Tongue root position in Mandarin Chinese aspirated and unaspirated obstruents

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Background: American English "voiced" stops, even without phonetic voicing during closure, have more advanced tongue root than the "voiceless" stops (Westbury 1983, Ahn 2018). This suggests that tongue root advancement might not be tied to phonetic voicing but to the implementation of a more abstract contrast. The current study compares tongue root position during Mandarin Chinese unaspirated and aspirated obstruents, which are acoustically similar to English "voiced" and "voiceless" ones in phrase-initial position, although the unaspirated series have less carryover voicing from the preceding vowel than English "voiced" stops (Deterding & Nolan 2007). This study tests whether different laryngeal categories in Mandarin, a language without phonological voicing, differ in their tongue root position.

Methods: Tongue ultrasound imaging and audio recording are used to determine tongue root position and VOT during fifteen native Mandarin speakers' obstruents (stops and affricates). Phrase-initial and intervocalic positions are compared to verify if unaspirated obstruents, when preceded by a vowel, show any carryover voicing. Data collection is ongoing, using a Telemed Micro ultrasound device outfitted with a Telemed MC4-2R20S-3 convex probe. The frame rate is approximately 82 Hz. Table 1 shows a representative subset of stimuli, which are matched closely for lingual activity near the target segments. We will compare the tongue root position of the frame closest to the release of the closures of target obstruents.

Unaspirated	Aspirated
宝剑 **p**aʊ˩tɕɛn˥˧ 'sword'	泡面 **pʰ**aʊ˥˧mjɛn˥˧ 'instant noodles'
导言 **t**aʊ˩jɛn˥˧ 'introduction'	套间 **tʰ**aʊ˥˧tɕɛn˥˧ 'apartment'
枣椰 **ts**aʊ˩jɛ˧ 'date palm'	草芥 **tsʰ**aʊ˩tɕɛ˧ 'grass'
照片 **tʂ**aʊ˥˧pʰjɛn˥˧ 'photograph'	朝鲜 **tʂʰ**aʊ˧ɕɛn˩˧ 'North Korea'
教鞭 **tɕ**aʊ˥˧pjɛn˥˧ 'teacher's pointer'	桥面 **tɕʰ**aʊ˧mjɛn˥˧ 'bridge deck'
稿件 **k**aʊ˩tɕɛn˥˧ 'draft (n.)'	考验 **kʰ**aʊ˩jɛn˥˧ 'trial, ordeal'

Phrase-initial frame:	**Intervocalic** frame:
__ 丢了	他把 __ 丢了
__ tjəʊ˧ lə	ta˧ pa˧ __ tjəʊ˧ lə
'__ is lost/missing'	'He lost the __'

Table 1: *Selected stimuli (top) and frame sentences (bottom)*

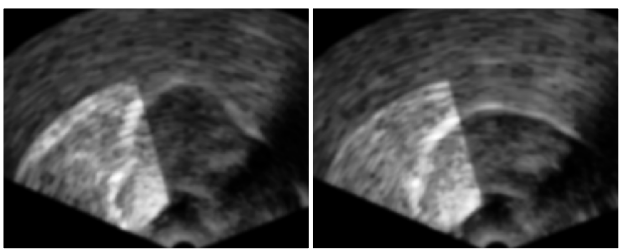

Figure 1: *Schematic PCA regions of interest for relatively advanced (left) and retracted (right) tongue root*

Ultrasound data will be analyzed in two ways. First, tongue contours for obstruent closure will be compared using SSANOVA (Davidson 2006), using a polar coordinate system to avoid distortions of the tongue root (Mielke 2015). Second, a section of each ultrasound image that contains the tongue root for each speaker will be submitted to principal component analysis (Figure 1., Hueber et al. 2007, Hoole & Pouplier 2017). High-ranked principal components representing tongue root displacement will be normalized for comparison across speakers and submitted to a mixed-effects linear regression predicting tongue root advancement with respect to the laryngeal category of the obstruents (aspirated vs. unaspirated) and their position in utterances (phrase-initial vs. intervocalic).

Predictions and discussion: If tongue root position during Mandarin aspirated and unaspirated obstruents is similar to each other, unlike the pattern found in English "voiced" and "voiceless" stops (Ahn 2018), English and Mandarin implement their laryngeal contrast differently. That is, if tongue root advancement found in English "voiced" stops, which may facilitate carryover voicing by enlarging the supralaryngeal cavity, is not present in Mandarin intervocalic unaspirated stops, tongue root advancement may be an articulatory correlate that differentiates English and Mandarin. The acoustic results of Mandarin intervocalic stops will also confirm if there indeed is a carryover voicing from the previous vowel in voiceless unaspirated stops. In contrast, if Mandarin patterns similarly to English (i.e., tongue root more advanced in unaspirated than aspirated obstruents), tongue root advancement may have a motivation other than facilitating phonetic voicing. Advanced or retracted tongue root may arguably co-occur with different types of two-way laryngeal contrast, albeit their precise acoustic correlates would remain to be clarified.

Methodologically, we hope to demonstrate that methods based on contour extraction (SSANOVA) are usefully complemented by dimensionality reduction methods such as PCA. Contour extraction methods capture inter-speaker anatomical variation in addition to linguistic contrast, providing a detailed picture of tongue posture and position. However, because these factors cannot be disentangled easily, inter-speaker comparison is difficult along with most forms of sophisticated statistical inference. Dimensionality reduction methods instead incorporate speaker-specific variation into the dimensions of variation used for input to statistical inference, enabling more sophisticated exploration of contrast implementation which takes individual anatomy and idiosyncrasy into account.

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