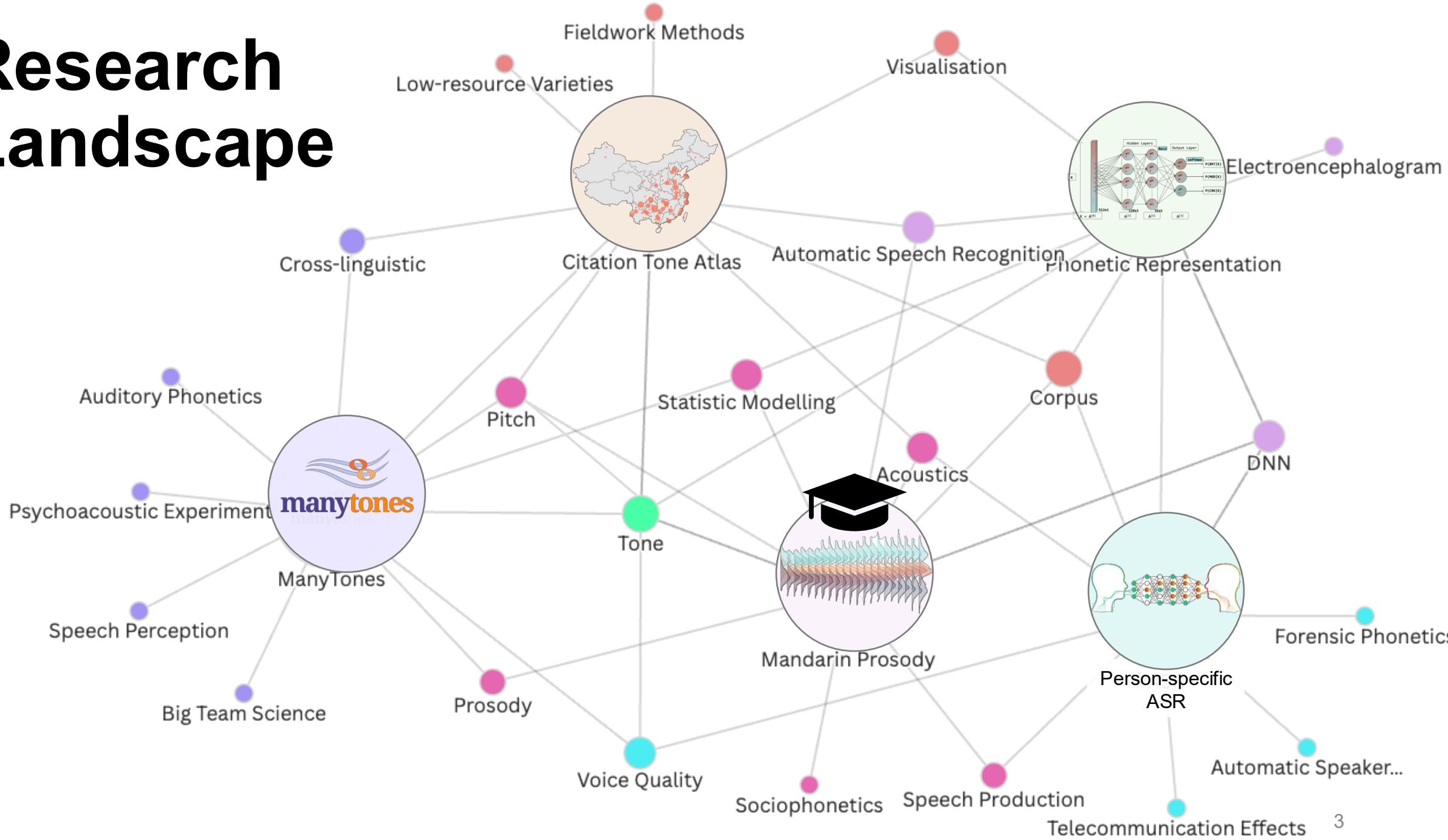
Research Landscape



RoadMap

1. Background
   - What is tonal representation?
   - Mandarin Tones and their representations
   - Neutral Tone: properties and approaches
2. Tone Change: Case Study of **Plastic Mandarin**
   - Research questions and hypotheses
   - Sociohistorical context for new dialect formation
   - Development of Plastic Mandarin and its tones
   - Data and Method
   - Results and discussion
3. Tone Development: **ManyTones** project
   - Research questions
   - Data and Method
   - Preliminary results and discussion
4. Conclusion

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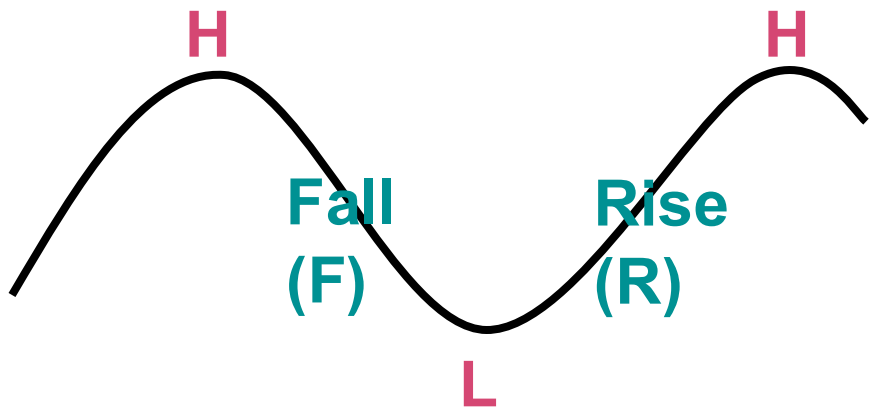
What is phonological representation? Why do we need it?

Abstract model that

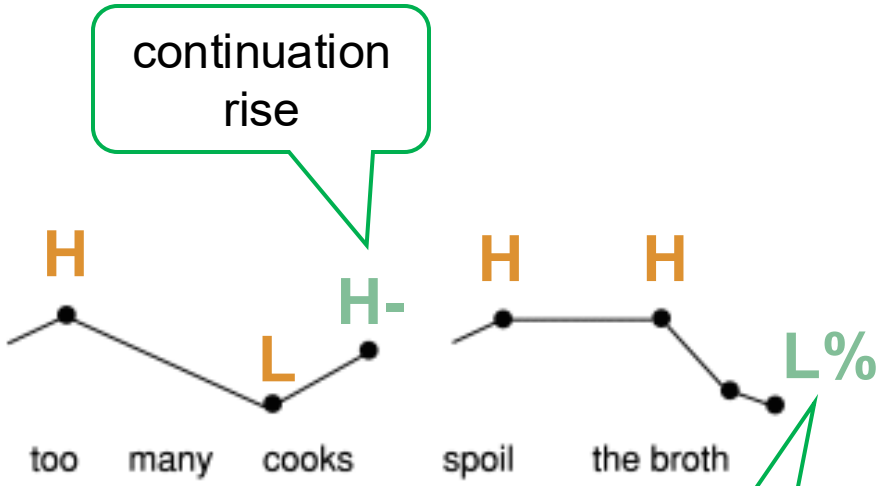
- captures **systematic** patterns in the sound structure of languages
- enables **general** and **predictive** understanding of the patterns
- *aligns well with implicit knowledge or **mental** representation (cognitively plausible)
- *supports computation of some kind (generation, parsing)

What is meant by tonal representation?

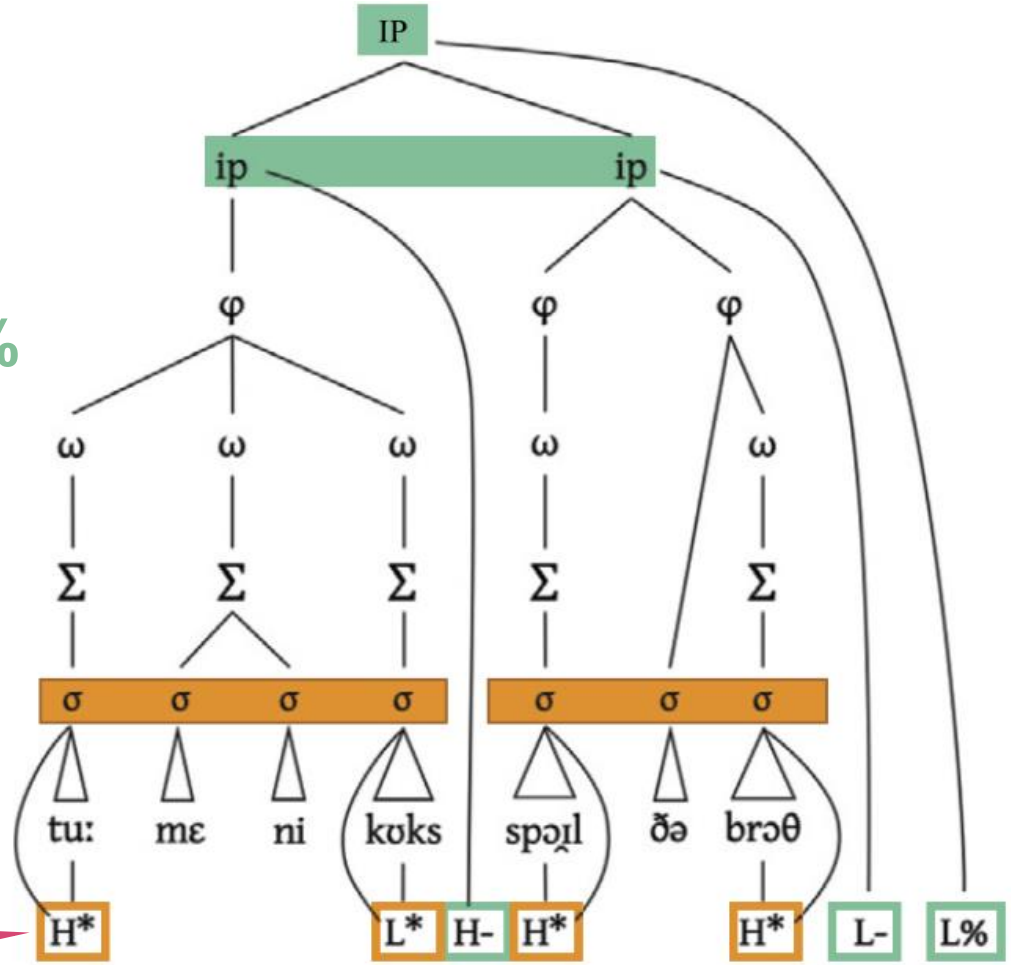
- Model continuous pitch movement in **discrete** categories
- Understand how pitch functions systematically
- Reveals underlying **regularities** across languages and dialects
- Allows us to explain and predict pitch contrasts and variation



What is meant by tonal representation?



The Autosegmental-Metrical Prosodic Tree (from Grice, 2022)



Too many cooks spoil the broth

Intonational Phrase

intermediate phrase (Minor intonational phrase)

Phonological phrase

Phonological word (prosodic word)

Foot

Syllable

Segmental structure

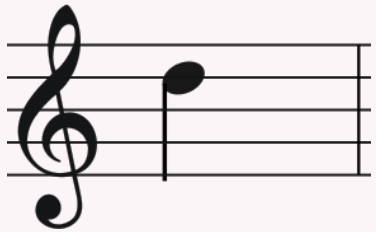
Tune

Tonal features are represented on a separate tier from phonemes

(Standard) Mandarin Tones

55 ˥˥

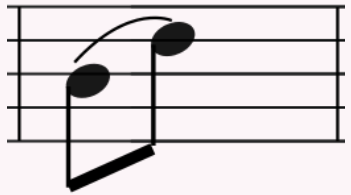
cat → mao → 猫



1

35 ˧˥

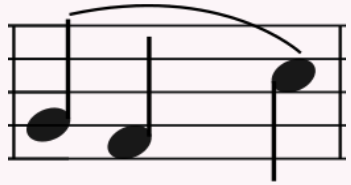
cat ↗ mao ↗ 毛

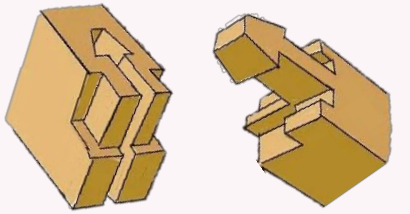


2

214 ˨˩˦

cat ↗↘ mao ↗↘ 卯

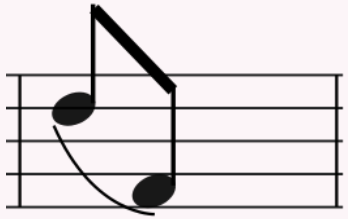




3

51 ˥˩

cat ↘ mao ↘ 帽



4

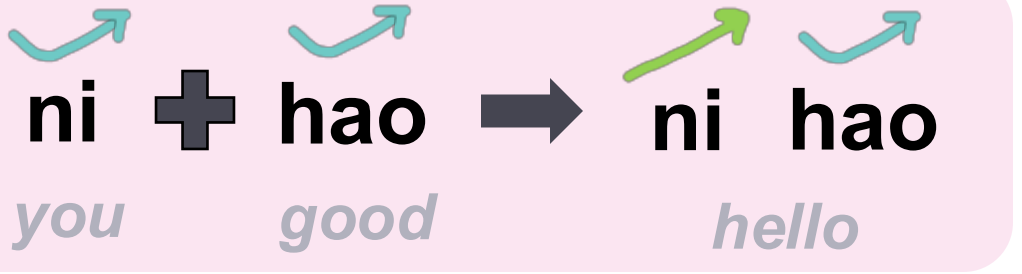
Many Representations of Tone

1	55 ˥˥	H	H
2	35 ˧˥	LH	R
3	214 ˨˩˧	L	L
4	51 ˥˩	HL	F

(Chao, 1930, 1948, 1968) (Duanmu, 2000) (Xu & Wang, 2001)

Tones change in context

T3 → T2 / __ T3



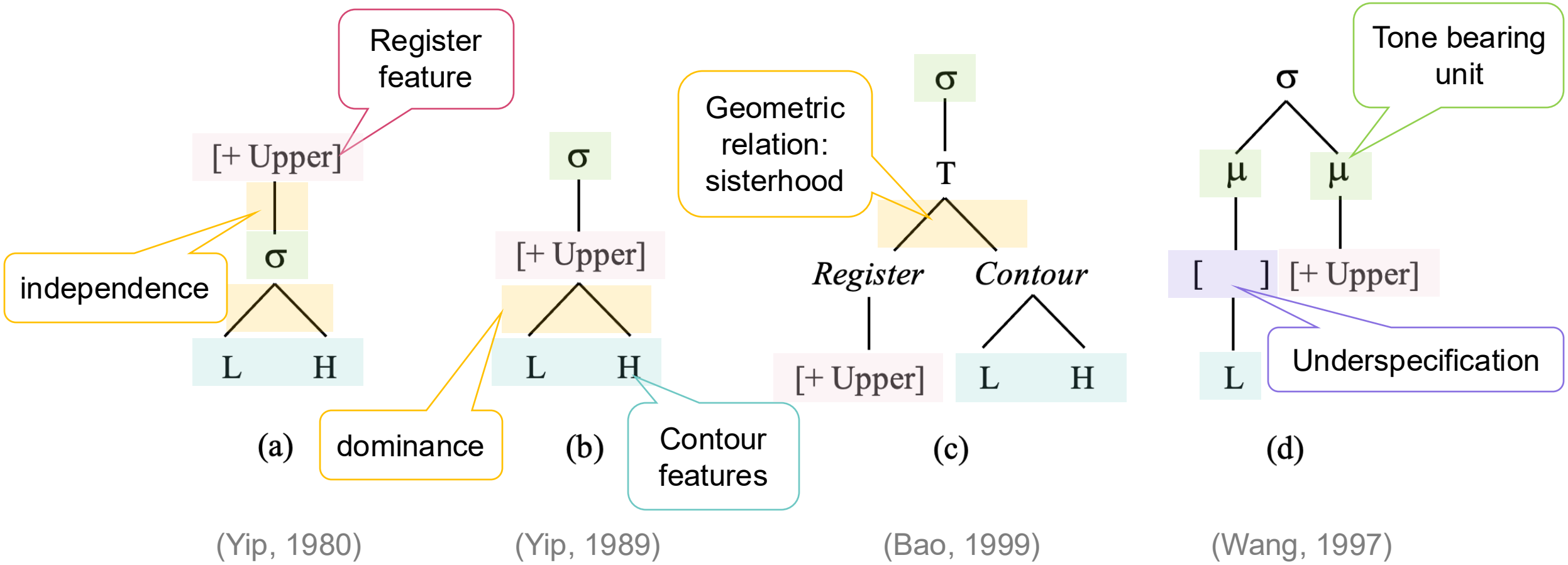
214 → 35 / __ 214

Underlying Representation

L → LH / __ L

Surface Form

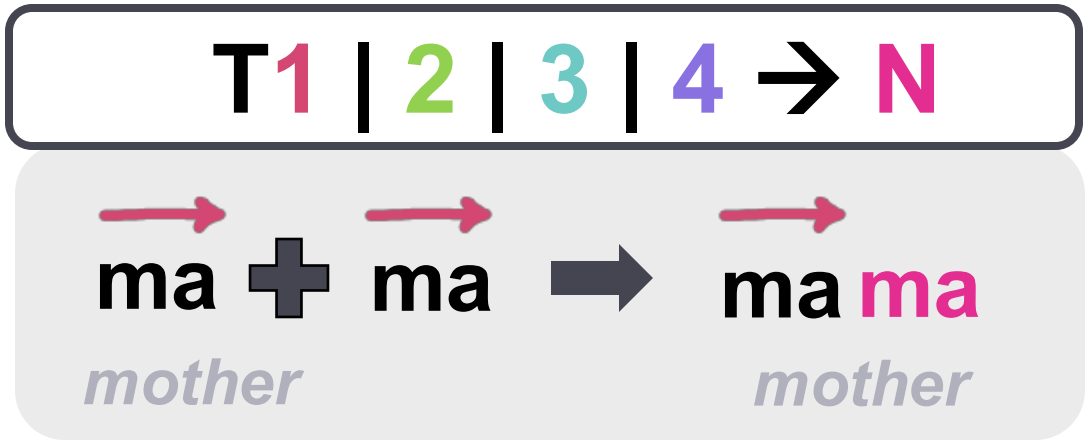
Competing feature geometry models



(Yip, 1980) (Yip, 1989) (Bao, 1999) (Wang, 1997)

