Articulatory and acoustic features of Mandarin rhotics: an ultrasound study

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INTRODUCTION

Background:

- English /ɹ/ can be articulated with various tongue shapes with minimal acoustic consequence (Delattre and Freeman, 1968; Westbury et al., 1998; Twist et al., 2007; Zhou et al., 2008; Mielke et al., 2010).
- The continuum of tongue variation is usually roughly categorized as retroflex and bunched tongue shapes.
- Nearly the entire literature on the articulatory variation has been focused on English /ɹ/.

Research questions:

- Can articulatory variation be found in Mandarin /ɹ/ sound?
- Is the articulation of Mandarin /ɹ/ affected by syllable position and vowel context?
- Is frication noise a consistent component for prevocalic /ɹ/?

METHOD

Participants: 1) 18 native Mandarin speakers (4M,15F) who naturally speak with a rhotic accent of Mandarin 2)16 native American English speakers (5M, 11F)

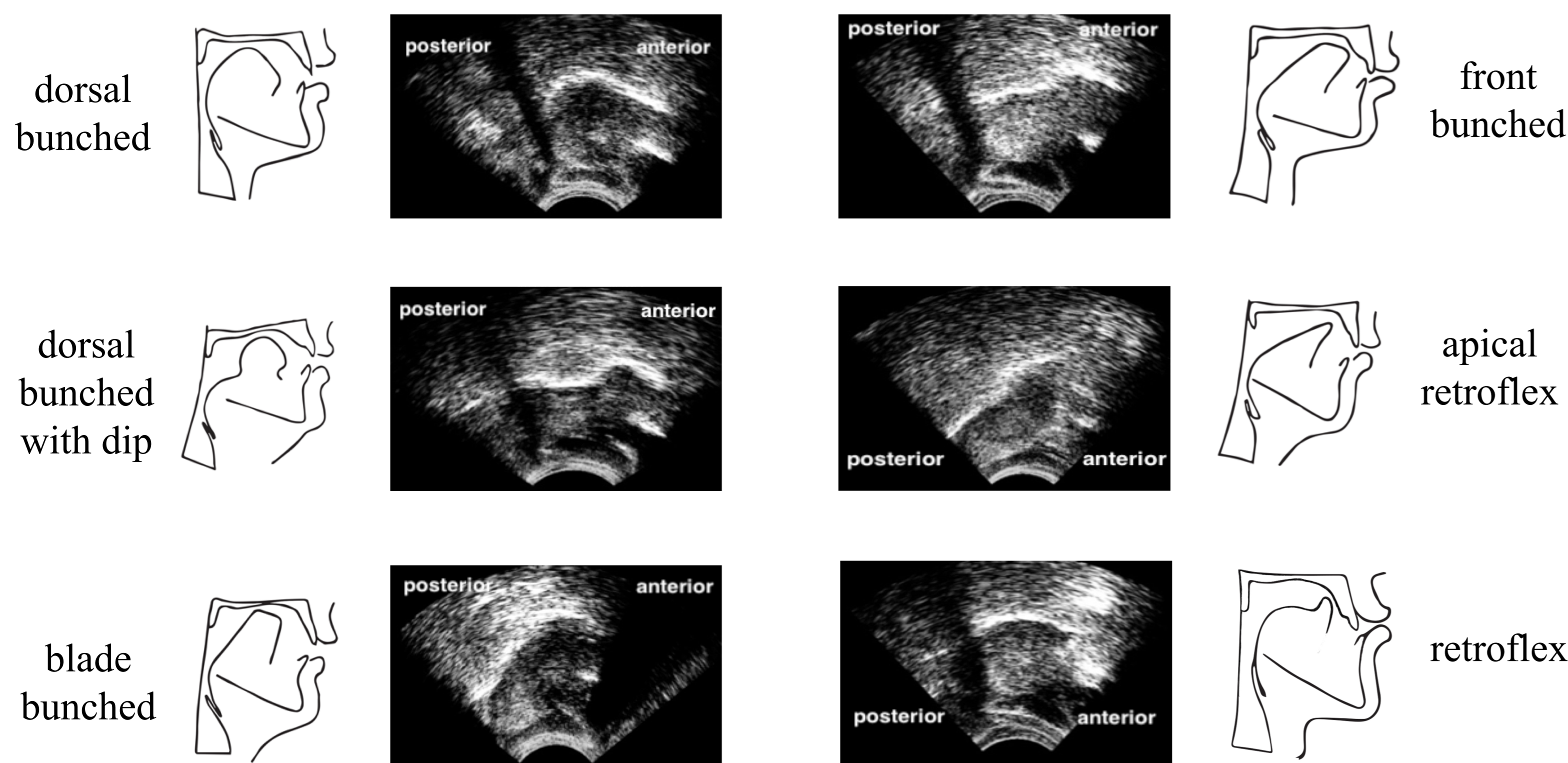**Stimuli**: Mandarin and English words with /ɹ/ sound

