

# Perception of Coarticulated Tones in Taiwan Mandarin and Taiwan Southern Min



Po-Hsuan Huang <sup>1</sup> Chenhao Chiu <sup>1, 2</sup>

<sup>1</sup>Graduate Institute of Linguistics, National Taiwan University

<sup>2</sup>Neurobiology and Cognitive Science Center, National Taiwan University

## Background

BM has been found to make use of normalization to deal with TC-induced tone variations [1, 2]:

The same surface tone is:

- perceived as **lower** when preceded by a **higher** tone offset.
- perceived as **higher** when preceded by a **lower** tone offset.

Therefore, a route from production to perception under TC is found for BM:

TC → target tone mistaken as another tone under TC-induced variations → retrieve the target through normalization.

However, two conditions may lead to different routes:

- Magnitude of TC.
- Different perceptual mechanisms.

## TM & TSM as test cases

Factor 1 Possibility of tonal confusion:

Tone inventory sizes:

- TM: 4 (55, 21, 51, 35)
- TSM: 7 (55, 33, 21, 51, 35, 54, 32)

→ TSM has a **higher** possibility of tonal confusion.

Factor 2 Recoverability of target tones:

	55	35	21(4)	51
Carry-over Raising	T2 (35)		T4(51)	T3 (21(4))
Lowering		T1 (55)		

	55	35	21	51	33
Carry-over Raising	T5 (35) T7 (33)		T1 (55)	T3 (21) T7 (33)	T3 (21)
Lowering			T2 (51) T7 (33)		T1 (55) T2 (51)
Anticipatory Raising	T3' (51)				T7' (21)
Lowering	T1' (33)		T2' (55)		T2' (55)

Table 1. Mapping between intended target tones and coarticulated tones in TM (top) and TSM (bottom). The top row lists the coarticulated (surface) tones. Based on the carry-over and anticipatory effects, the intended target tones can be identified through normalization and filled in the corresponding cells. Impossible mappings between target and coarticulated tones are left blank. The apostrophes indicate that tone sandhi is applied.

→ TSM has a **lower** recoverability of target tones, due to the many-to-one mapping.

Two possibilities:

- TSM may have weaker TC to avoid TC-induced tone variations ← disfavored by previous studies [3]
- TSM may have weaker normalization for TC due to the lower recoverability, and may make use of **other** perceptual mechanisms. ← focus of the present study

## Another possible mechanism: Tone acceptance ranges

In this study, we propose a novel mechanism to deal with TC-induced tone variations: tone acceptance ranges.

