A phonetic correlate of velar palatalization: shorter front cavity

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Background

Velar palatalization is a common sound change involving a velar consonant becoming a palatal affricate or fricative before a front vocoid (Bhat, 1978). For example, Mandarin underwent the following change (Cheng, 1973).

k, kʰ, x → tɕ, tɕʰ, ɕ / before high front vowels

The phonetic and articulatory bases of the change are not well understood. This project works towards an account of the mechanisms underlying velar palatalization by searching for phonetic correlates of the change. In particular, this study examines acoustic properties that may distinguish a language, L_V, that has undergone velar palatalization and a baseline language, L_B, that has not.

- L_V: Mandarin, in the 16th or 17th century (Cheng, 1973).
- L_B: Cantonese, no velar palatalization in the last millennium.

Hypotheses

We hypothesize the following possible phonetic differences.

1. The conditioning vowels [i, y] are further front in Mandarin than in Cantonese, resulting in fronter closure of the velar stop through coarticulatory assimilation.
2. The velar stops involve more coarticulation to the following vowel in Mandarin than in Cantonese, resulting in fronter closure of the velar stop preceding front vocoids.

Methods

We recorded Cantonese ($n = 7$) and Mandarin ($n = 8$) speakers producing target monosyllabic words embedded in carrier phrases.

Cantonese
我 把 __ 讀 給 你 聽
ŋɔ13 pa35 __ tɐu2 kʰɐp5 nei13 tʰɛŋ5
‘I read __ for you to hear’

Mandarin
我 把 __ 读 给 你 听
uɔ35 pa21 __ tu35 keɪ35 ni21 tʰɪŋ55
‘I read __ for you to hear’

Monosyllabic target words, all coda-less, three repetitions per syllable:

1. [i]/[y]: high front vowel, preceded by homorganic glide or glottal stop.
   - C. [jiː, jyː]; M. [ji∼ʔi, ɥy]
2. [k$^{(h)}$V]: velar stop followed by vowels ranging from [u] to [ei].
   - C. [kuː, kʰuː, kɔː, . . . , kɐi, kʰɐi, kei, kʰei]; M. [ku, kʰu, kou, . . . , kai, kʰai, kei]

Formants F1-F4 measured at vowel midpoint and at voicing onset in Praat. Formant frequency normalized by speaker (Johnson, 2020).

$$Fn' = Fn/\Delta F, \quad \Delta F = \text{mean}_{ij}\left[\frac{F_{ij}}{i - 0.5}\right]$$

References

Bhat, D. N. S. (1978). A general study of palatalization. In *Universals of Human Language*, volume 2. Phonology, page 47–92. Cambridge University Press.

Cheng, J. (1973). *A synchronic phonology of Mandarin Chinese.* Monographs on linguistic analysis; no. 4. Mouton, The Hague.

Johnson, K. (2020). The ΔF method of vocal tract length normalization for vowels. *Laboratory Phonology 11.*