An illustration of **T2** **/35 ɬ/**

The Puzzle: Neutral tone representation



reduplicatives

Neutral Tone in Standard Mandarin

lái **le** 来了	[laɪ˧˥ lə]	came
dōng xī 东西	[tʊŋ˥˥ ɕi˥]	east and west
dōng ***xi*** 东西	[tʊŋ˥˥ ɕɪ]	thing(s)
qí zǐ 棋子	[ʈʂʰi˧˥ ʈsɻ˨˩˦]	chess piece
qí ***zi*** 旗子	[ʈʂʰi˧˥ ʈsɻ]	flag

Occurrence and Obligatoriness

- Many are grammatical morphemes
- Never in initial positions
- Some are obligatory and some are optional
- Frequent: One-third of all syllables in colloquial speech (Duanmu, 2007)

Neutral Tone in Standard Mandarin

	gè		*zhèi ge*	
(a)	个	/kɤ˨/	这个	[ʈʂei˥ kə]
	CL		this one	
	fāng		*dì fang*	
(b)	方	/faŋ˥˥/	地方	[ti˥ fə̃]
	direction		place	
	fǔ		*dòu fu*	
(c)	腐	/fu˧/	豆腐	[toʊf˥]
	rotten		bean curd	

Phonetic Realisation

- Vowel centralisation
- Reduced duration (Lin & Yan, 1980)
- Segment deletion
- Voicing or nasalisation change
- **Varied** but predictable pitch

Neutral Tone in Standard Mandarin

Pitch Realisation

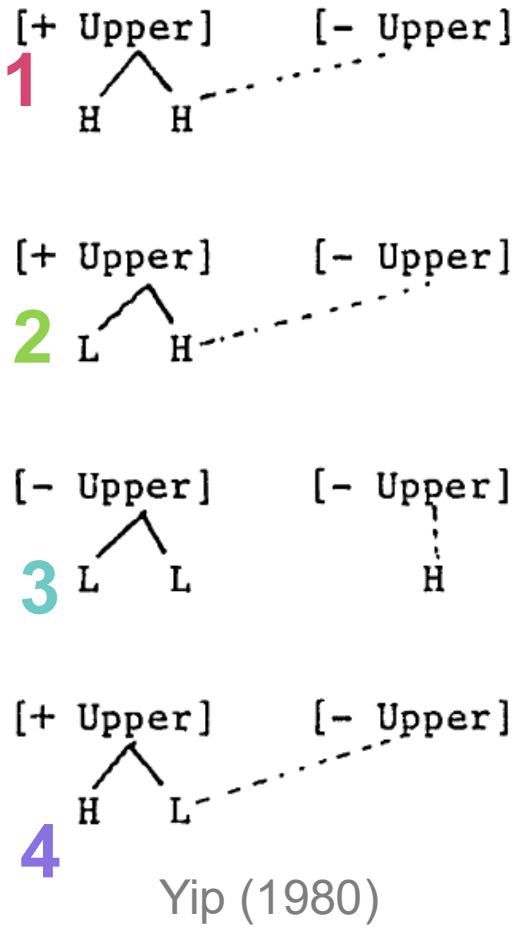
- Neutral tone pitch pattern is largely predicted by the **preceding tone**

Preceding tone		Neutral tone			
		Chao, 1968	Shih, 1987	Chen, 2000	Lee & Zee, 2008
1	˥˥	half-low	starts high, then falls	mid	mid falling
2	˧˥	mid	starts high, then falls, but not as low as after H	mid	high falling
3	˨˩˦	half-high	starts fairly low, then rises	half-high	mid-level
4	˥˩	low	starts fairly low, and falls even lower	low	low falling

Approaches to Neutral Tone

Is it the fifth lexical tone?

		Underlying Representation	
		Specified	Underspecified
Explaining surface Variability	Feature spreading	Yip (1980): [-upper] Lin (2006): L	Shen (1992) Li (2003): boundary L%
	Target Interpolation or approximation	Van Santen et al.(1998): A single mid target Xu & Wang (2001)'s PENTA model: A static mid target	Kochanski & Shih (2003)'s STEM-ML model: No soft template



Yip (1980)

Neutral Tone in Changsha

Pitch Realisation

Citation tone		Neutral tone	
		Pattern A	Pattern B (s w)
1	˥	3	5
2	˧˥	3	3 or 5
3	˥˩	4	3
4	˥	5	3 or 5
5	˩˧	2	3 or 5
6	˧˥	4	3 or 5

Zhong (2003)

- Both left-dominant (s w) and right-dominant (w s) words (Lin, 2011)
- Neutral tone pitch pattern A depends on the **underlying tone** (Zhong, 2003)
- Word-final neutral tone: short and level (Guo & Chen, 2022)

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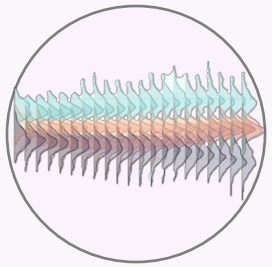


Tone change:
Case Study of Plastic Mandarin

In this talk: **Citation tones (A) and neutral tone (B)**

Central propositions

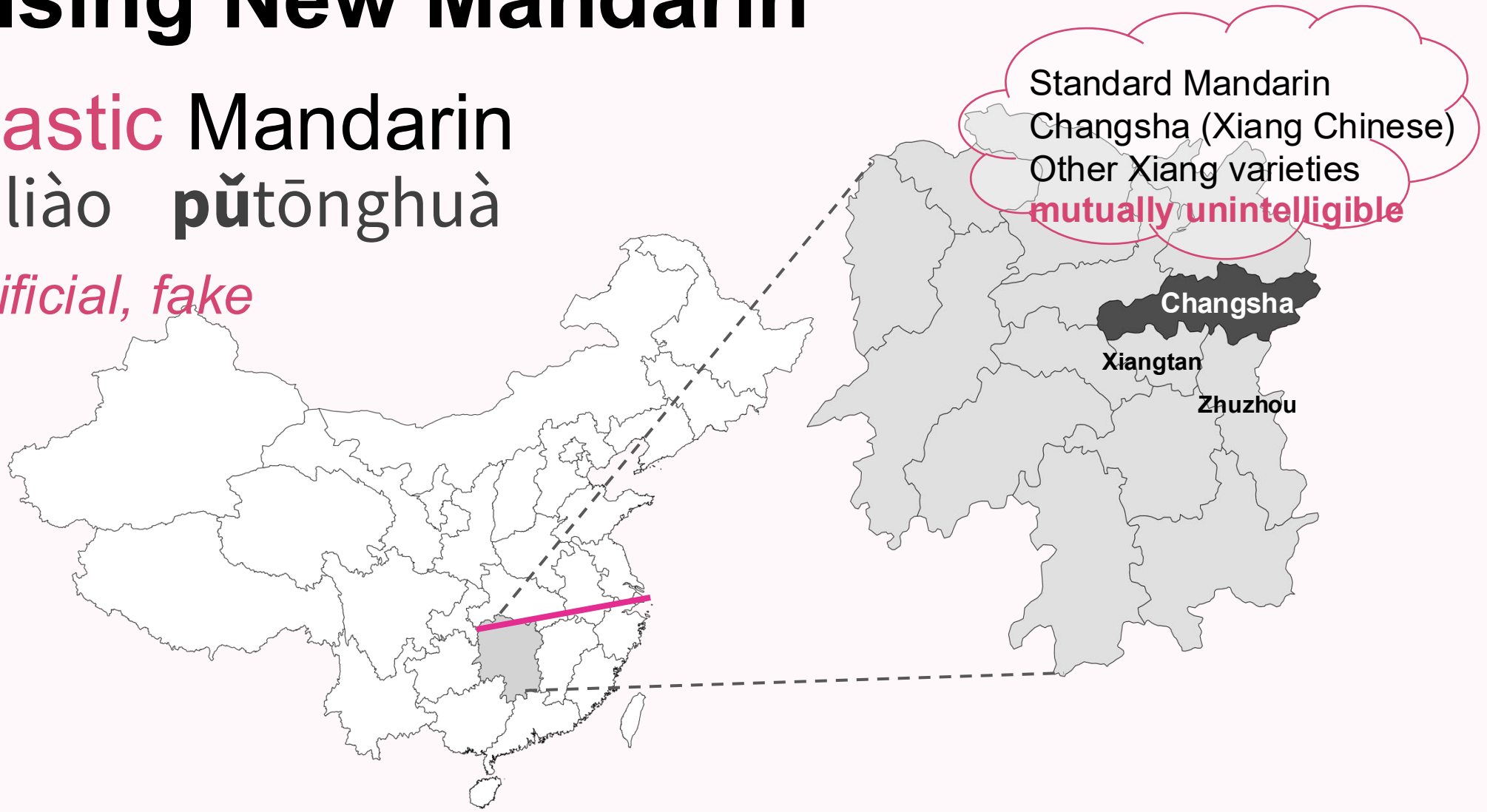
1. Mandarin Neutral Tone is **underspecified** and interacts with tonal features at different prosodic hierarchy
2. Mandarin Neutral Tone associated with post-lexical boundary tone is more **pertinacious** than lexical tones in language variation and change

Crystalising New Mandarin

Plastic Mandarin

sùliào **pǔ**tōnghuà

artificial, fake



Crystalising New Mandarin

Language contact

- Large-scale migration of newcomers
- Existing variety “swamped” by the incomer varieties

e.g. **South African English** (Lass, 1990)

- Mutually unintelligible varieties of migrants
- No language shared by a large enough minority
- An economically or politically powerful language as a remote target

e.g. **Portuguese-Lexified Creoles** (Cardoso, 2020)

Less obvious contact

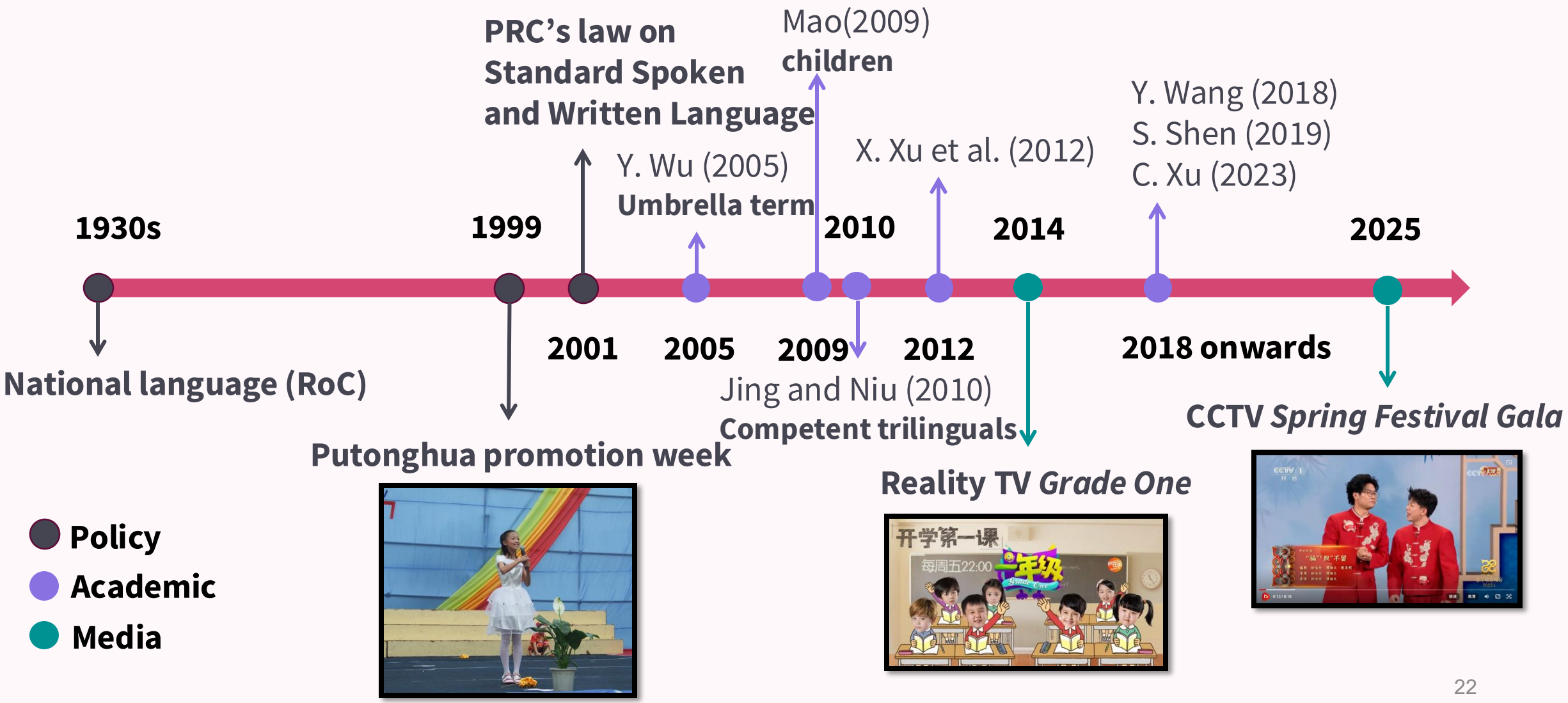
- A population adopts a different language
- A standard or official language
- Digital communication

High Standard Mandarin
Education and other formal domains

Plastic Mandarin

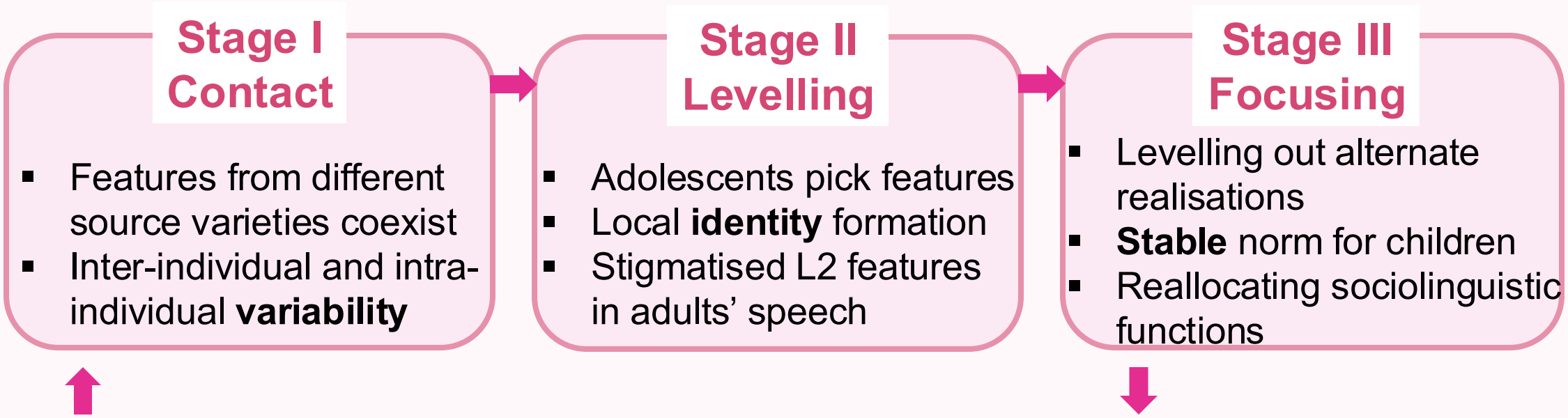
Low Changsha
Conversations at home and wet market

Plastic Mandarin Timeline



Crystalising New Mandarin

Trudgill's three-stage model of New Dialect Formation (Trudgill et al., 2000)
Three-stage model for Plastic Mandarin



Crystalising Tonal Change

	师生	读书
	'teacher(s) and student(s)'	*'read book(s)'*
	shī shēng	**dú shū**
Standard Mandarin	/ʂʐ̩˥ ʂəŋ˥/	/tu˧˥ ʂu˥/
Changsha	[sz̩ˈ sənˈ]	[təʊˈ ɕyˈ]
Hunan-accented Mandarin	[sz̩˥ sən˥]	[təʊ˧˥ ɕy˥]
Plastic Mandarin	[ʂʐ̩ˈ ʂəŋˈ]	[tuˈ ʂuˈ]

Velar nasal **/ŋ/**
- Alveolar [n]

Retroflex fricative **/ʂ/**
- Alveolar [s]
- Alveolo-palatal [ɕ]

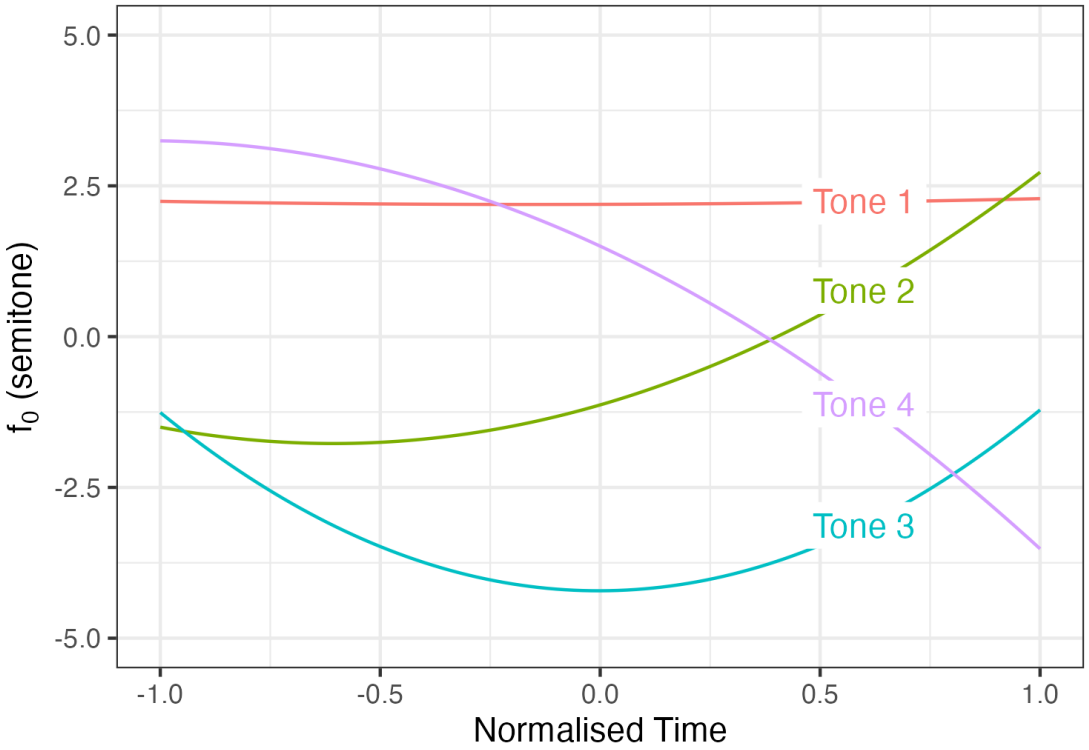
Hunan-accented examples taken from a transcript in Y. Wu (2005, p.29)

