Enhancement of Phonological Contrast: Acoustics of Apical and Retroflex Vowels in Mandarin Chinese

In the most recent rendition of their enhancement theory, Keyser and Stevens (2003) claim that when a phonological contrast defined by the distinctive features lacks perceptual saliency, it may be enhanced by introduction of articulatory gestures secondary to the feature-defining gestures. The enhancement hypothesis converges with another line of thinking, referred to as "licensing by cue" (Steriade 1997). The latter theory maintains that phonological contrasts are licensed in positions that are high on a scale of perceptibility. By inference, the contrast can be conveyed in positions with low perceptibility, but only at the cost of additional articulatory effort, which we interpret as the enhancing gesture in the enhancement theory. It is in this connection that we examine the acoustics of apical and retroflex vowels in Mandarin Chinese and propose that they are derived from the underlying /i/, but realized as what they are in CV syllables in order to enhance the phonological contrast between the preceding strident fricatives /s/, /ʂ/ and /ɕ/. We further propose that the choice of enhancing gestures is tied to the phonological system of the language: the same phonological contrast may be enhanced by different gestures in different languages.

Mandarin Chinese has the well-known three series of strident fricatives (1). The apical vowel /ɿ/ appears after /s/ and the corresponding affricates; the retroflex vowel /ɭ/ after /ʂ/ and the corresponding affricates (2). Despite of their straightforward distribution, their phonological status has been elusive. Students of Mandarin phonology disagree as to whether they are contextual variants of /i/ or syllabic consonants (see Duanmu 2000:36-37 for a summary of the two views). A detailed acoustic study of the Mandarin CV syllables was conducted to investigate the acoustic properties of the strident fricatives in different pre-vocalic contexts and their articulatory basis. The acoustic data reveal the following patterns: First, the three fricatives have distinct spectral prominences in discrete frequency ranges. For /s/ the lowest prominent spectral peak is in the F4 range or higher, associated with the cavity in front of the constriction formed between the tongue tip and the alveolar ridge. For /ɕ/ it is in the F3 range, associated with the long palatal channel formed between the raised tongue body and the palate. For /ʂ/ it is in the F2 range, associated with the acoustic coupling between the turbulence noise source to the cavity behind the constriction. These defining acoustic attributes are associated with the distinct tongue configurations. Second, the difference in tongue shapes is also manifested on F2 frequency at vowel onset: highest for /ɕ/, followed by /ʂ/, and lowest for /s/, indicating that the back cavity is shortest for /ɕ/ and longest for /s/. Third, /ɿ/, /ɭ/ and /i/ are distinguished by the first three formants, especially F2, with no visible formant transitions from the preceding fricatives.

The acoustic patterns observed above receive a straightforward explanation in the enhancement theory we are adopting. The phonological contrast between the three fricatives is encoded in their different place features. However, due to the palatalization process, the place distinction is likely to be compromised when they are followed by /i/. Enhancement is needed to make the place distinction robust in this context. One possible way is to use the lip rounding gesture to enhance the place contrast, as what happens in English to enhance the contrast between /s/ and /ʃ/. Such an option is not available in Mandarin Chinese because rounding is a contrastive. Another possible way is to modify the following vowel such that the acoustic patterns that distinguish the three fricatives are preserved in the following vowel. The apical vowel /ɿ/ and the retroflex vowel /ɭ/, which are both derived from an underlying /i/, are produced to enhance the defining articulatory and acoustic attributes of the three fricatives. In particular, /i/, with a fronted tongue body, is most compatible with the formation of the palatal channel in /ɕ/, aiming at producing the spectral peak in the F3 range. Its position of vocal tract narrowing is further fronted after /s/ and /ʂ/ so that a longer back cavity is formed to give rise to lower F2.

In sum, we suggest that the apical and retroflex vowels in Mandarin Chinese are introduced to enhance the three contrastive fricatives when their defining acoustic attributes are subject to neutralization. We also propose that the enhancing strategy is a language-specific option, tied to the phonological system of the language in question.

(1) Three series of strident fricatives and corresponding affricates:

Dental	Retroflex	Palatal
s, ts, ts^h	ʂ, ʈʂ, $ʈʂ^h$	ɕ, tɕ, $tɕ^h$

(2) Distribution of apical and retroflex vowels:

a. ɿ / {s, ts, ts^h} ___

b. ʅ / {ʂ, ʈʂ, $ʈʂ^h$} ___

cf. i / {ɕ, tɕ, $tɕ^h$} ___

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