Syllable positions	Vowel contexts	Sample words
Prevocalic	/ɿ a ɤ u/	/rʅ/ 'sun' 日 /rɤ/ 'hot' 热 /ru/ 'enter' 入 /ran/ 'but' 然 /rɑŋ/ 'allow' 让
Postvocalic	/i ɿ ʅ y u a ɤ/	/sɿr/ 'thread' 丝儿 /tʂʅr/ 'branch' 枝儿 /yr/ 'fish' 鱼儿
Syllabic		/ɹ/ 'son' 儿 /ɹ/ 'ear' 耳 /ɹ/ 'two' 二

Table 1. Sample words for the Mandarin stimuli

Procedure: Participants read the target words in their native languages while being recorded with ultrasonic machines. Some speakers were recorded with Siemens ACUSON X300 system, some with EchoB ultrasound machine together with the Articulate Assistant Advanced (AAA) software.

ARTICULATORY FEATURES OF MANDARIN /ɹ/

Similar to English /ɹ/, Mandarin /ɹ/ can be produced with various tongue shapes.

*Articulatory gestures of Mandarin /ɹ/.*

- The six tongue shapes were categorized as bunched (tongue tip pointing down) and retroflex gestures (tongue tip pointing up) by two trained phoneticians.
- Mandarin prevocalic /ɹ/ were articulated with only bunched tongue shapes in our data.
- Each speaker used the same gesture (bunched or retroflex gesture) in the syllabic and postvocalic position
- The tongue shape of Mandarin /ɹ/ was not influenced by vowel contexts

Participants	Prevocalic				Syllabic	Postvocalic						
	/ʅ/	/a/	/ɤ/	/u/		/i/	/ɿ/	/ʅ/	/y/	/u/	/a/	/ɤ/
M1	Bunched				**Retroflex**	**Retroflex**						
W1	Bunched				**Retroflex**	**Retroflex**						
M2	Bunched				**Retroflex**	**Retroflex**						
W2	Bunched				**Retroflex**	**Retroflex**						
M3	Bunched				Bunched	Bunched						
W3	Bunched				Bunched	Bunched						
W4	Bunched				**Retroflex**	**Retroflex**						
W5	Bunched				**Retroflex**	**Retroflex**						
W6	Bunched				Bunched	Bunched						
W7	Bunched				Bunched	Bunched						
W8	Bunched				Bunched	Bunched						
W9	Bunched				**Retroflex**	**Retroflex**						
W10	Bunched				Bunched	Bunched						
W11	Bunched				Bunched	Bunched						
W12	Bunched				Bunched	Bunched						
W13	Bunched				**Retroflex**	**Retroflex**						
M4	Bunched				Bunched	Bunched						
W14	Bunched				Bunched	Bunched						