A. Research Questions

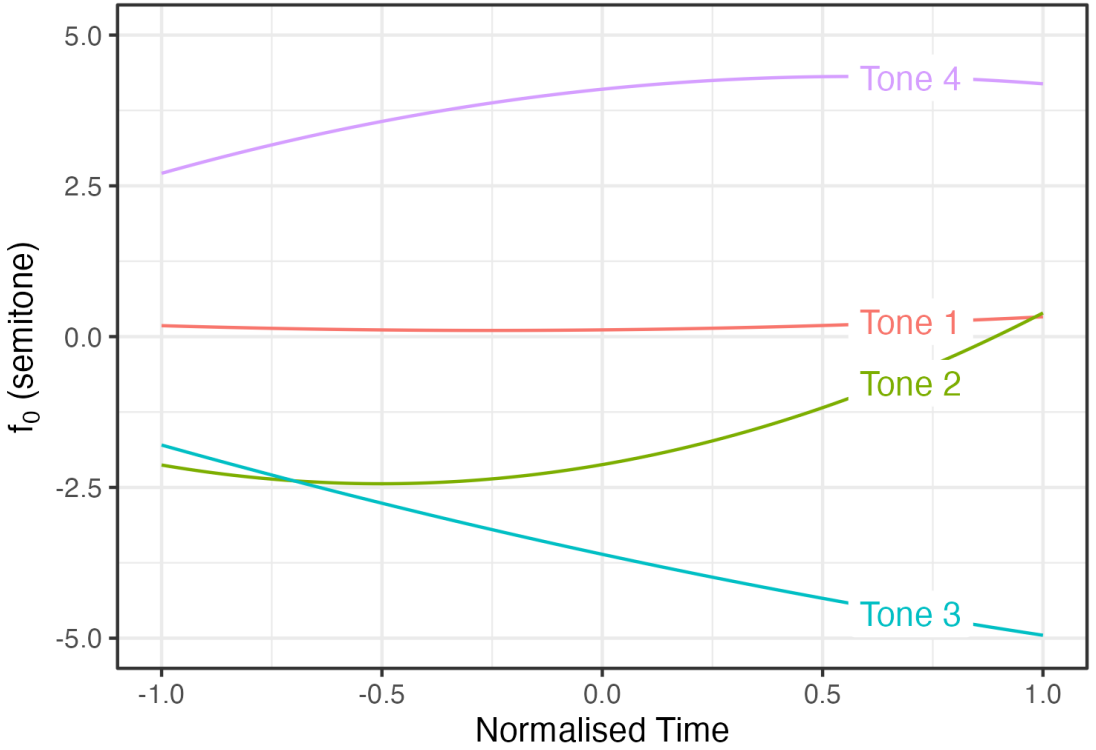
RQ1 What is the prototypical pitch contour of each tone in Plastic Mandarin?

RQ2 How similar the pitch contours are between the tones of Plastic Mandarin and Changsha?

RQ1. Plastic Mandarin Tones

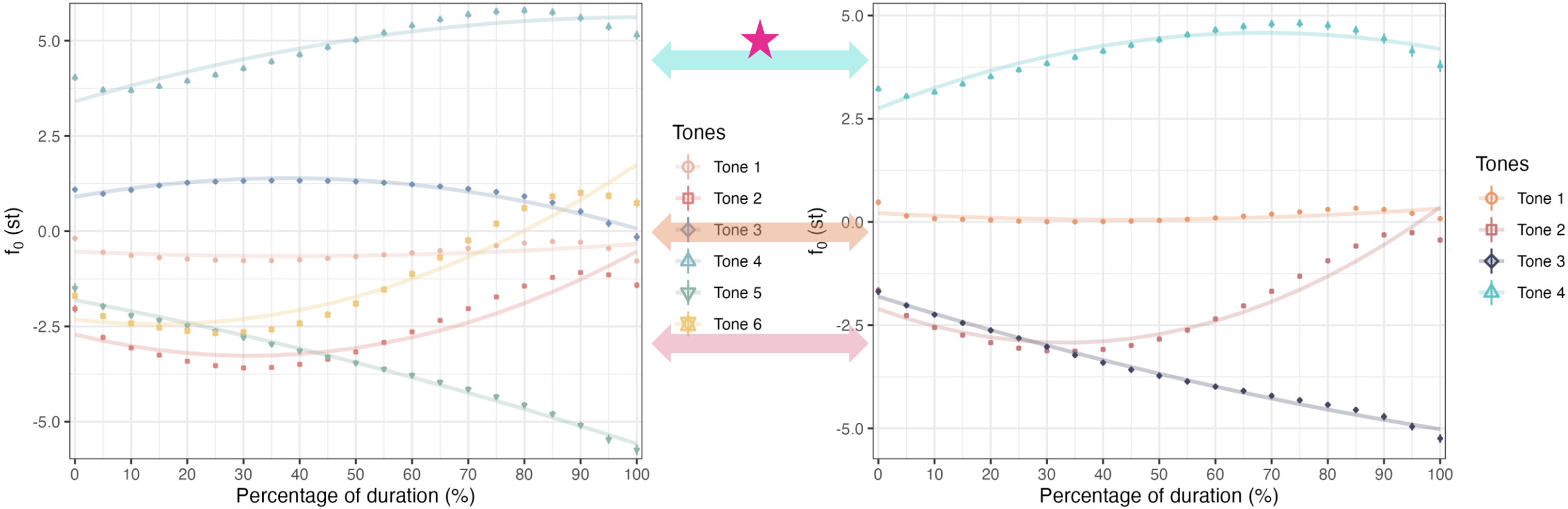


Standard Mandarin (Xu, 2025)



Plastic Mandarin

RQ2. Changsha VS Plastic Mandarin Tones

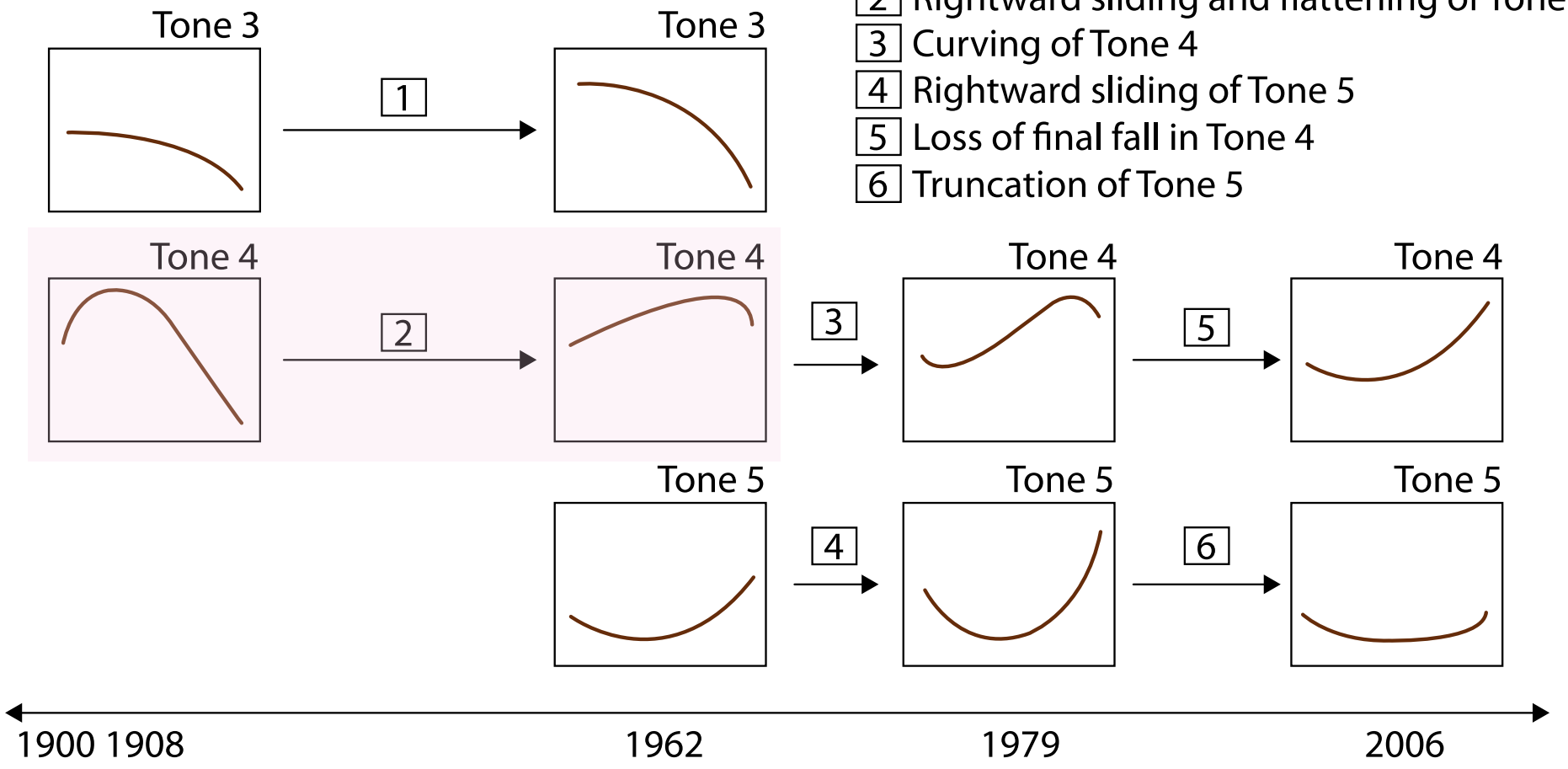


Changsha (Xu, 2025) Plastic Mandarin

Recurrent tone contour changes

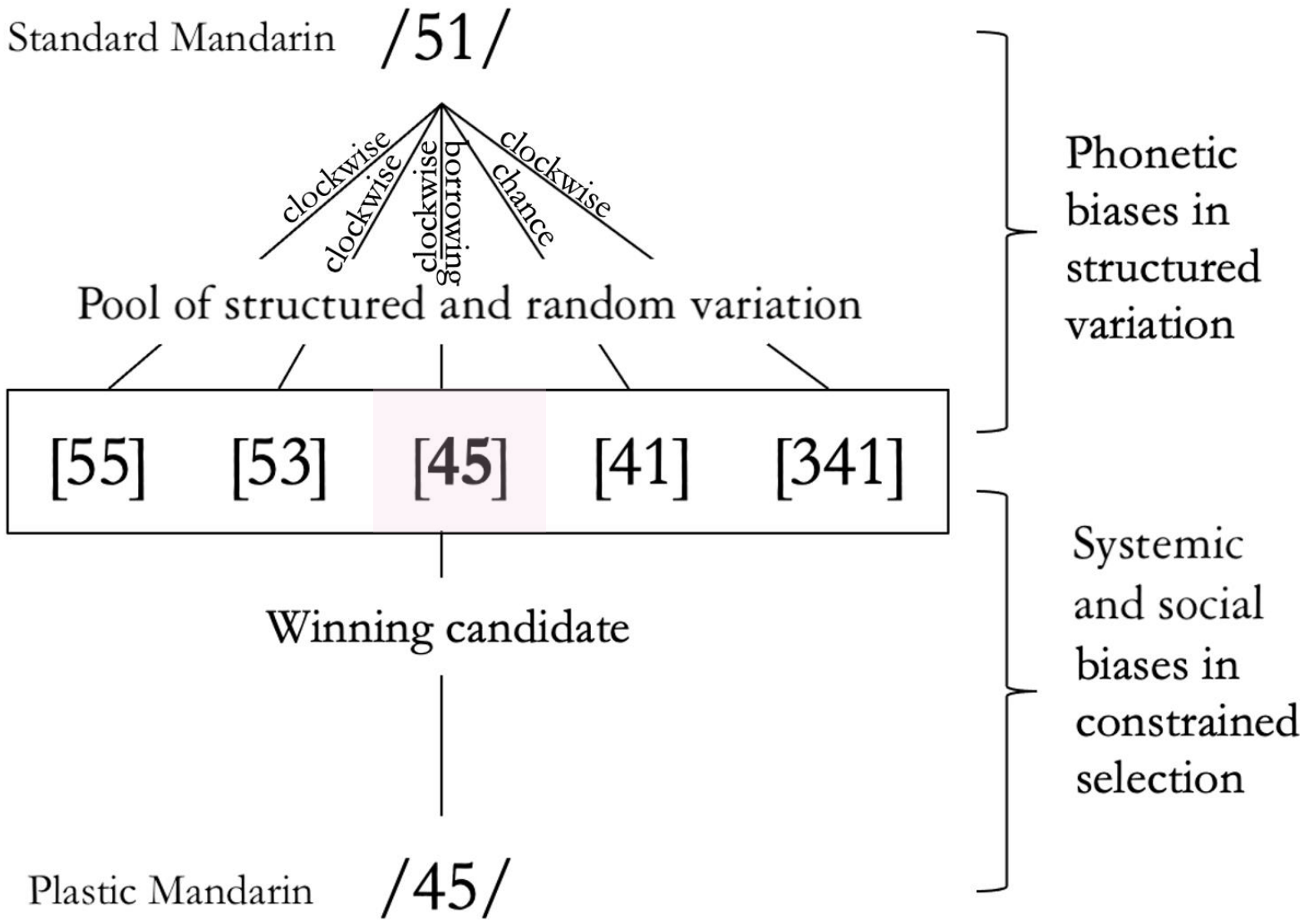
Clockwise tone shift cycle

1 Onset raising of Tone 3
2 Rightward sliding and flattening of Tone 4
3 Curving of Tone 4
4 Rightward sliding of Tone 5
5 Loss of final fall in Tone 4
6 Truncation of Tone 5

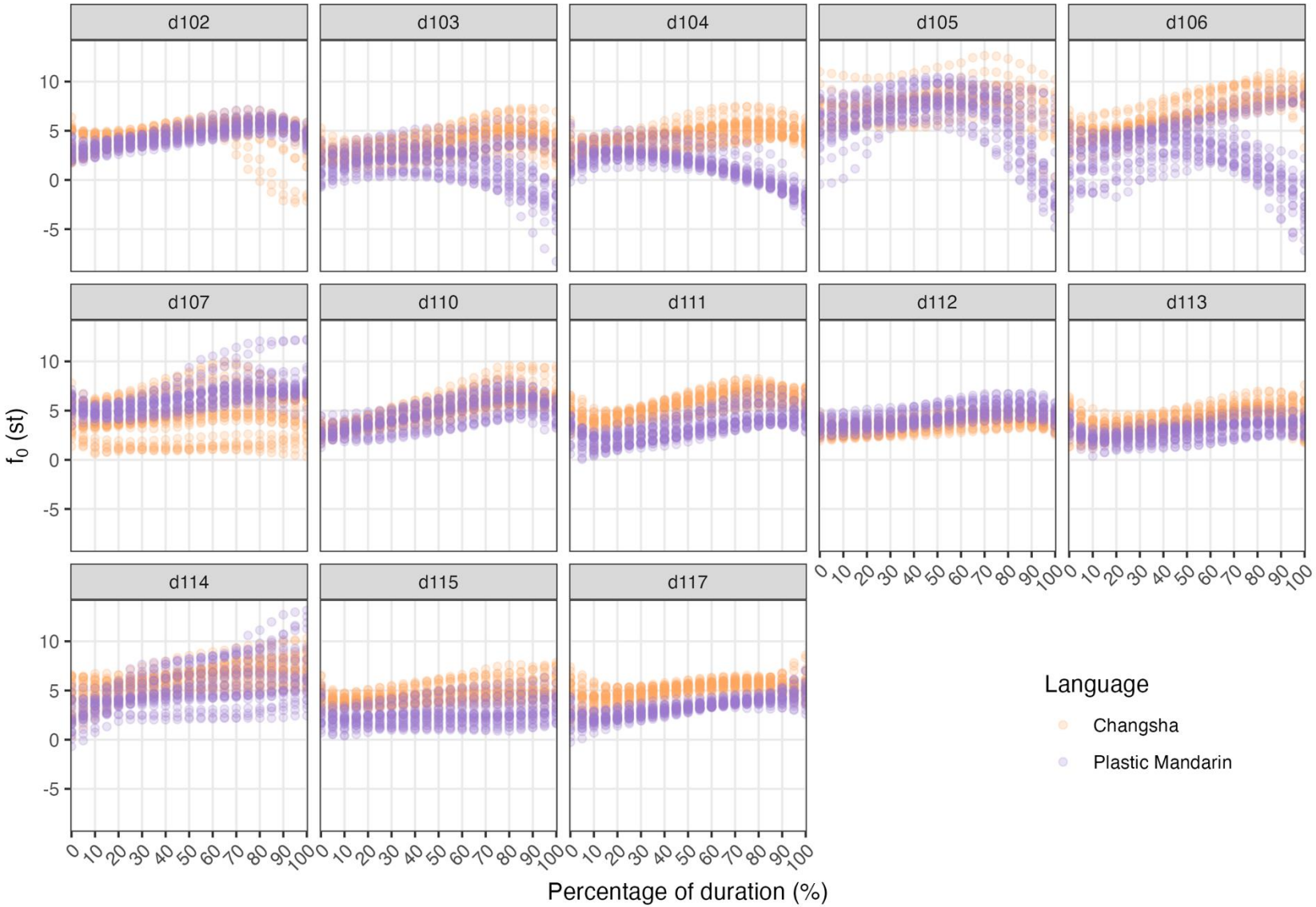


Tone changes in Bangkok Thai (Pittayaporn, 2018)

Mandarin lexical tone variation



Mandarin lexical tone variation



B. Research Questions

RQ1 How is a neutral tone realised in various tonal contexts in Plastic Mandarin?

