Articulatory and acoustic features of Mandarin rhotics: an ultrasound study

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Rhotic sounds in the world languages have a wide range of variants, and are famous for their complexity in production. The current study examined the articulatory and acoustic features of Mandarin /ɹ/ using ultrasound imaging. It has been well-studied that English /ɹ/ can be articulated with various tongue shapes with minimal acoustic consequence (Delattre & Freeman, 1968; Mielke et al., 2010, 2016; Twist et al., 2007; Zhou et al., 2008). The continuum of tongue variation was usually roughly categorized as retroflex and bunched gestures based on the tongue tip positions. It is unclear, however, if the articulatory variability is a language-specific phenomenon unique to English, or a universal phenomenon that can be found in other similar rhotic sounds, such as Mandarin /ɹ/. In addition, there has been a debate if Mandarin prevocalic rhotic sound is an approximant or a fricative in Mandarin phonology (Duanmu, 2007; Karlgren, 1915; Lee & Zee, 2003; Lin, 2007). The current study will provide phonetic data that could potentially answer these two questions.

Eighteen native Mandarin speakers (four male speakers and fifteen female speakers) were recorded reading Mandarin words with prevocalic, syllabic and postvocalic /ɹ/ with ultrasound imaging. Among them, six speakers were recorded with the Siemens ACUSON X300 ultrasound system at Haskins Laboratories with blue dots head correction (Chen et al., 2017; Tiede, 2018), and twelve were recorded with the EchoB ultrasound system together with the Articulate Assistant Advanced (AAA) software at the Chinese University of Hong Kong. All the Mandarin speakers were all born and grew up in Northern China (Beijing, Hebei and Shandong Province), so they naturally speak with a rhotic accent of Mandarin. Sixteen monolingual English speakers (five male speakers and eleven female speakers) were recorded reading English words containing /ɹ/ sound to compare Mandarin /ɹ/ with English /ɹ/. Among them, ten speakers were recorded with the Siemens system, and the other six were recorded with the EchoB system.

The results showed that, similar to English rhotics, Mandarin /ɹ/ could be articulated with various tongue shapes, and these could be categorized as bunched gesture (tongue tip pointing down) or retroflex gesture (tongue tip curling up) (Figure 1). The variation between bunched and retroflex /ɹ/, however, was only found in the postvocalic and syllabic /ɹ/. Mandarin prevocalic /ɹ/ was uniformly produced with the tongue tip pointing down (bunched gestures). Moreover, in English, retroflex gestures were preferred when /ɹ/ was adjacent to low vowels or back vowels, while the bunched gestures were preferred in the high vowel and front vowel contexts. The tongue shape of Mandarin /ɹ/, however, was not influenced by vowel contexts. If a speaker chose to use a bunched or retroflex gesture, he/she would continue with that gesture despite the segmental changes.

Acoustically, frication noise was often observed in the Mandarin prevocalic /ɹ/, but not in all prevocalic tokens. It suggests that the fricative noise was not an obligatory phonetic cue in Mandarin prevocalic /ɹ/ production. Large interspeaker variation was found in using frication noise in the production of prevocalic /ɹ/. Moreover, Mandarin /ɹ/ had a higher F3 and larger

F3-F2 difference than English /ɹ/ in the prevocalic and syllabic positions, and a higher F2 in the prevocalic position, indicating less rhoticity in Mandarin /ɹ/ than in English /ɹ/.

In summary, the results of the current study showed that the articulatory variation was not language-specific phenomenon unique to English /ɹ/. Also, it might be more appropriate to categorize Mandarin prevocalic rhotic sound as an approximant rather than a fricative because it lacks the consistent presence of frication noise which is the most important phonetic cue for fricatives.
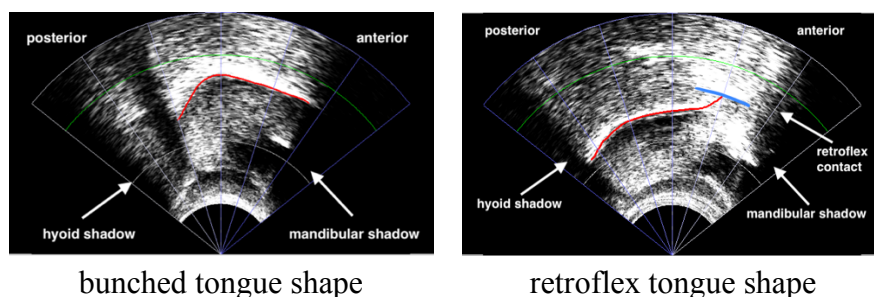

bunched tongue shape   retroflex tongue shape

Figure 1: *Typical bunched and retroflex tongue shapes in Mandarin /ɹ/.*

Reference:
Chen, W.R., Tiede, M., & Chen, S. (2017). *An optimization method for correction of ultrasound probe-related contours to head-centric coordinates*. Ultrafest VIII, Potsdam.
Delattre, P., & Freeman, D. C. (1968). A dialect study of American R's by X-ray motion picture. *Linguistics*, *6*(44). https://doi.org/10.1515/ling.1968.6.44.29
Duanmu, S. (2007). *The Phonology of Standard Chinese*. Oxford University Press, Incorporated. http://ebookcentral.proquest.com/lib/cuhk-ebooks/detail.action?docID=415943
Karlgren, B. (1915). *Etudes sur la phonologie chinoise* (Vol. 5). E.-J. Brill. https://www.persee.fr/doc/befeo_0336-1519_1916_num_16_1_5301
Lee, W.-S., & Zee, E. (2003). Standard Chinese (Beijing). *Journal of the International Phonetic Association*, *33*(1). https://search-proquest-com.easyaccess2.lib.cuhk.edu.hk/docview/224986928/fulltextPDF/EBF0380E05C54702PQ/1?accountid=10371
Lin, Y.H. (2007). *The Sounds of Chinese with Audio CD* (1 edition). Cambridge University Press.
Mielke, J., Baker, A., & Archangeli, D. (2010). Variability and homogeneity in American English/r/allophony and/s/retraction. *Laboratory Phonology*, *10*, 699–730.
Mielke, J., Baker, A., & Archangeli, D. (2016). Individual-level contact limits phonological complexity: Evidence from bunched and retroflex /ɹ/. *Language*, *92*(1), 101–140. https://doi.org/10.1353/lan.2016.0019
Tiede, Mark K. (2018). GetContours (Version 1.3). Retrieved from https://github.com/mktiede/GetContours
Twist, A., Baker, A., Mielke, J., & Archangeli, D. (2007). Are "Covert" /ɹ/ Allophones Really Indistinguishable? *University of Pennsylvania Working Papers in Linguistics*, *13*(2).
Zhou, X., Espy-Wilson, C. Y., Boyce, S., Tiede, M., Holland, C., & Choe, A. (2008). A magnetic resonance imaging-based articulatory and acoustic study of "retroflex" and "bunched" American English /r/. *The Journal of the Acoustical Society of America*, *123*(6), 4466–4481.