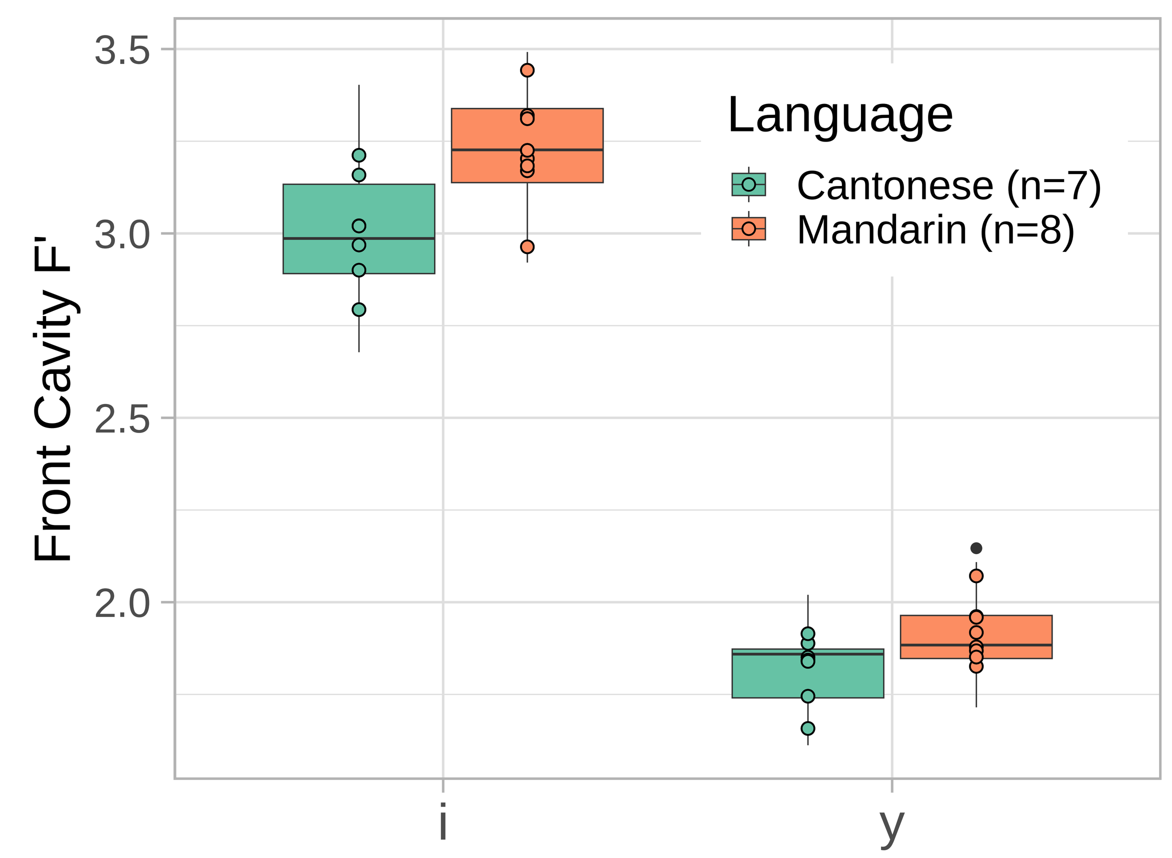
Results

Hypothesis 1: Fronter [i, y] in Mandarin → higher F3 in [i] and F2 in [y].

- Fronter vowel → shorter front cavity → higher front cavity formant.
- Front cavity corresponds with F3 in [i] and F2 in [y].
  - [i]: F1—back cavity, F2—back cavity, *F3—front cavity*
  - [y]: F1—back cavity, *F2—front cavity*, F3—back cavity

Linear mixed effects model (`R`, `tidyverse`, `lme4`, `lmerTest`).

- $F'_{\text{front},V} \sim$ nucleus $*$ language $+$ (nucleus | speaker)
  - contrast-coded nucleus, dummy-coded language (base = Cantonese).
- Significant difference between languages ($t(13) = 3.491, p = 0.004$).

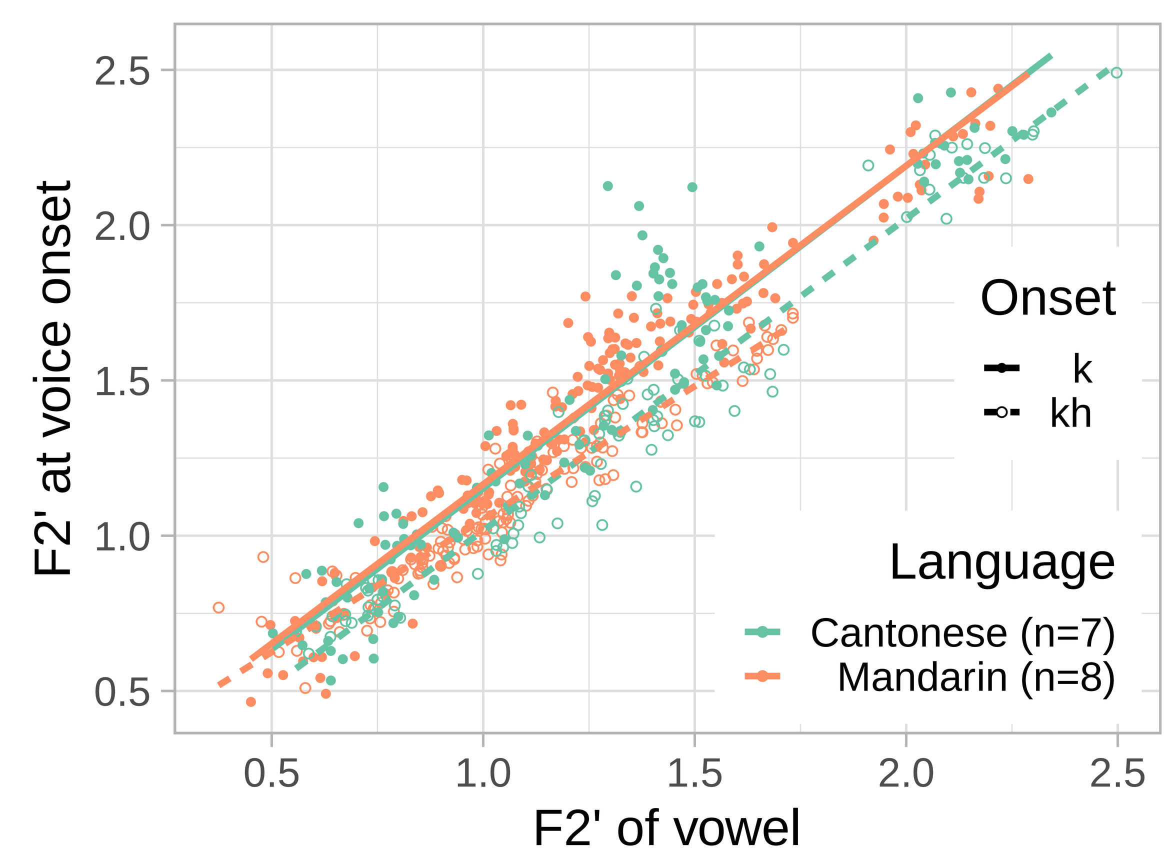


Hypothesis 2: More velar-vowel coarticulation in Mandarin → greater locus equation slope.