RQ2 How do neutral tone patterns in Plastic Mandarin (PM) compare to those in Standard Mandarin (SM)?

RQ3 Is there a pitch target for neutral tone?

B. Research Questions

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Preceding tone

Duration

Following tone

B. Research Questions

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RQ3 Is there a pitch target for neutral tone?

H1

PM ≈ SM neutral tones

H2

PM ≈ Changsha neutral tones

H3

PM neutral tones are unique

B. Research Questions

RQ1 How is a neutral tone realised in various tonal contexts in Plastic Mandarin?

RQ2 How do neutral tone patterns in Plastic Mandarin (PM) compare to those in Standard Mandarin (SM)?

RQ3 Is there a **pitch target** for neutral tone?

H1

Yes, underlyingly a mid or low tone

H2

No

H3

Yes, attracts a low boundary tone

Data and Method

Plastic Mandarin

- 16 females, 5 males
- Age: 17 ± 0.7 years
- On average 15.7 years in Changsha

Standard Mandarin

- 9 females, 5 males
- Age: 24 ± 2 years
- Mandarin region in northern China
- 8/14 spent more than 10 years in Beijing

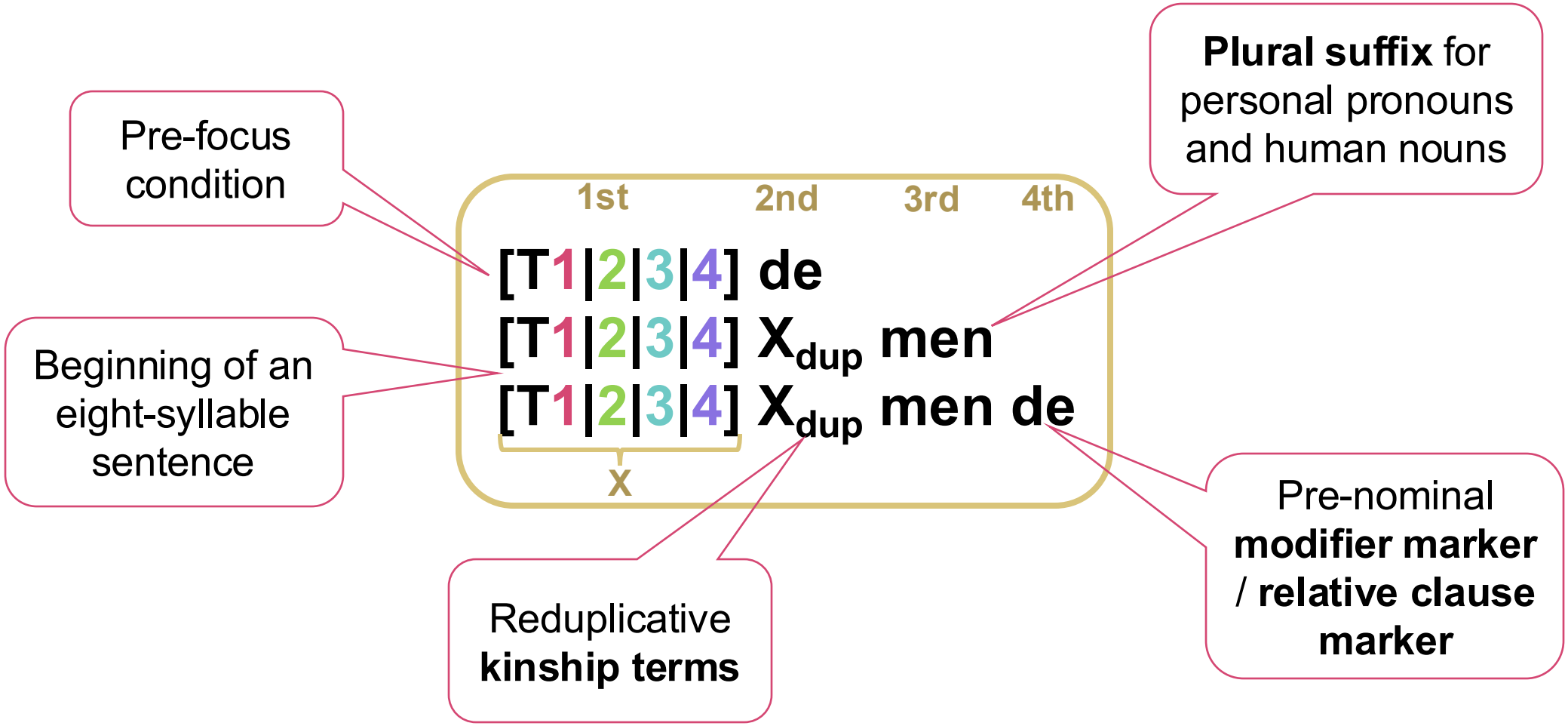
Disguised friendship game

- Peer group pair design
- Carefully design materials
- Increasing number of neutral tones

1st	2nd	3rd	4th
[T1|2|3|4]	de		
[T1|2|3|4]	X_{dup}	men	
[T1|2|3|4]	X_{dup}	men	de

X

Data and Method



Data and Method

0 Transcription

1 Annotation

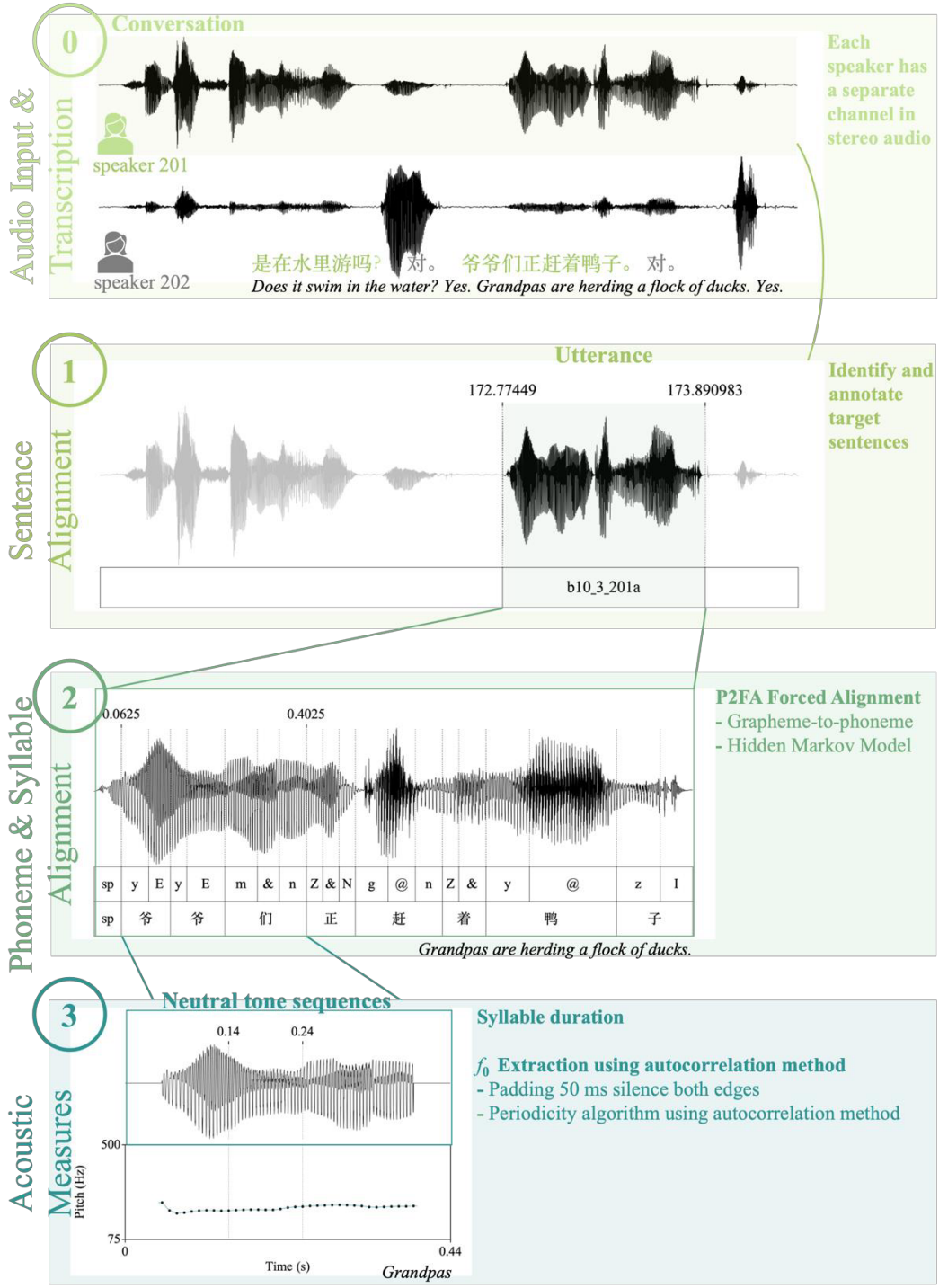
2 Forced Alignment

3 Acoustic Measurement

4 Data Normalisation

5 Generalised Additive Mixed Models

(Xu, 2024)

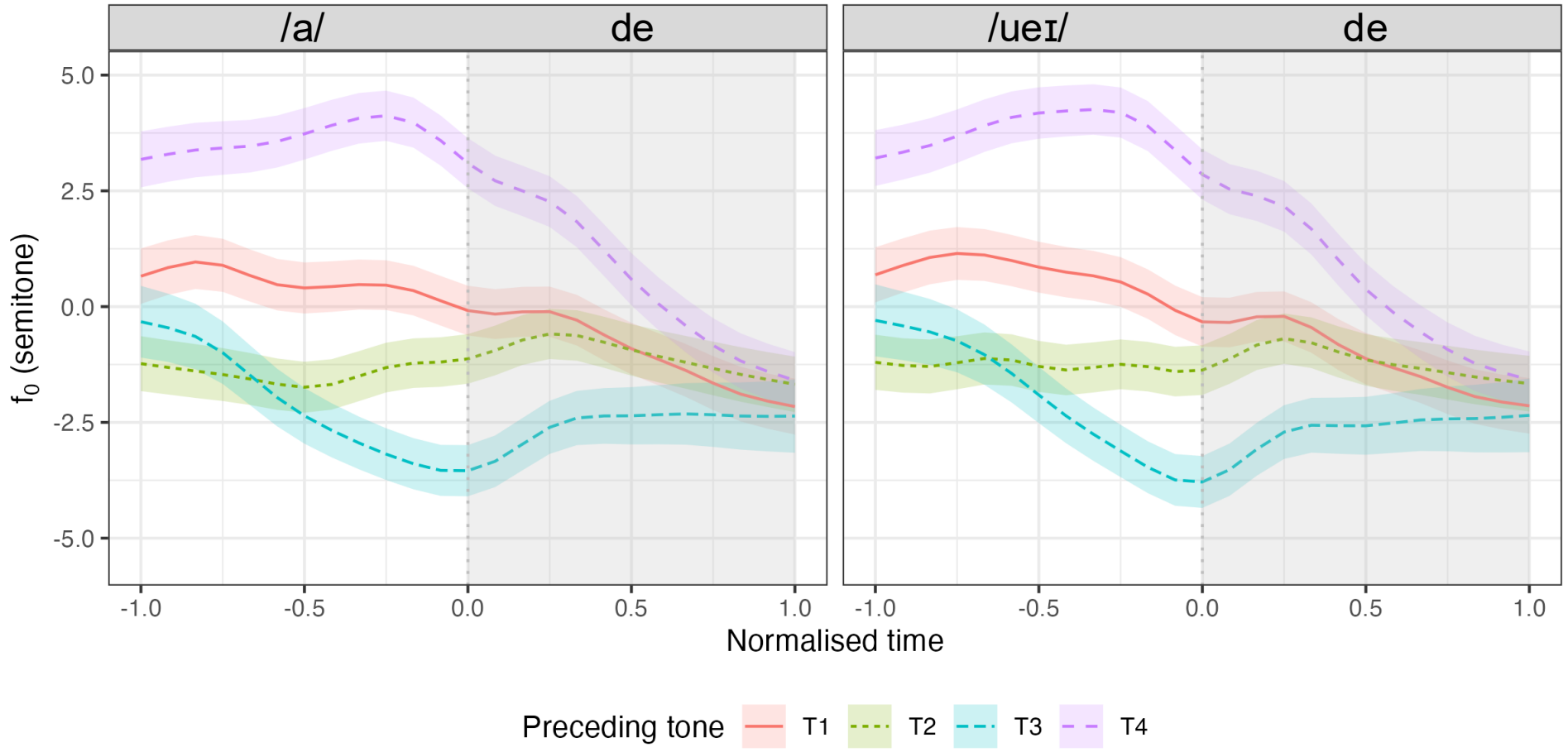


Results (RQ1): Neutral tones in Plastic Mandarin

How is a neutral tone realised in various tonal contexts in Plastic Mandarin?

Preceding tone matters!

[T1|2|3|4] de

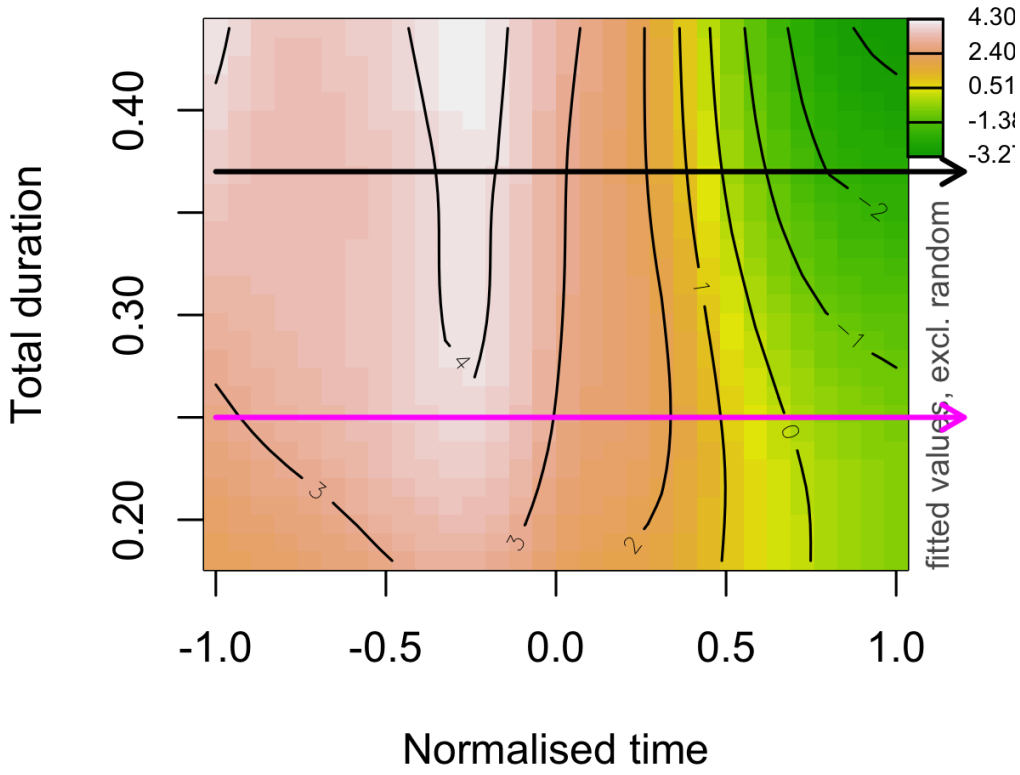


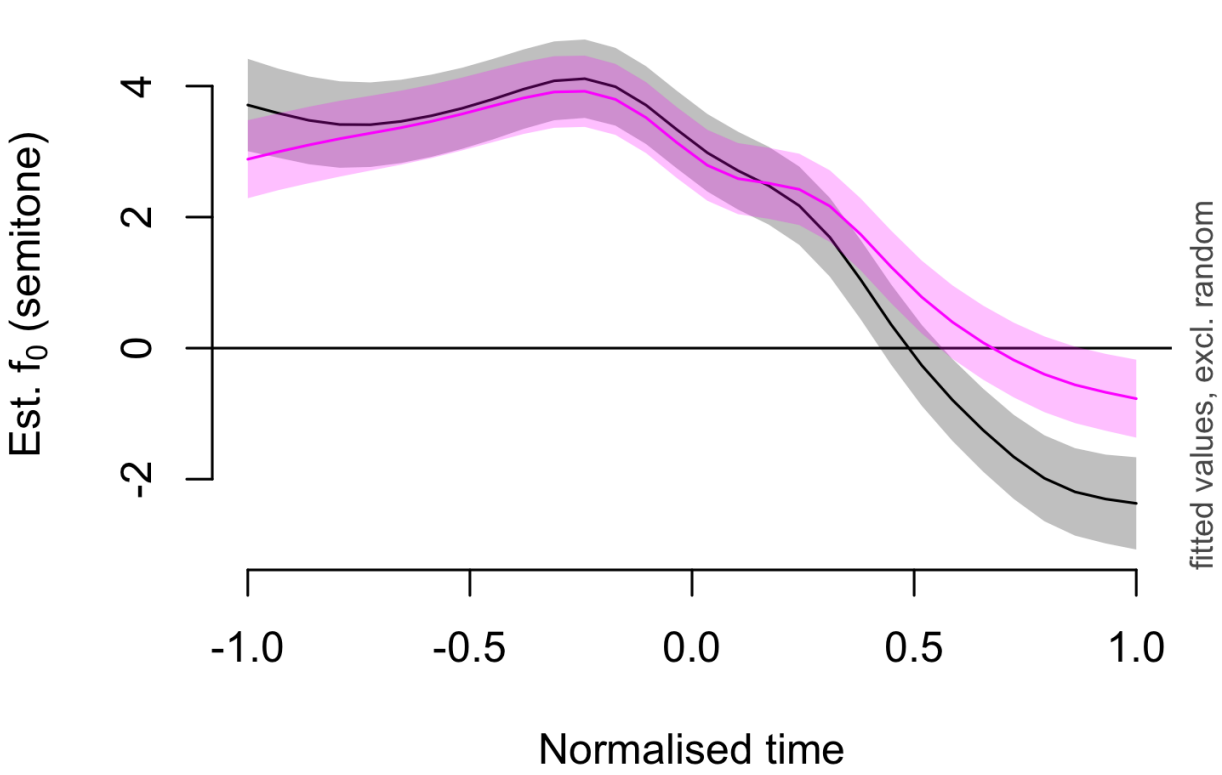
Results (RQ1): Neutral tones in Plastic Mandarin

How is a neutral tone realised in various tonal contexts in Plastic Mandarin?