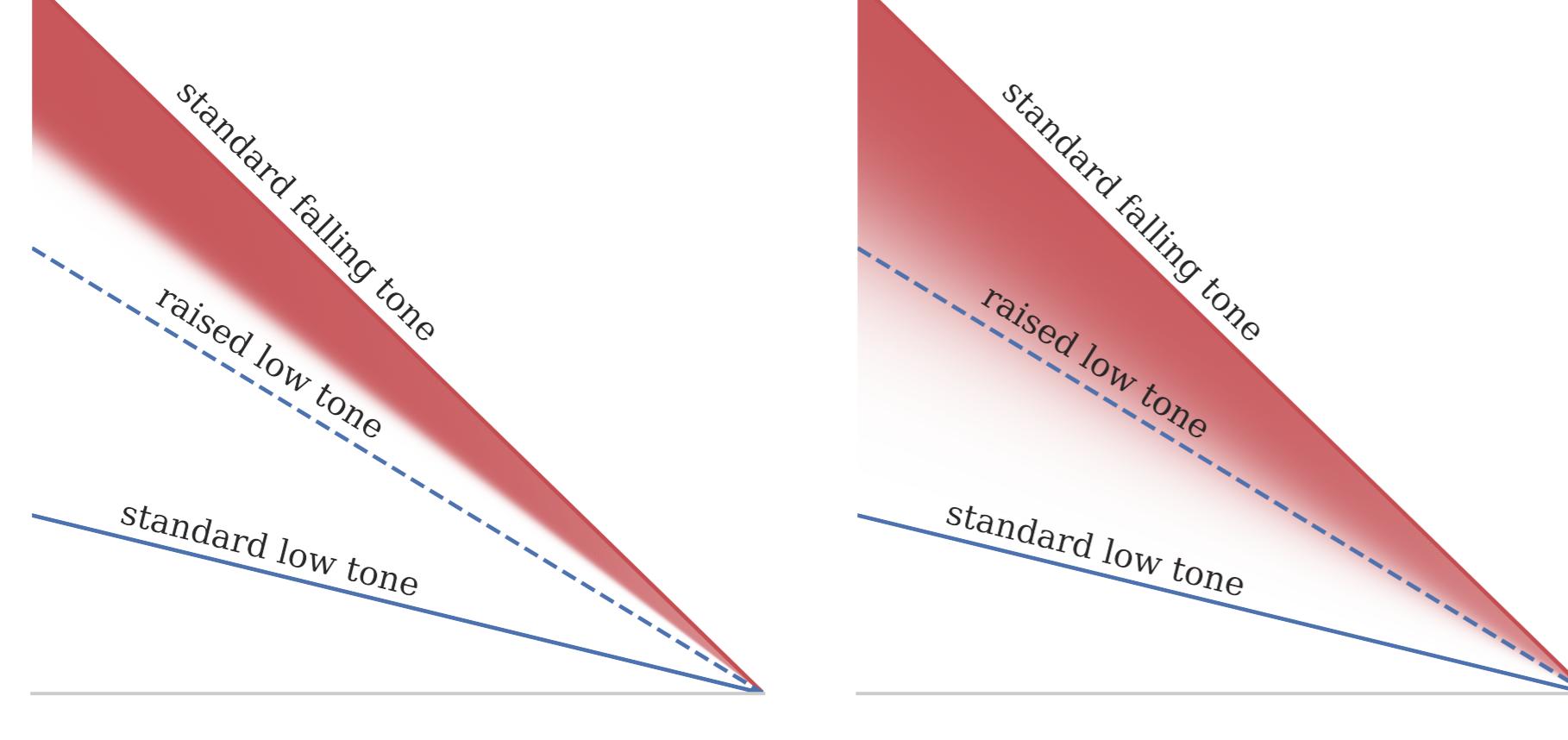


Figure 1. An illustration of narrower (left) and wider (right) tone acceptance ranges of a falling tone. The red areas indicate the acceptance ranges. The darkness of the redness indicates the probability of acceptance.

Under the same degree of TC-induced tone variations, a raised low tone may be

- in a language w/ wider acceptance ranges: accepted as a falling tone → retrieve the target tone through normalization
- in a language w/ narrower acceptance ranges: still perceived as a low tone → weaker normalization induced

## Research questions

- Does TSM have weaker normalization for TC than TM? (factor 1 → exp. 1)
- Does TSM have narrower tone acceptance ranges than TM? (factor 2 → exp. 2)

## Experiment 1: Magnitude of normalization for TC

### Methods

#### Participants & stimuli

##### Participants

- 25 Taiwanese college students (15 females; 20–27 y.o., mean=21.93)
  - 15 Taiwan Mandarin monolingual
  - 28 Taiwan-Mandarin-Taiwan-Southern-Min bilingual (11 advanced; 17 intermediate)

##### Stimuli

Low-to-falling tone continua preceded by lexical tones w/ different levels of tone offsets in minimal pairs.

- TM version: 10 levels×3 tones (55, 51, 35)
- TSM version: 10 levels×4 tones (55, 51, 33, 21)

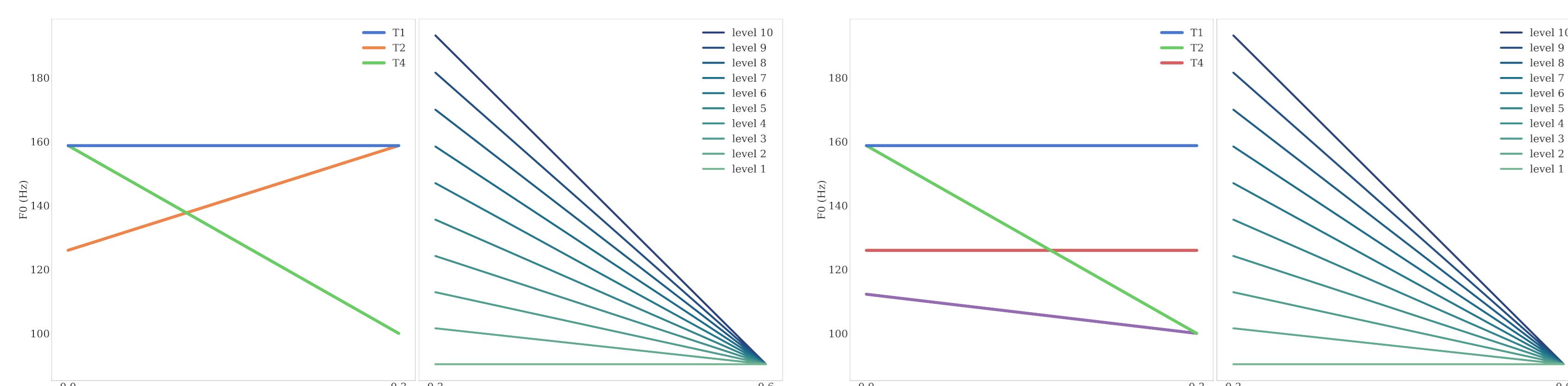


Figure 2. Illustration of synthesized tone contours (left: TM; right: TSM).