- Locus equation—linear model relating F2 at stop release to F2 in vowel (Lindblom, 1963; Sussman et al., 1991).
- Slope can serve as a measure of stop-vowel coarticulation.
- Greater slope (nearer to 1 than 0) → more stop-vowel coarticulation.

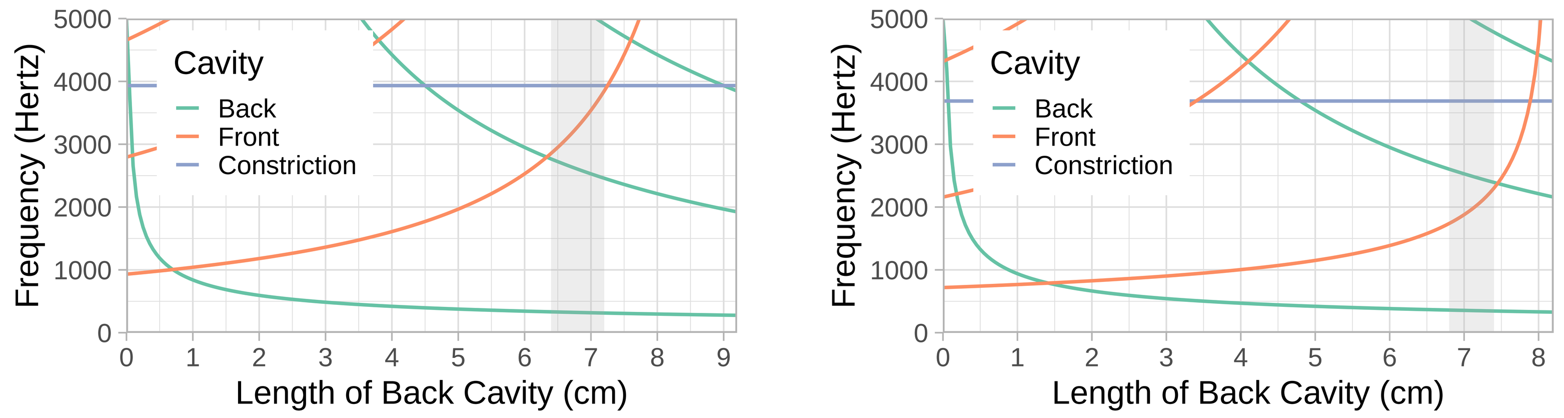
Linear mixed effects model (`R`, `tidyverse`, `lme4`, `lmerTest`).

- $F2'_C \sim F2'_V *$ onset $*$ language $+$ ($F2'_V$ | speaker)
  - contrast-coded onset, dummy-coded language (base = Cantonese).
- Significant difference between slopes in unpredicted direction.
  - ($F2'_V *$ Mandarin) interaction estimated at -0.08 with $t(16) = -2.6, p = 0.02$.



Front Cavity Formant

Tube models of the vocal tract configurations for [i] (left) and [y] (right).



Nomograms of idealized formant frequencies predicted by tube models, with expected realization in the shaded regions.

- Back cavity length varies, and front cavity length varies in response.
- Vocal tract length fixed to 14cm. Constriction length fixed as well.

Front cavity of [i] corresponds with F3 and front cavity of [y] with F2.

Discussion

Our results support hypothesis 1 but not hypothesis 2.

- A possible phonetic precondition of velar palatalization is an **especially front articulation of the conditioning vocoid**.

Building on the finding about shorter front cavity, we propose new hypotheses about the mechanisms underlying velar palatalization that can explain two poorly understood properties of the change.

- **Dorsal to coronal**: why do dorsal consonants become coronal through assimilation to dorsals (which front vowels are usually assumed to be)?
  - We hypothesize that the conditioning vowels' front cavities are so small that their articulation involves the tongue blade. Coarticulation of the velar with this *coronal* vowel can explain the consonant's change from articulation with the tongue body to articulation with the tongue blade.
- **Frication**: why do stops become affricates, introducing additional frication?
  - We hypothesize that the conditioning vowels' front cavities shorten by lengthening the tongue constriction.
    - Coarticulation of the velar stop with this vowel might result in a long channel behind the stop closure.
    - A long channel behind a stop closure facilitates frication.

  Coarticulation of the stop with a vowel that has a long constriction can explain the additional frication.

References (*cont.*)

Lindblom, B. (1963). Spectrographic study of vowel reduction. *The Journal of the Acoustical Society of America*, 35(11):1773–1781.

Sussman, H. M., McCaffrey, H. A., and Matthews, S. A. (1991). An investigation of locus equations as a source of relational invariance for stop place categorization. *The Journal of the Acoustical Society of America*, 90(3):1309–1325.

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