Table 2. Summary of the tongue gestures by all speakers

ACOUSTIC FEATURES OF MANDARIN /ɹ/

- Frication noise was only observed in prevocalic /ɹ/, but never in syllabic and postvocalic /ɹ/.
- Frication noise was found in many prevocalic /ɹ/ tokens, but not all tokens.
- Frication noise was more often observed when /ɹ/ is followed by high vowels (/ɿ u/) than the two allophones of the low vowels /a/ ([a] and [ɑ]).
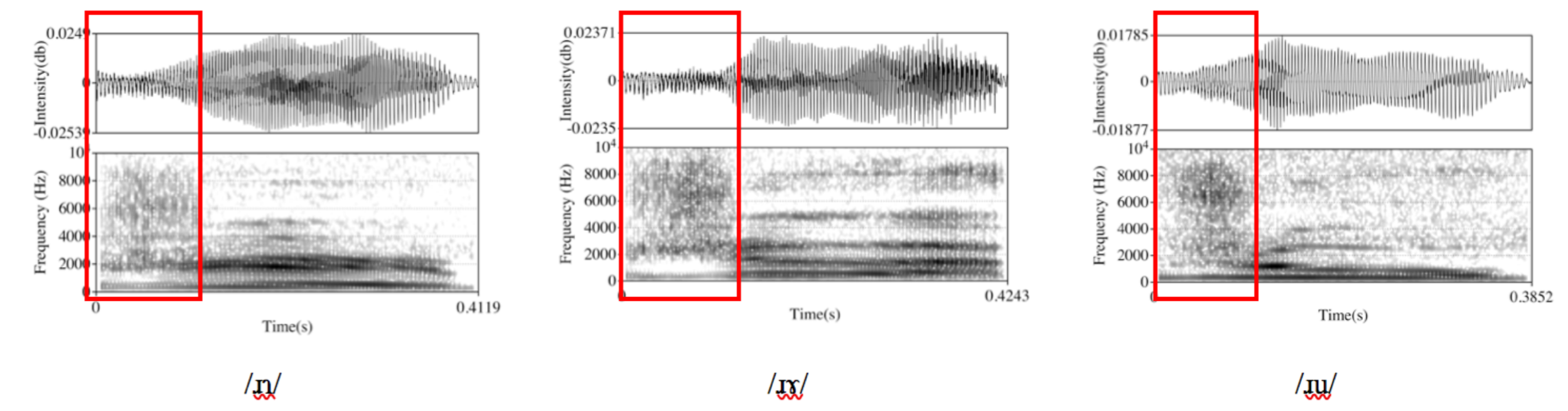

Waveforms and spectrograms of prevocalic /ɹ/ in various vowel contexts by Speaker W10.

Speakers	/ɿ/ Mandarin apical vowel	/u/	/ɤ/	/a/	
				[a]	[ɑ]
M1	+	+	+	+	+
W1	some tokens	some tokens	–	–	–
M2	+	+	+	+	+
W2	+	+	+	–	–
M3	+	+	+	+	–
W3	+	+	+	+	+
W4	+	+	+	–	–
W5	some tokens	some tokens	+		some tokens
W6	+	–	some tokens	–	–
W7	+	+	+	some tokens	some tokens
W8	+	+	+	+	some tokens
W9	+	+	+	+	+
W10	+	+	+	+	some tokens
W11	–	some tokens	+	some tokens	–
W12	+	+	+	–	some tokens
W13	+	some tokens	some tokens	–	–
M4	+	some tokens	+	+	+
W14	+	+	+	–	some tokens

Table 3. Summary of frication observed in Mandarin prevocalic /ɹ/ (+ indicates the presence of frication; – indicates absence of frication; "some tokens" means that frication could be found in some repetitions)