Duration matters!

da4 de



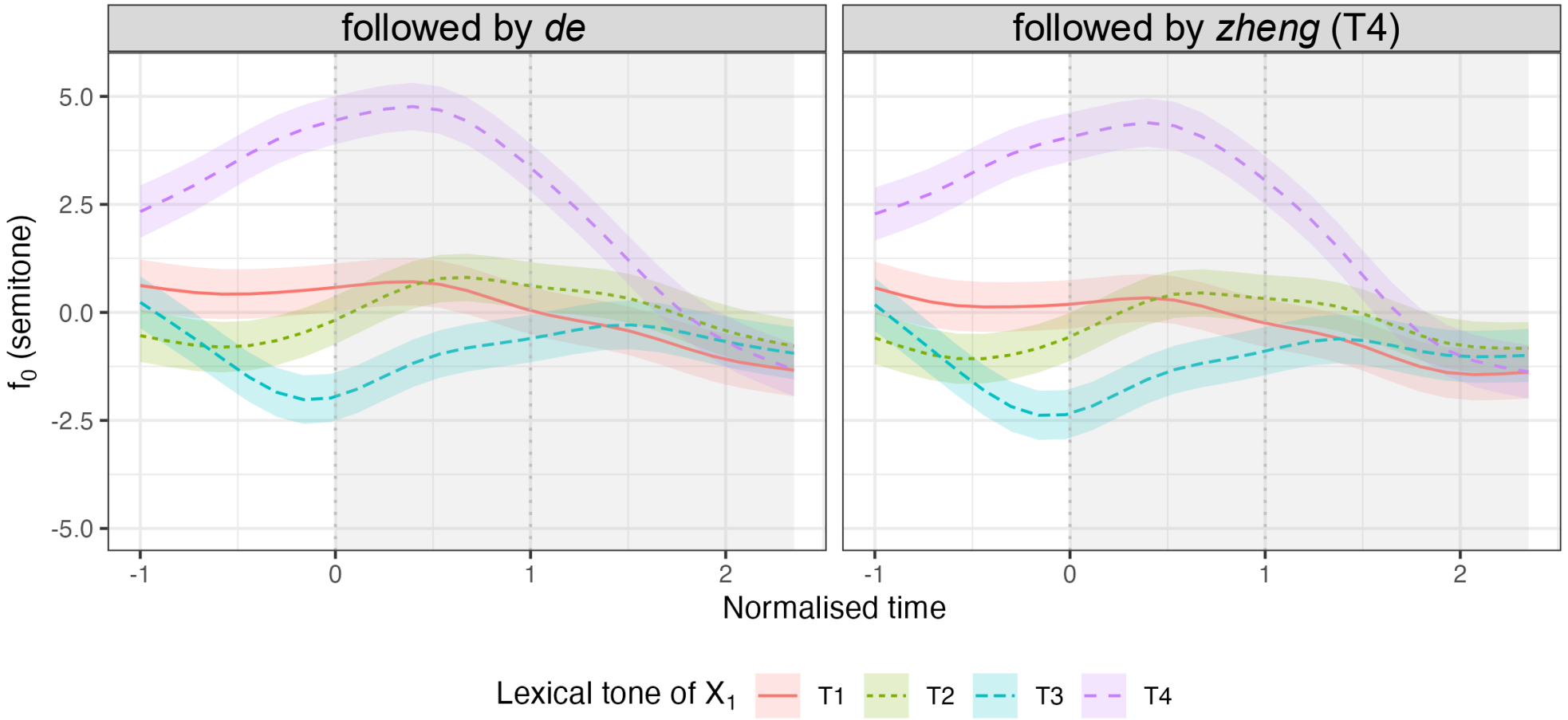


Results (RQ1): Neutral tones in Plastic Mandarin

How is a neutral tone realised in various tonal contexts in Plastic Mandarin?

Following tone: not so much

[T1|2|3|4] X_{dup} men

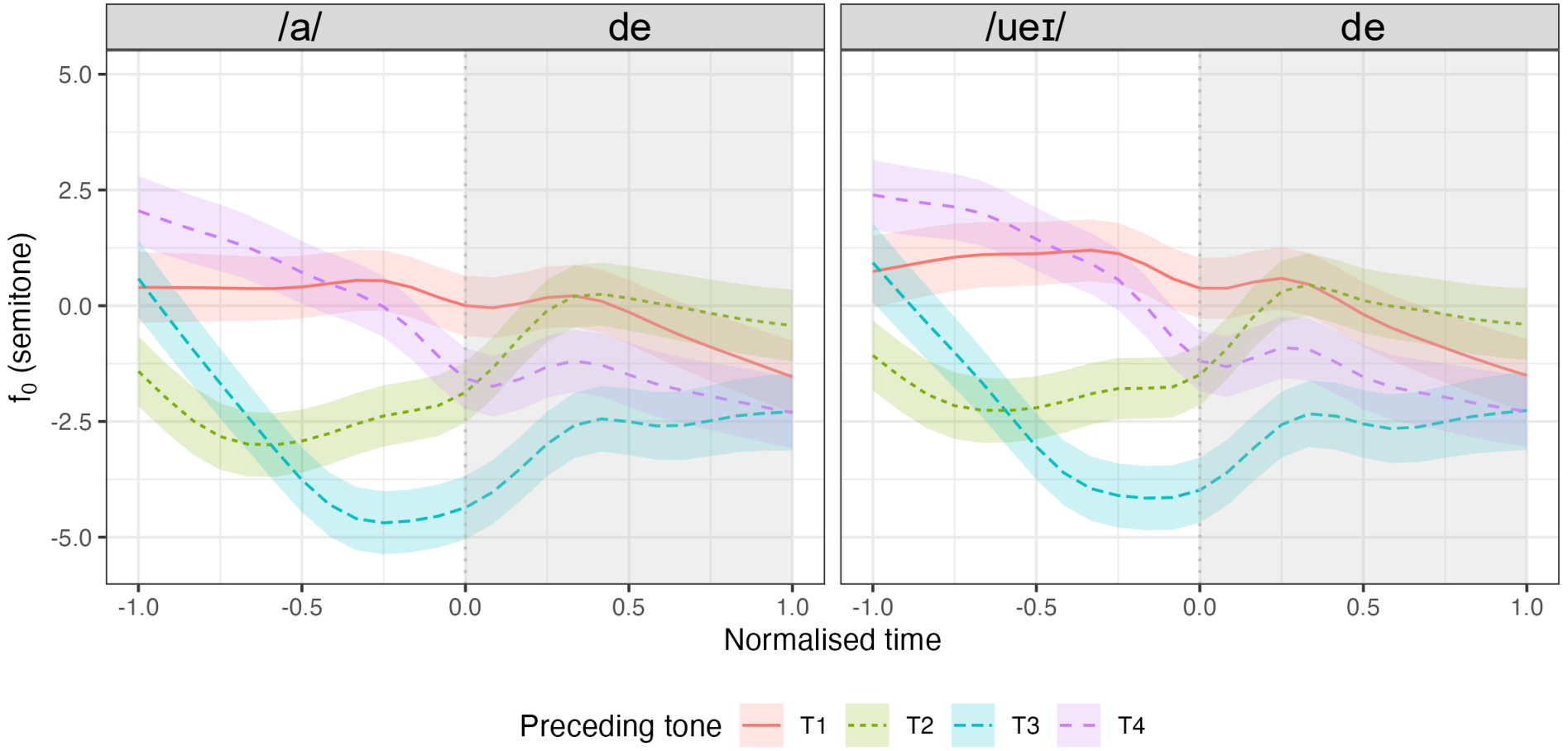


Results (RQ2): Neutral tones in Standard Mandarin

How do neutral tone patterns in Plastic Mandarin compare to those in Standard Mandarin?

Similarly preceding tone matters

[T1|2|3|4] de

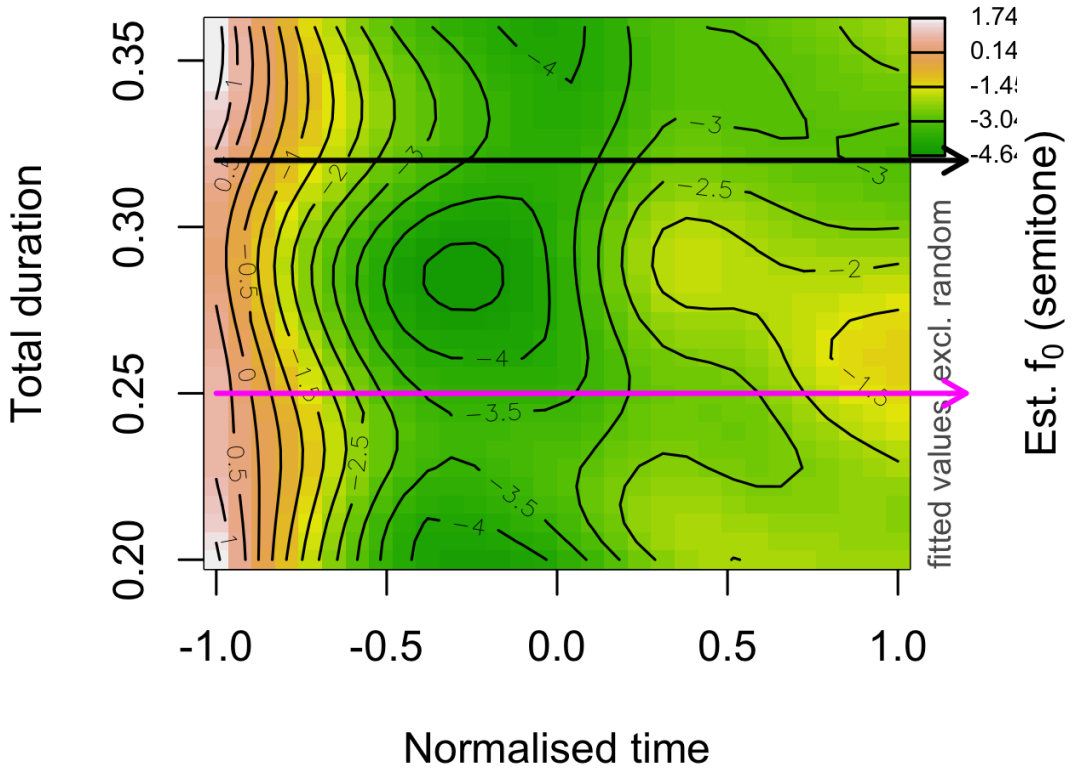


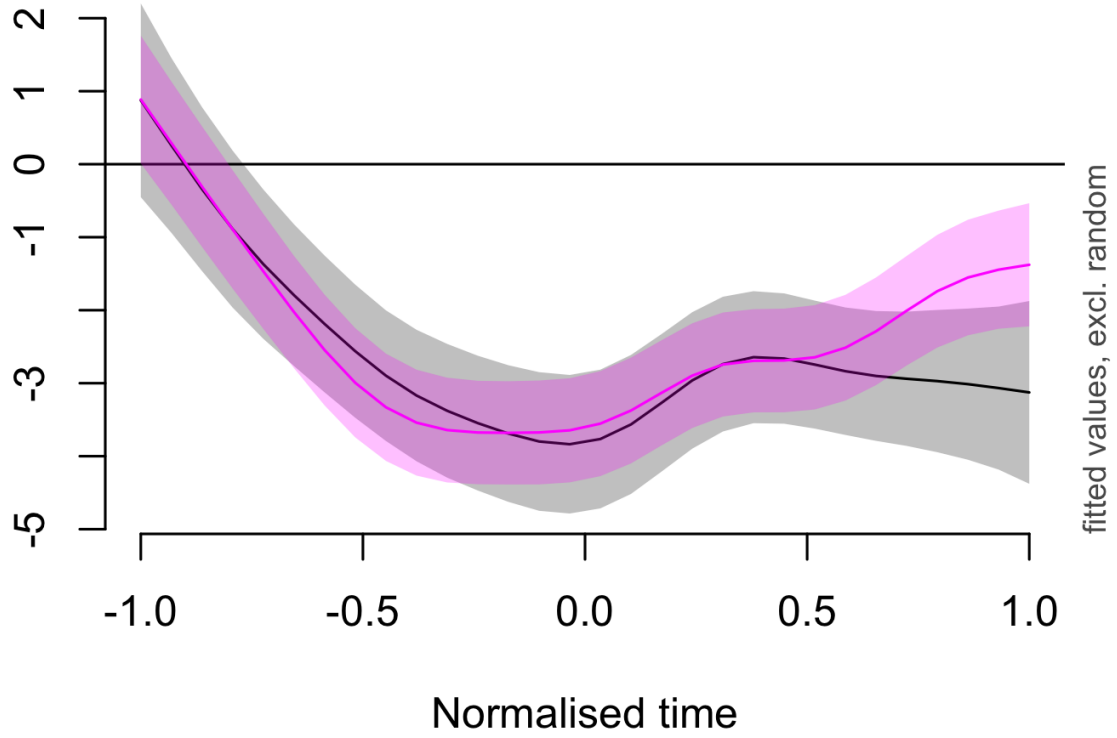
Results (RQ2): Neutral tones in Standard Mandarin

How do neutral tone patterns in Plastic Mandarin compare to those in Standard Mandarin?

Similarly duration matters

da3 de



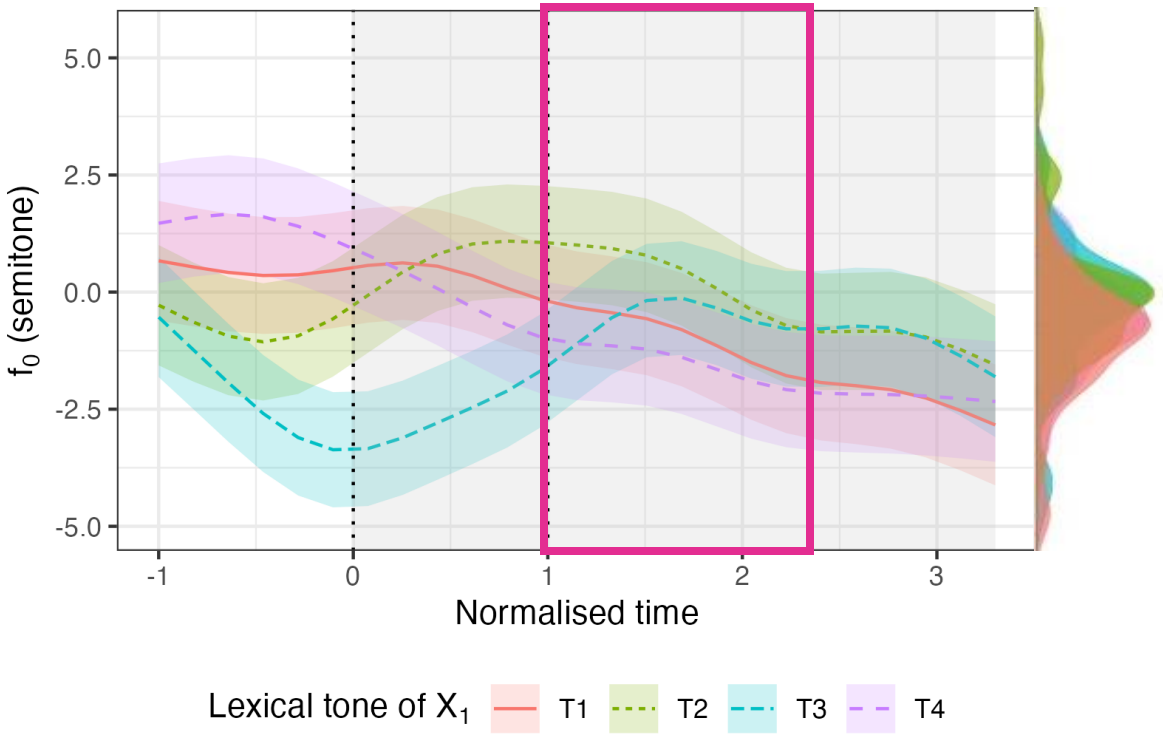


Results (RQ2): Neutral Tone Comparison

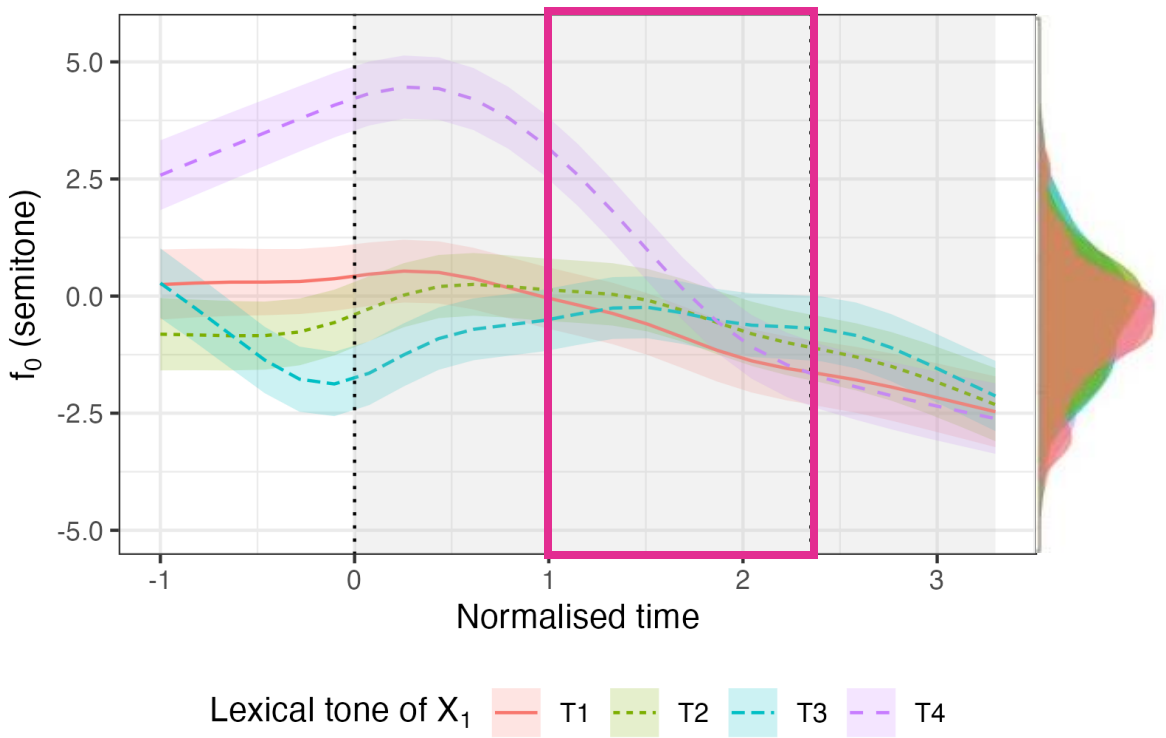
How do neutral tone patterns in Plastic Mandarin compare to those in Standard Mandarin?