## Procedure

- Fixation (1s) → auditory stimulus (.6s) → inter-stimuli interval (.4s) → target alternatives
- 5 repetitions for each combination

## Analyses

- The participants' responses were converted into 0 (low tone response) and 1 (falling tone response).
- The responses were then fitted through mixed-effect logistic regression models.

## Results

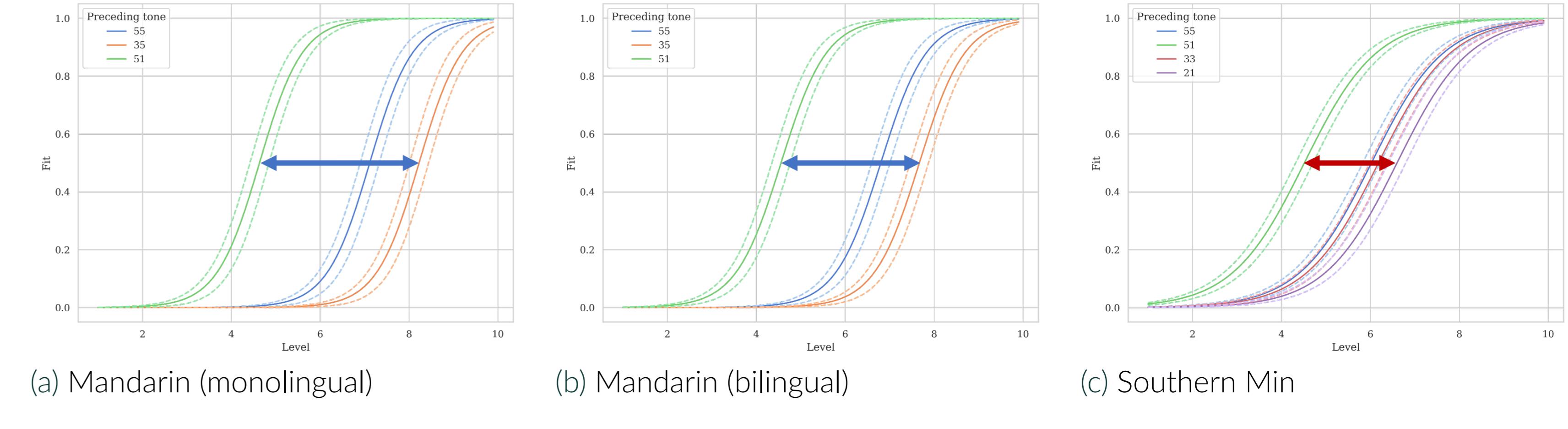


Figure 3. Logistic regression fits of falling tone response across different preceding tones.

→ TSM had smaller magnitudes (red arrow) of normalization for TC than TM (blue arrows).

## Experiment 2: Tone acceptance ranges

### Methods

#### Participants & stimuli

##### Participants

The same participants as Exp. 1 were recruited.

##### Stimuli

- Word-non-word continua w/ a high-level tone + a low-to-high continua.
- The second syllable went from a standard low tone to a standard falling tone from level 1 to level 10.
- 10 words chosen:
  - 55+21: 5 (more like a non-word on level 1; more like a word on level 10)
  - 55+51: 5 (more like a word on level 1; more like a non-word on level 10)

##### Procedure

- Fixation (1s) → auditory stimulus (.6s) → inter-stimuli interval (.4s) → A circle (accepted) & a cross (not accepted)
- 10 repetitions for each combination

##### Analyses

- Steepness of acceptance climbs:** determined as the maximum of the slopes between the response rate of each of the 10 levels.
- Threshold of acceptance:** determined w/ probit analysis [4].
- t-tests used to examine statistical significance.