Formant patterns

- No significant differences between bunched and retroflex speakers in the first three formants of /ɹ/ sound.
- Mandarin /ɹ/ has a significantly higher F3 than English /ɹ/ in prevocalic and syllabic position.
- The F3-F2 of Mandarin /ɹ/ was significantly higher than that of English in all syllable positions
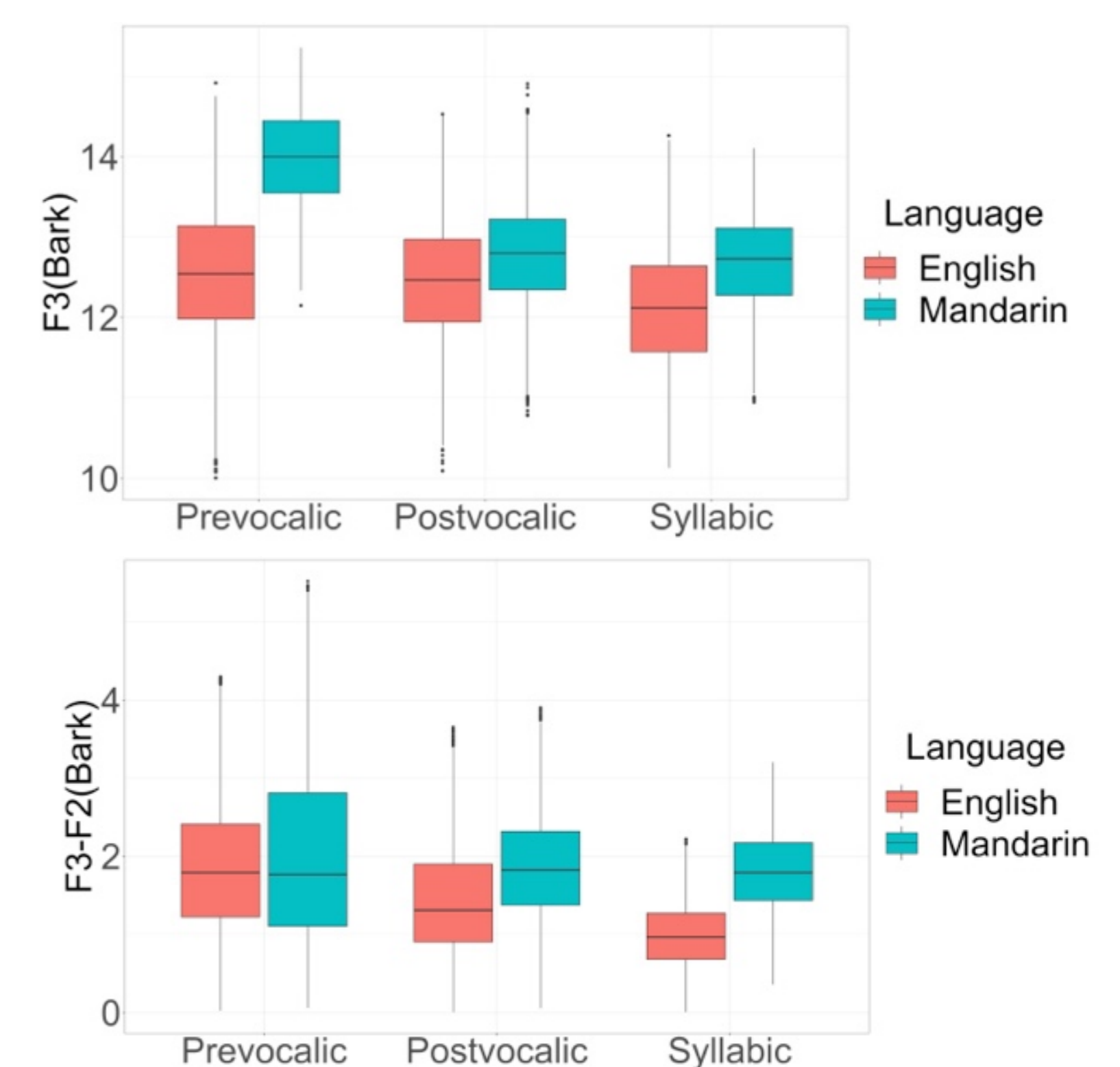
DISCUSSION AND CONCLUSIONS

- Like English /ɹ/, Mandarin /ɹ/ can be articulated with various tongue shapes.
- Our data showed that Mandarin prevocalic /ɹ/ was articulated with only bunched gestures, while syllabic and postvocalic /ɹ/ could be produced with either the retroflex or bunched gestures.
- The tongue shape of Mandarin /ɹ/ was not influenced by vowel contexts
- Mandarin /ɹ/ had a higher F3-F2 values than English /ɹ/ in all syllable positions and a higher F3 in prevocalic and syllabic positions, which indicates that Mandarin /ɹ/ is less rhotic than the one in English.
- Our data suggested that it might be more appropriate to categorize Mandarin prevocalic rhotic sound as an approximant with an optionally fricated onset rather than a fricative because it lacks the consistent presence of frication noise which is the most salient feature of fricatives.

Selected references

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