Similarly converging contours

[T1|2|3|4] X_{dup} men de



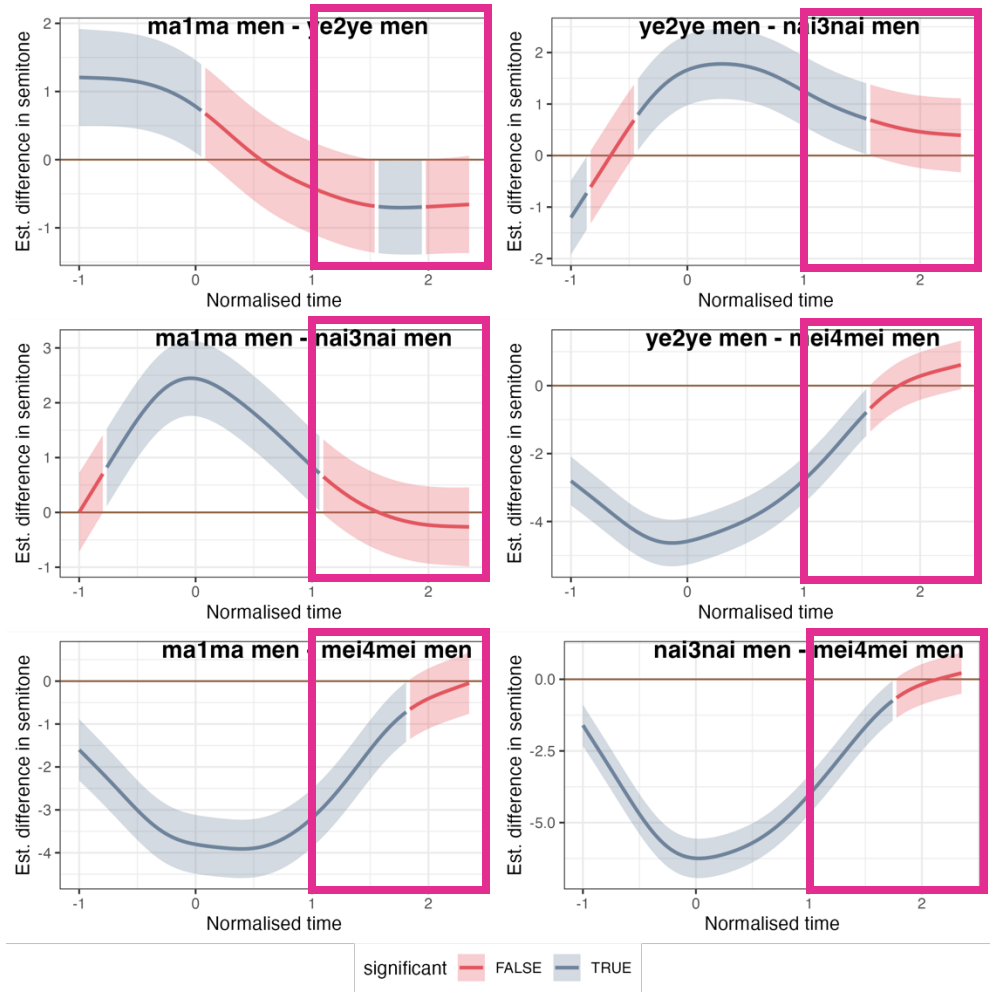
Standard Mandarin



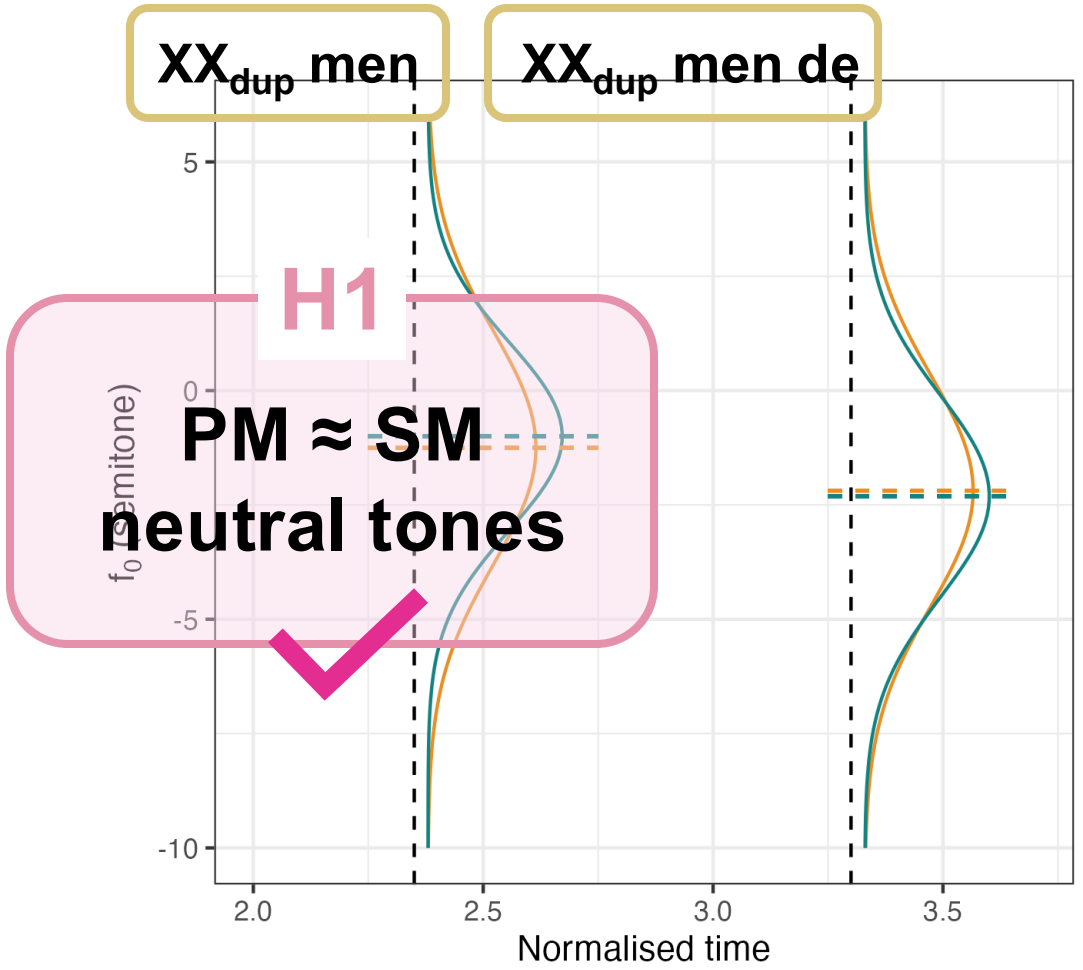
Plastic Mandarin

Results (RQ2): Neutral Tone Comparison

How do neutral tone patterns in Plastic Mandarin compare to those in Standard Mandarin?



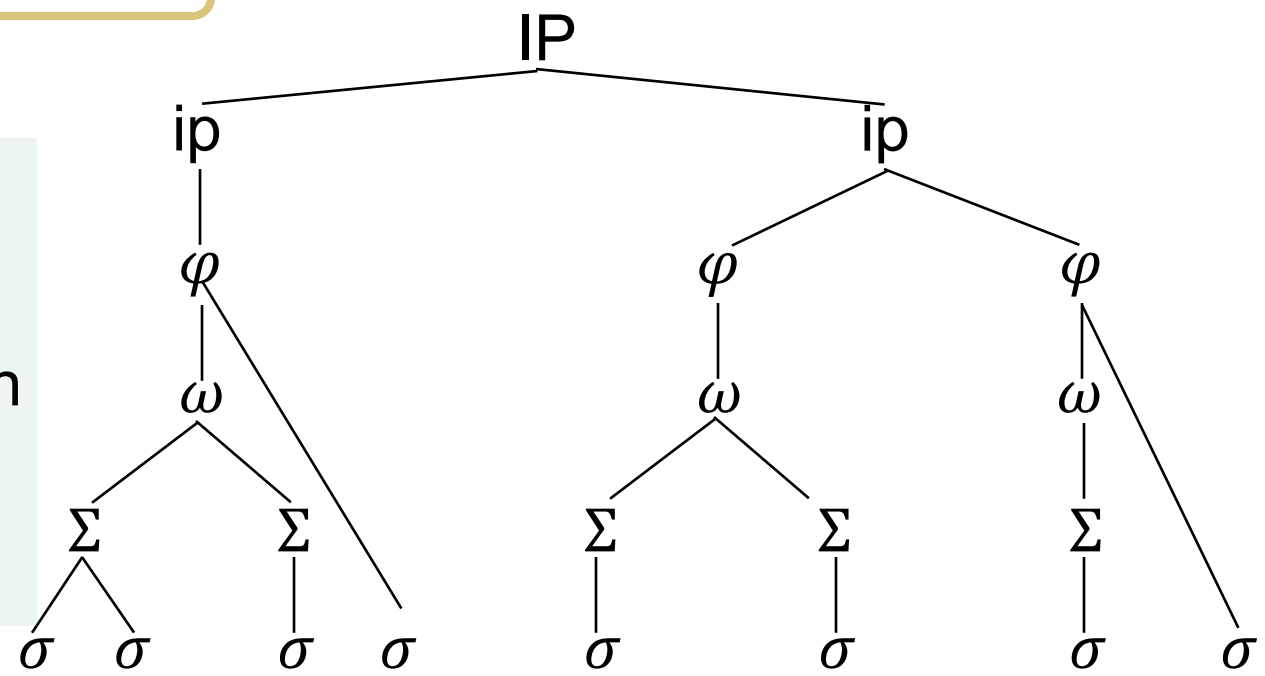
Plastic Mandarin



Standard Mandarin Plastic Mandarin

mei4mei men de

The location of a neutral tone syllable tends to coincide with the **right edge** of a prosodic constituent



Intonational Phrase

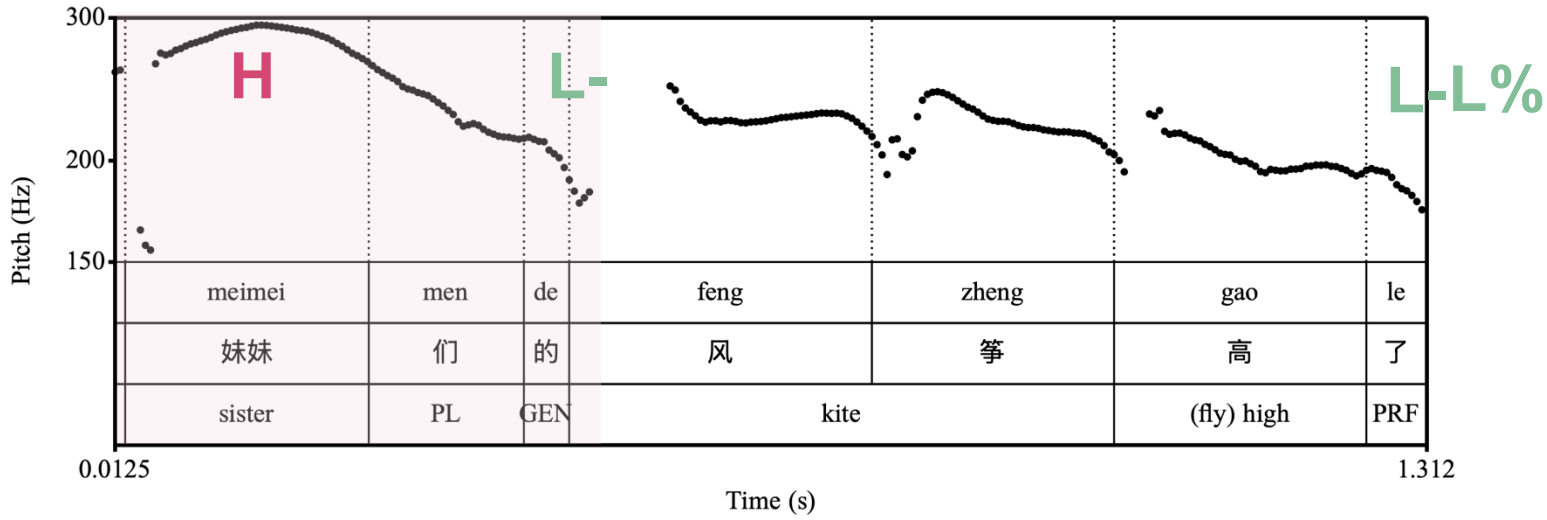
intermediate phrase

Phonological phrase

Phonological word

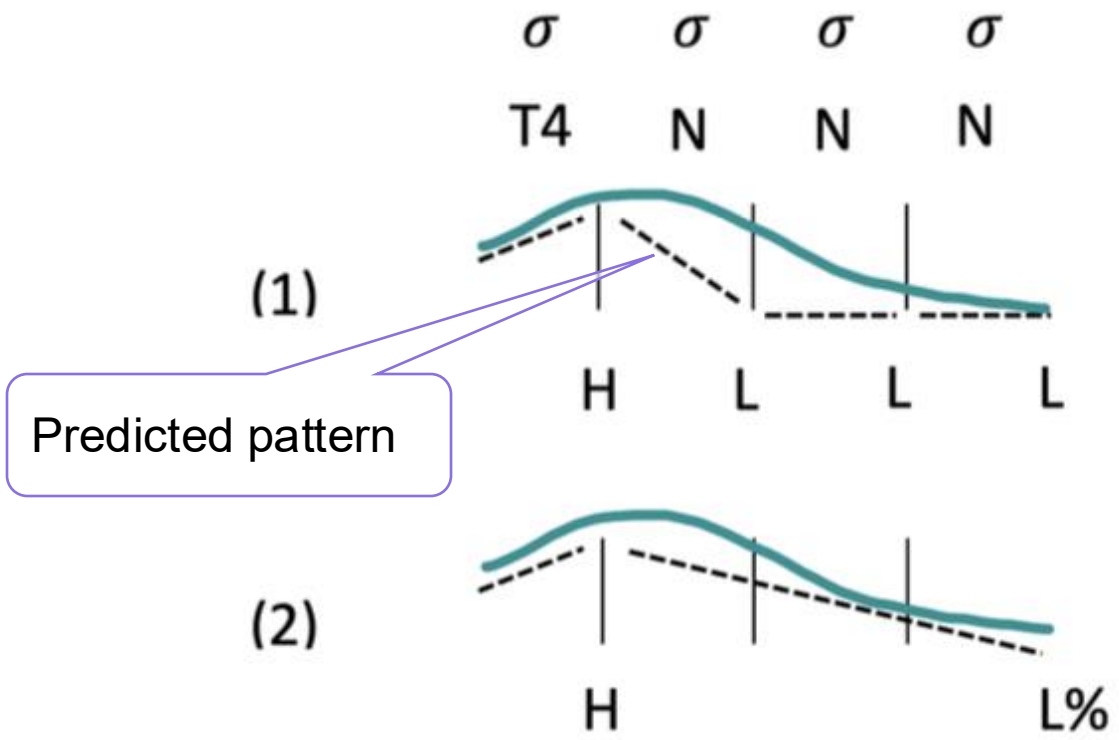
Foot

Syllable



Results (RQ3): Invariant Pitch Target of Neutral Tone

Is there a pitch target for neutral tone?



H3

Yes, attracts a low boundary tone

2. Discussion

Standard-Plastic Mandarin variation

What's changed?

Lexical tones (A):

Systematic tone variation

What remains persistent?

Neutral tone (B):

Prosodically conditioned in a similar fashion

- **Low** pitch target at the end of a **sequence**
- Strength of effects of neighboring tones
- Asymmetric influence of preceding and following tones

Attracting a **boundary low tone** (L%)

Cross-dialectal insight: Constancy at higher prosodic levels?