## Results

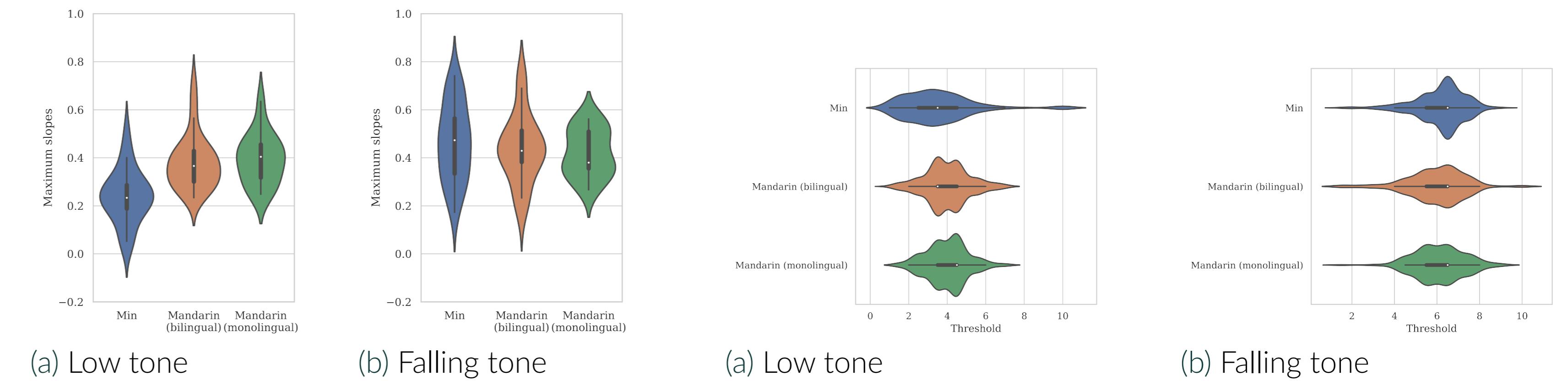


Figure 4. Maximum slopes of the acceptance rate climbs for the low tone and the falling tone for advanced speakers.

Figure 5. Thresholds of acceptance for the low tone and the falling tone.

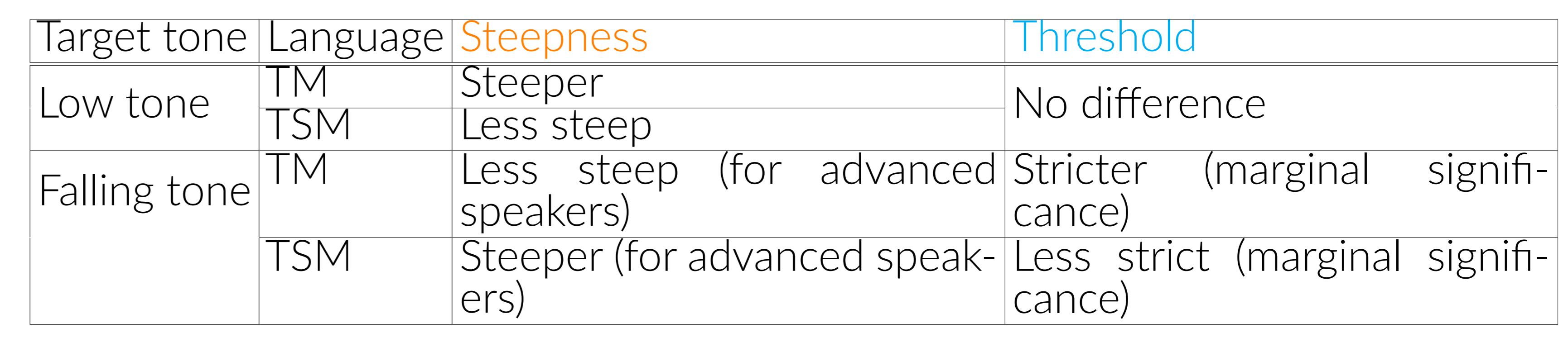


Table 2. Summary of the results of Exp.2.

## Discussion

### Magnitude of normalization for TC

Our results supported the prediction that the lower recoverability of target tones in TSM led to less reliance on normalization for TC.

### Tone acceptance ranges

On the other hand, TSM may make use of narrower tone acceptance ranges to block out coarticulated tones, reducing the probability of confusing them with other lexical tones.

## Conclusions

Overall, this study investigated the perception of coarticulated tones in Taiwan Mandarin and Taiwan Southern Min. Two different perceptual strategies were found. Taiwan Mandarin, like Beijing Mandarin, made use of normalization to cope with TC-induced tone variations. On the other hand, Taiwan Southern Min had weaker normalization, but narrower tone acceptance ranges, which presumably could help reduce the probability of confusing a coarticulated tone with another lexical tone.

## References

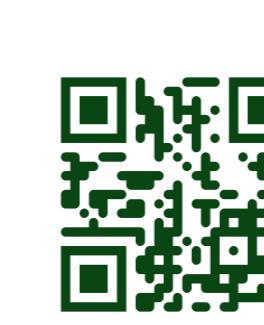
- [1] Y. Xu, "Production and perception of coarticulated tones," *Journal of the Acoustical Society of America*, vol. 95, no. 4, pp. 2240–2253, 1994.
- [2] H. Zhang, H. Ding, and W.-S. Lee, "The influence of preceding speech and nonspeech contexts on Mandarin tone identification," *Journal of Phonetics*, vol. 93, p. 101154, 2022.
- [3] P.-H. Huang and C. Chiu, "Tonal coarticulation in Taiwan Mandarin and Taiwan Southern Min," 2023, Hanyang International Symposium on Phonetics and Cognitive Sciences of Language 2023.
- [4] D. J. Finney, *Probit Analysis*, 3rd ed. Cambridge: Cambridge University Press, 1971.



Our lab



This paper



Authors' websites