RoadMap

1. Background
   - What is tonal representation?
   - Mandarin Tones and their representations
   - Neutral Tone: properties and approaches
2. Tone Change: Case Study of **Plastic Mandarin**
   - Research questions and hypotheses
   - Sociohistorical context for new dialect formation
   - Development of Plastic Mandarin and its tones
   - Data and Method
   - Results and discussion
3. Tone Development: **ManyTones** project
   - Research questions
   - Method
   - Preliminary results and discussion
4. Conclusion

Tone development: *ManyTones* project

In this talk: **Perception of f0 perturbations across many languages**

Aims

1. To enhance our knowledge on microprosodic pitch perception in speech
2. To create an online framework for large-scale auditory perceptual research

Consonant-related f_0 perturbations (CF0)

English
- Aspirating
- Non-tonal

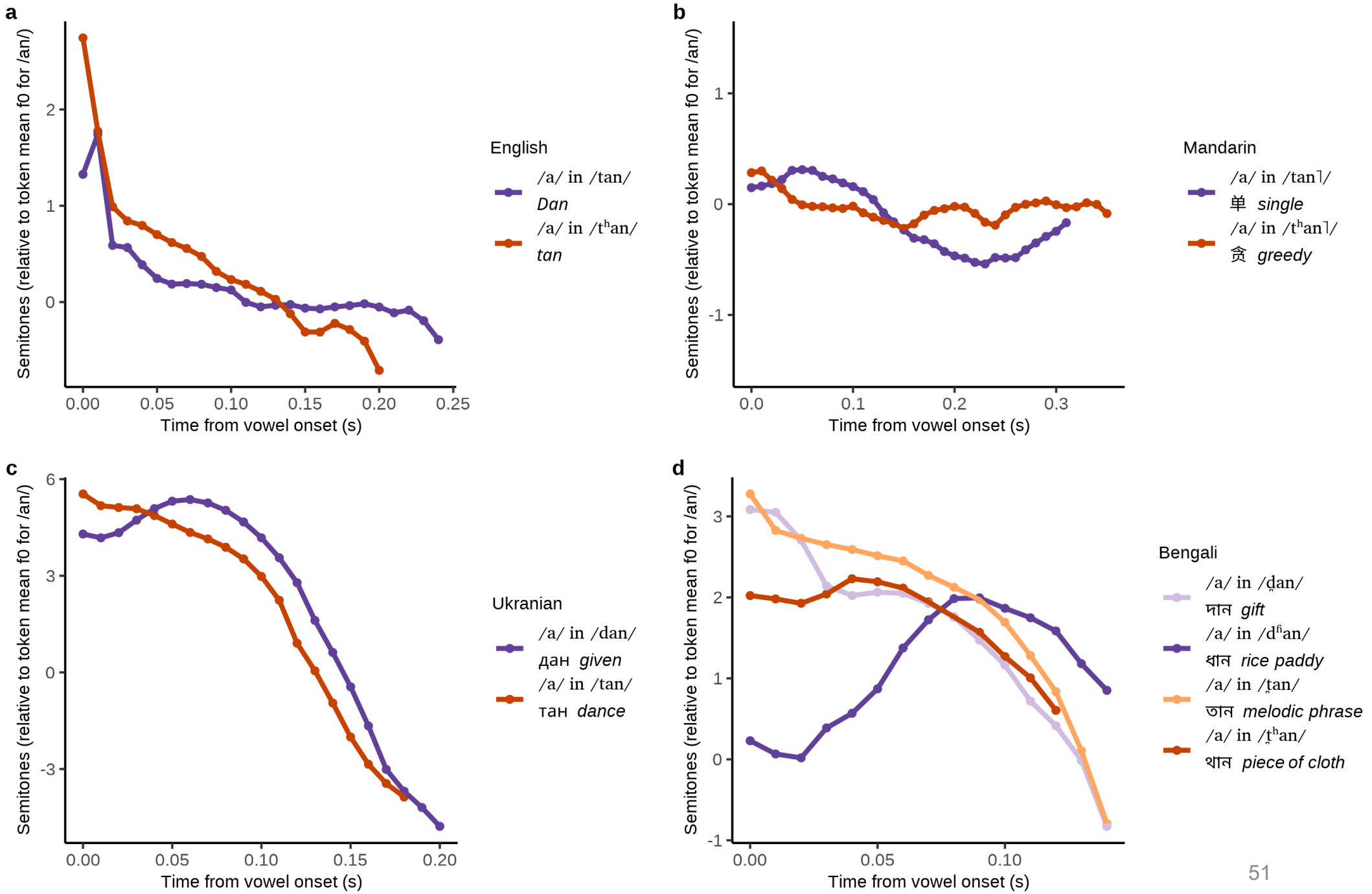
Ukrainian
- True voicing
- Non-tonal

/tan/ **/dan/**

Mandarin
- Aspirating
- Tonal

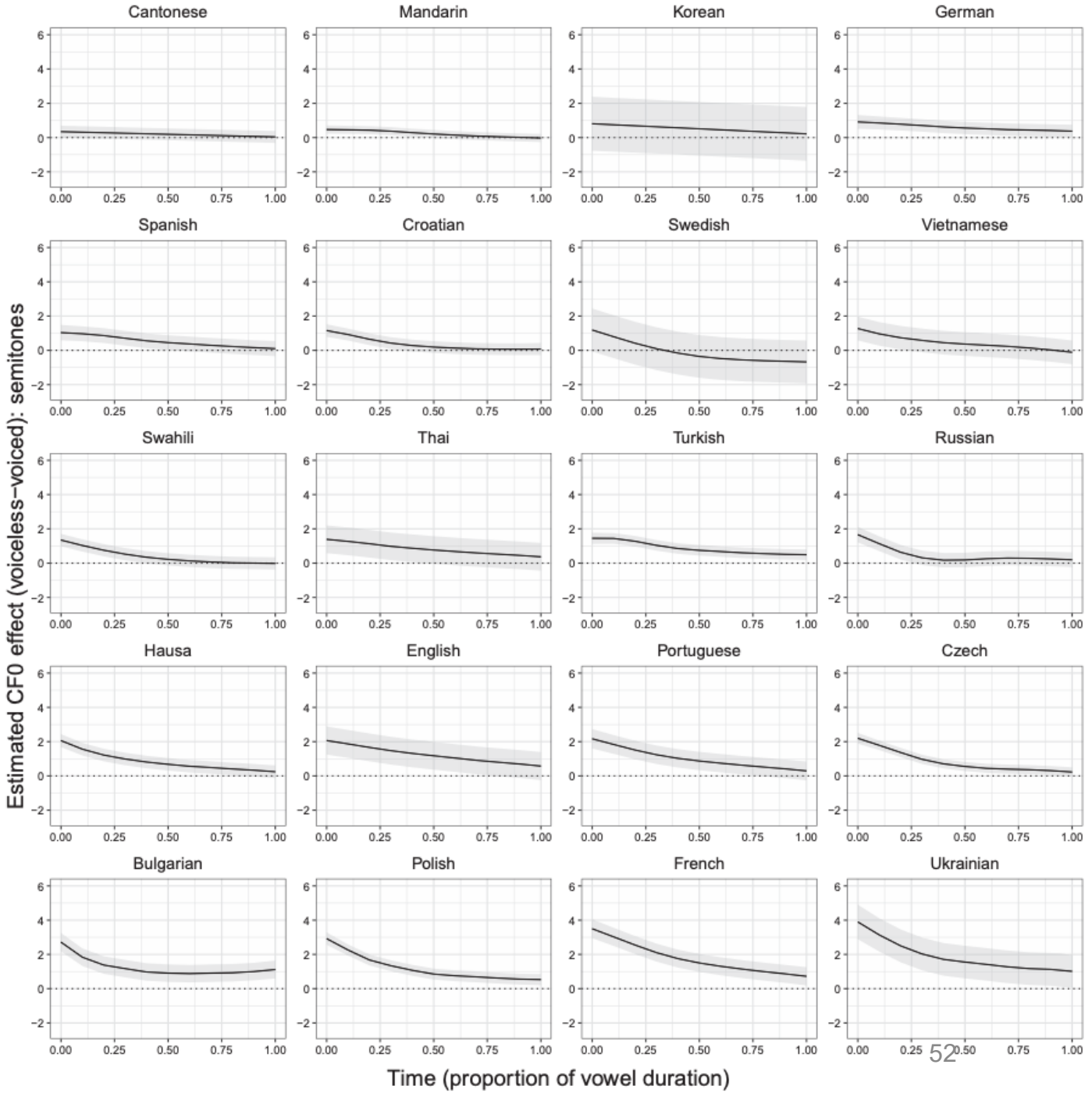
Bengali
- Four-way contrast
- Non-tonal

CF0

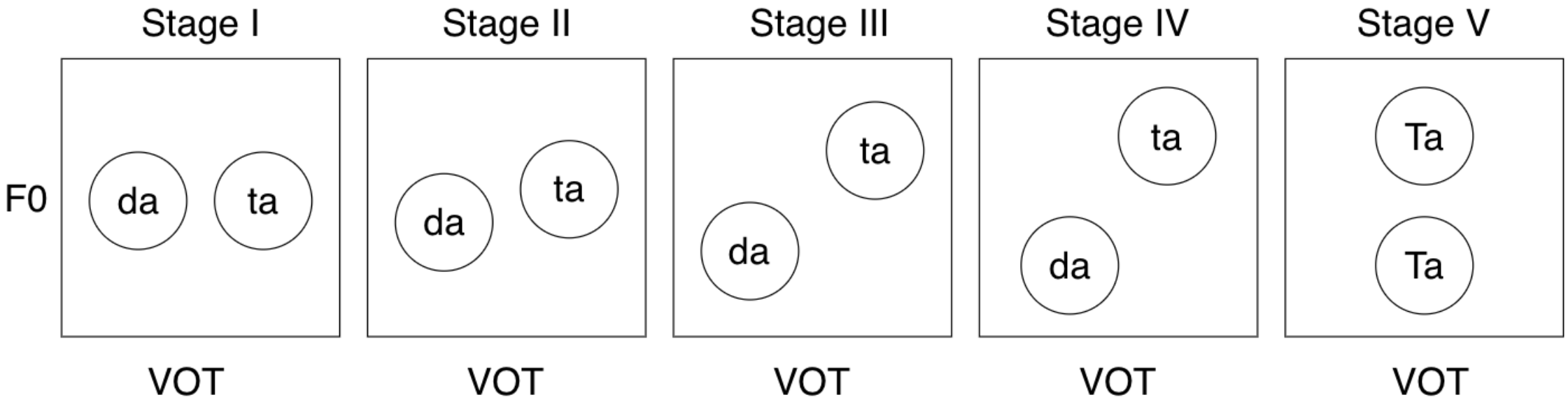

a
Semitones (relative to token mean f0 for /an/)
Time from vowel onset (s)
English
/a/ in /tan/
Dan
/a/ in /tʰan/
tan
b
Semitones (relative to token mean f0 for /an/)
Time from vowel onset (s)
Mandarin
/a/ in /tan˥/
单 single
/a/ in /tʰan˥/
贪 greedy
c
Semitones (relative to token mean f0 for /an/)
Time from vowel onset (s)
Ukranian
/a/ in /dan/
дан given
/a/ in /tan/
тан dance
d
Semitones (relative to token mean f0 for /an/)
Time from vowel onset (s)
Bengali
/a/ in /d̪an/
দান gift
/a/ in /dʱan/
ধান rice paddy
/a/ in /t̪an/
তান melodic phrase
/a/ in /t̪ʰan/
থান piece of cloth

CF0

- f_0, especially at vowel onset, is **higher following a voiceless** obstruent than following a voiced one.
- The **temporal extent** and **magnitude** of CF0 **vary** considerably.
  - Effect size: 0.4 to 3.9 semitones (Ting et al., 2025)
  - Duration*: 20 to 140 ms (various studies)



The Development of contrastive tones



Five stages of tonogenesis based on Maran (1973). VOT = voice onset time.

Source: Kang, 2014

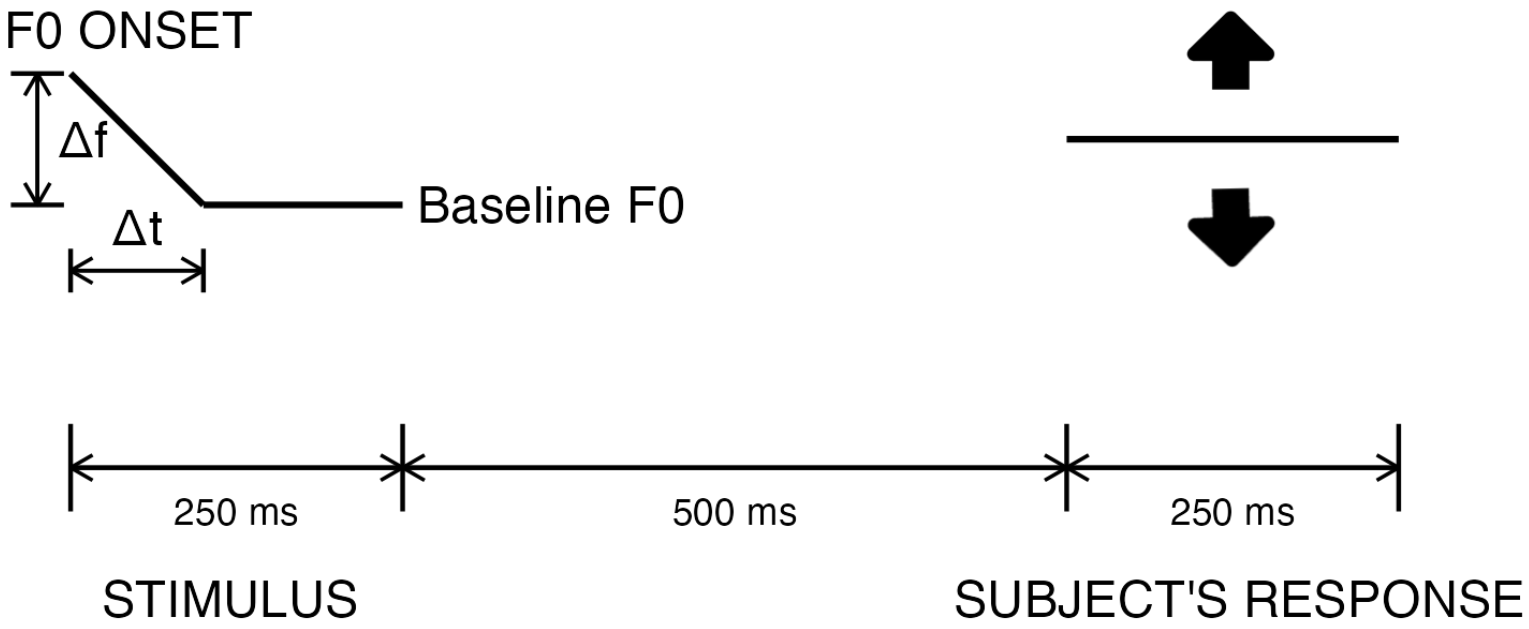
Research Questions

RQ1 To what extent can f_0 perturbations can be perceived depending on the **duration** and **extent** of the perturbation?

RQ2 Does the perception of f_0 perturbations vary across listeners with different language experience? If so, how?

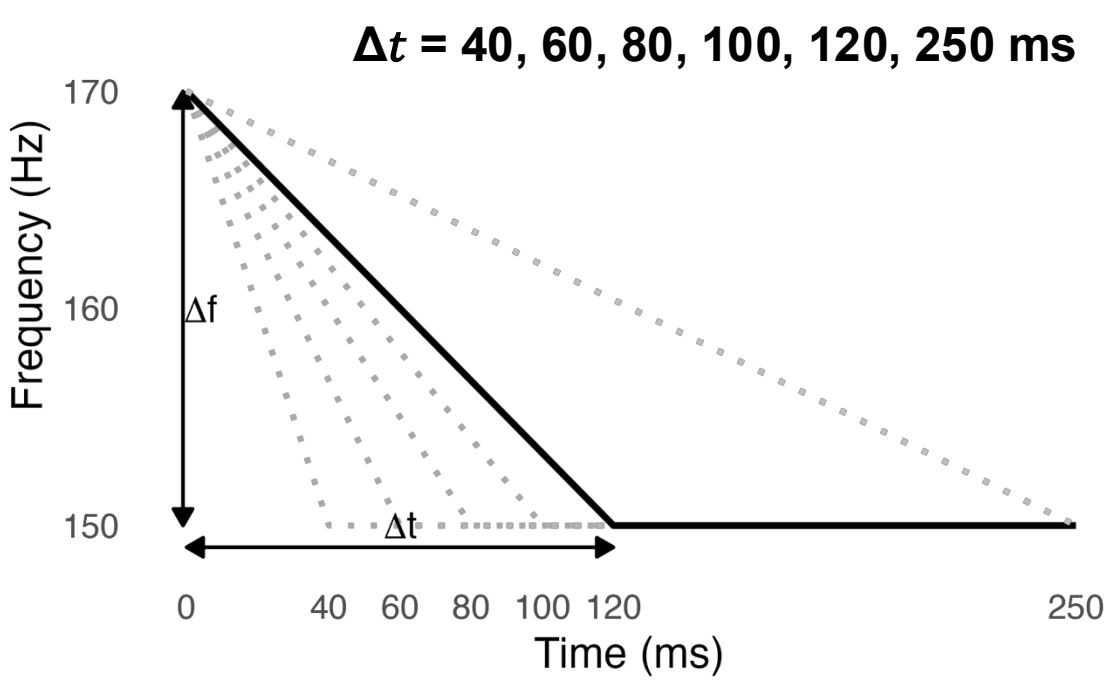
Method: Experiment Paradigm

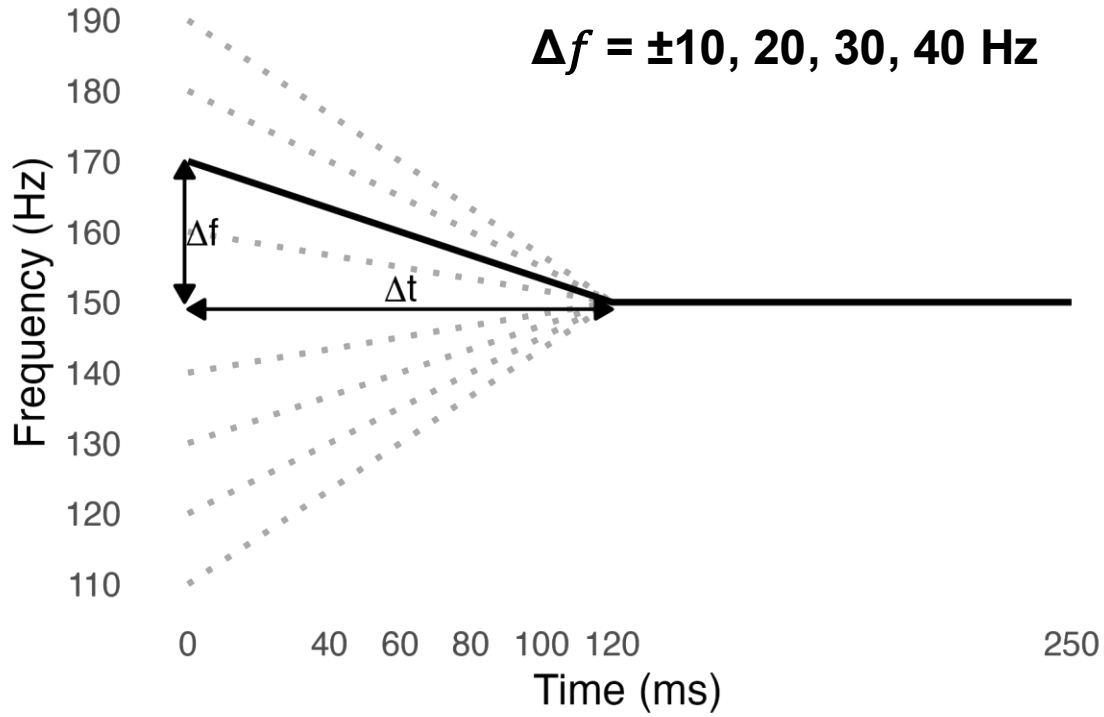
The Pitch-matching Paradigm



Hombert (1975, p.223 Part I)

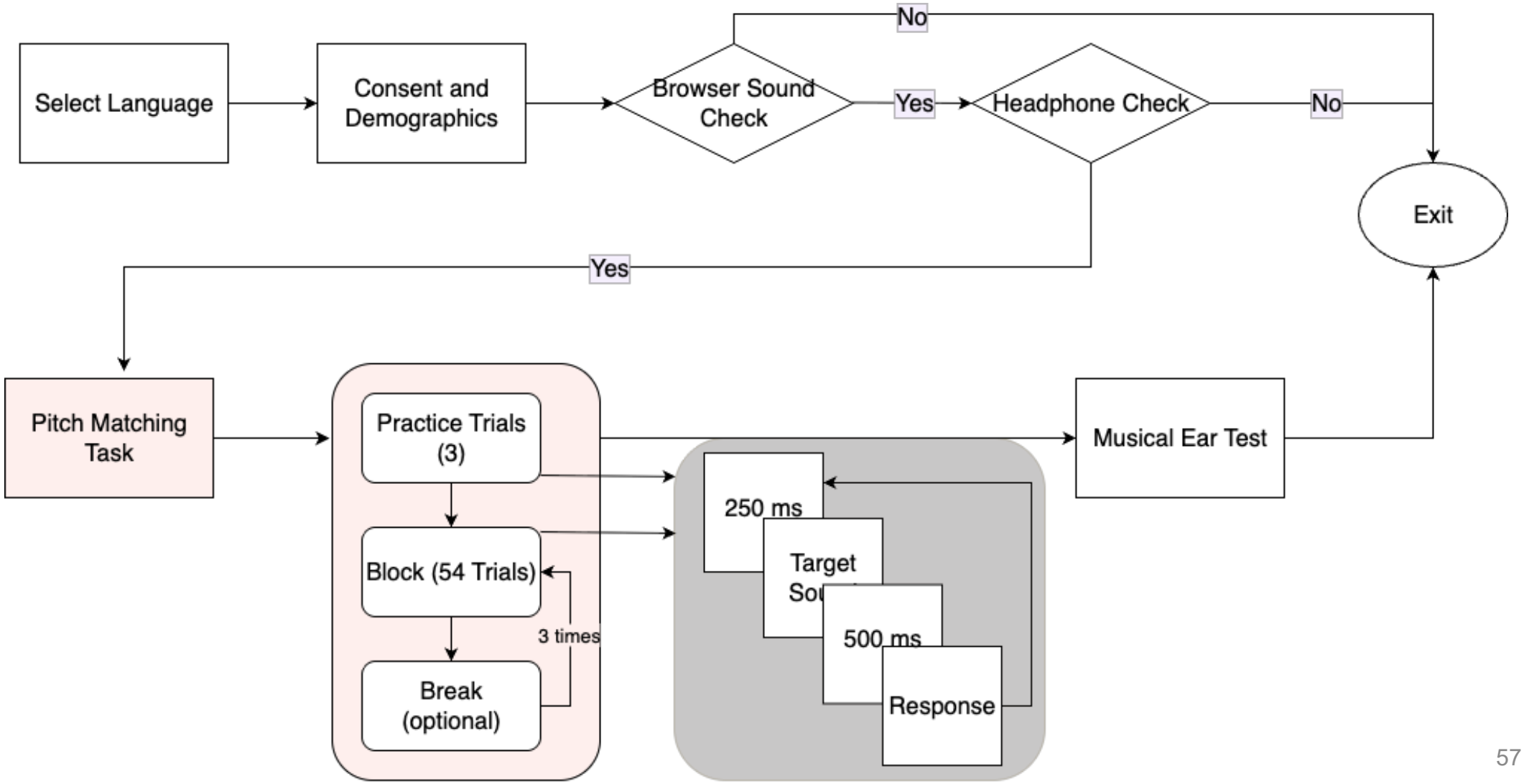
Method: Stimuli (Pilot)



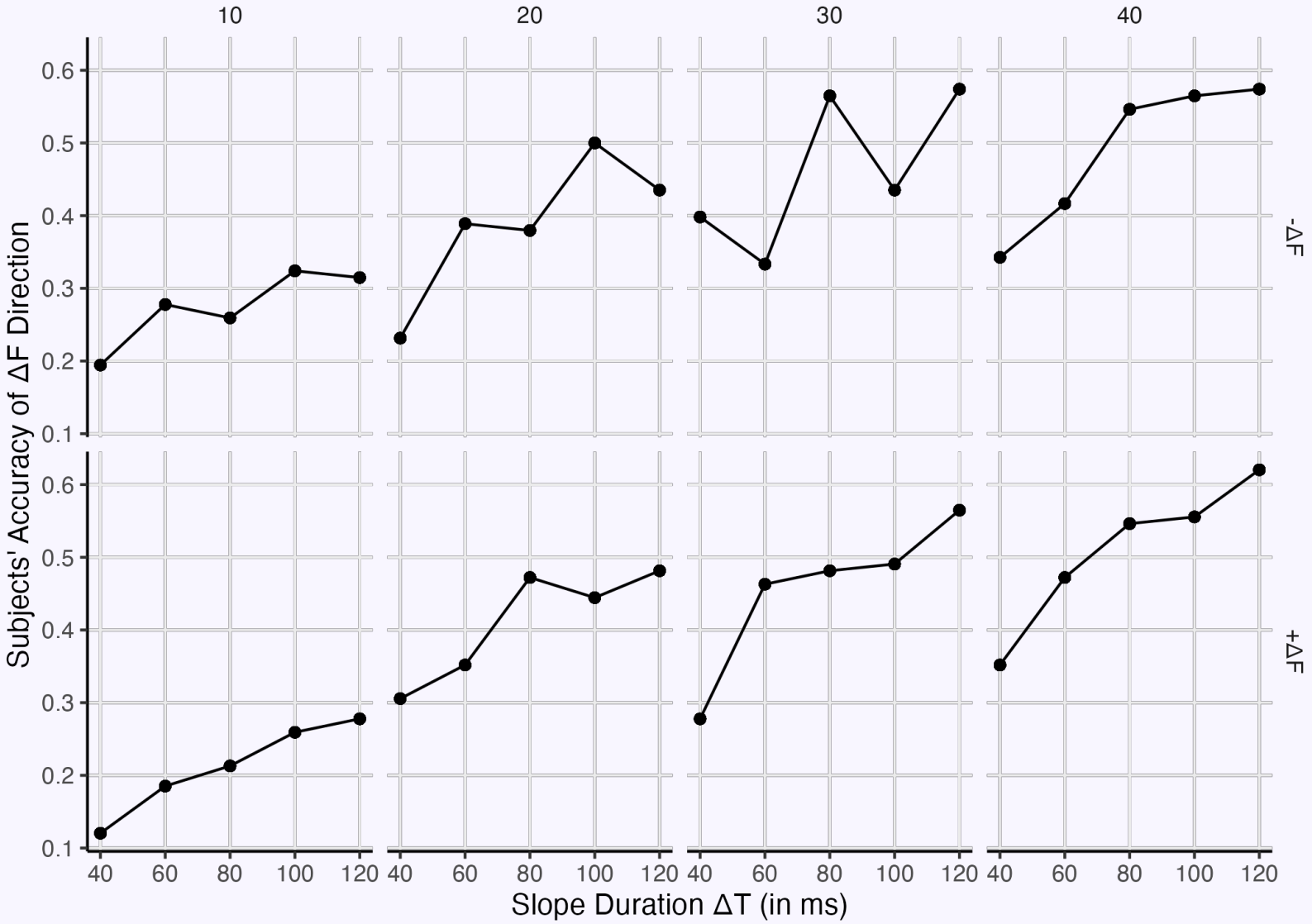


- 3 sound token type: baseline f_0 = 150 Hz
  - Complex tone with 12 harmonics
  - Vowel [i:]
  - Syllable [ti:] (with short-lag VOT ≈12 ms)
- Resynthesised from a male recording (44.1 kHz, 16 bit, mono)
- Intensity normalised to 75 dB
- Fixed token length of 250 ms

Method: Procedure



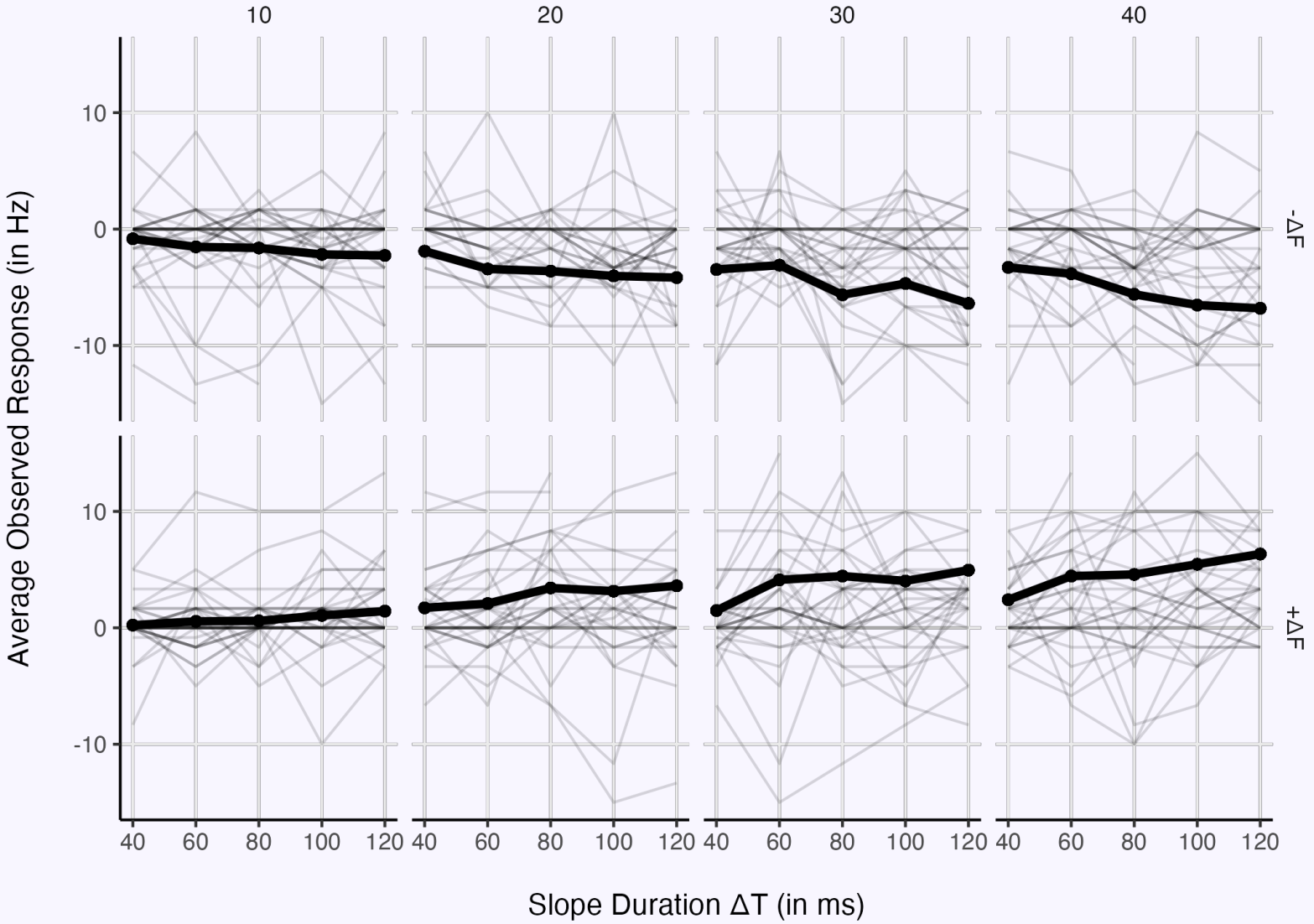
Pilot results I



Accuracy (A) of judging ΔF direction

- Generally:
  $$A \propto (|\Delta F|, \Delta T)$$
- When |ΔF| =10Hz, accuracy is very low even with ΔF =120 ms.
- The accuracy increase is not linear

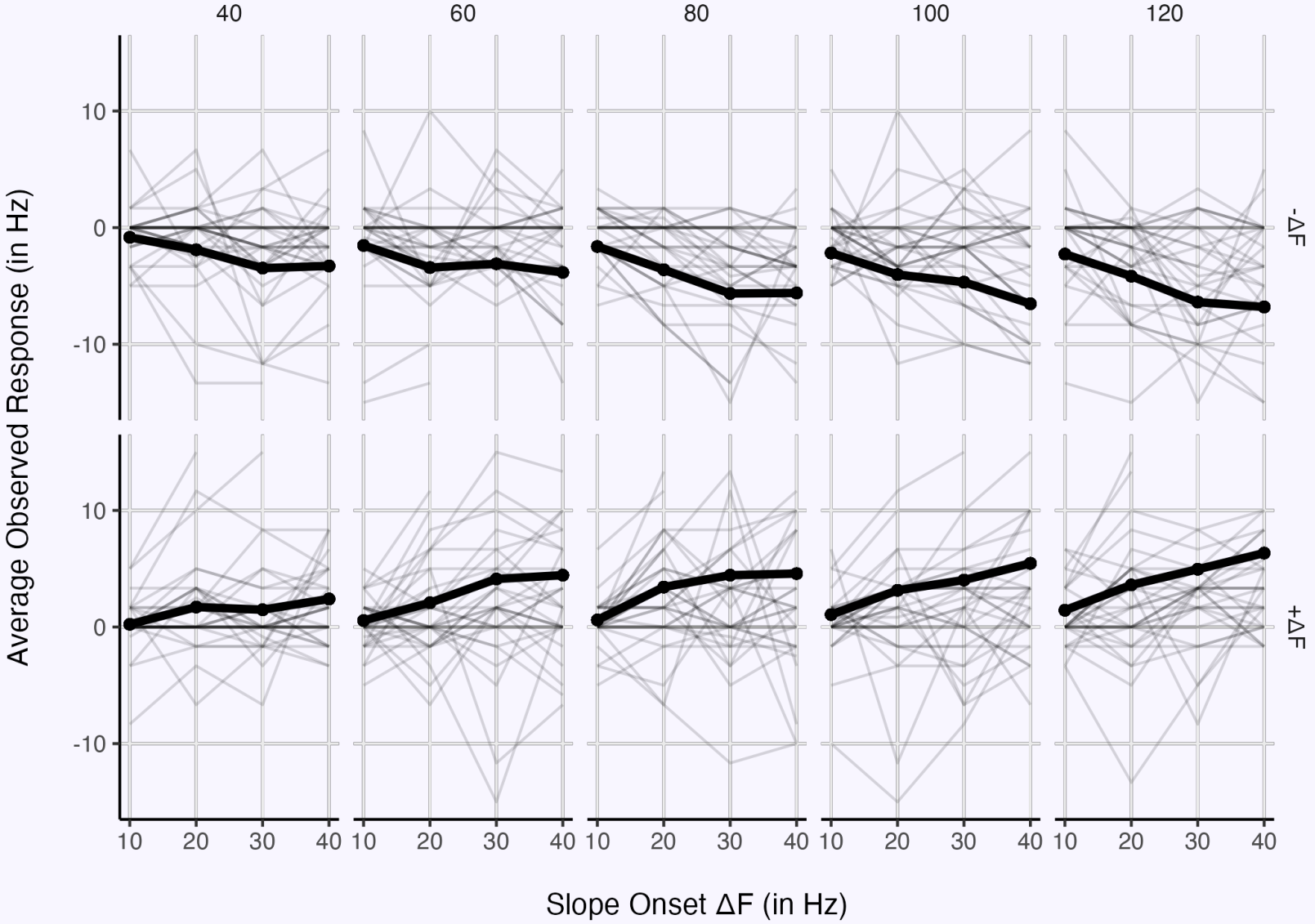
Pilot results II



Average perceived ΔF (R)

- The average perceived ΔF is relatively small |R|<10 Hz.
- In some cases (e.g. 20 ms), R reaches a plateau even with increased ΔT.
- There is considerable individual variation.

Pilot results III



Average perceived ΔF (R)

- R is roughly linear with respect to |ΔF|, (only) when ΔT is large.

$$\frac{\partial^2 R}{\partial(\Delta F)^2} \to 0$$

Big Team Science

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Data Lead

Timo B. Roettger

Analysis Lead

Chenzi Xu

Method Lead

Scientific Lead

Xinbing Luo

Project Manager

Cong Zhang

Ethics Lead

Indranil Dutta

Outreach Lead

Big Team Science

Join as a collaborator

- Open to research labs, fieldworkers, linguists, cognitive scientists, and musicians
- Collaborate in data collection and analysis
- Co-author in high-impact, multi-author publications

Take-home Messages

- Tones vary and change!
- Neutral tone in Mandarin may be underlyingly **underspecified** and acquire a target via **prosodic structure**
- Tone features at higher prosodic hierarchy are more **pertinacious** (resistant to change)
- Perspectives of language **variation and change** help us understand tonal phenomena
- The number of tone targets in tone languages is **fewer** than the number of syllables in connected speech

Thank you!

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