Relating frication to articulation in Standard Mandarin apical vowels

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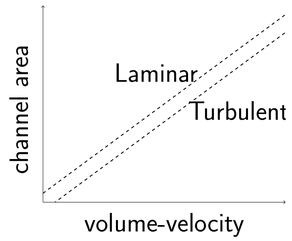
Background

Premise: Sibilant production necessitates both the formation of a narrow *constriction* in the vocal tract and air projected at a *certain velocity* through this constriction [1, 5]

Channel size vs. airflow velocity



The production of frication noise rests on a certain *balance* being struck between channel size and airflow velocity.

Standard Mandarin apical vowels

Three way place contrast in sibilants, i.e. /s ɕ ʂ/, neutralized before [i], such that *si *ʂi. Two apical segments, [ɿ] and [ʅ], replace [i] here, which occur only after sibilants they are homorganic with, e.g. [sɿ] and [ʂʅ] [2].

Still unclear:

1. What is the nature of lingual transition from onset sibilant to apical vowel [4, 3]?
2. Do the apical vowels have frication noise targets [4, 7]?

This study: looked at sequences where each apical vowel occurs adjacent to the sibilant they are homorganic with on *both* sides, e.g. [sɿ.sa].

Materials & Method

Method: Ultrasound tongue imaging & audio recorded
Subjects: 5 native speakers of Standard Mandarin
Stimuli: Disyllabic nonce words, with matching C_1 and C_2:

C_1	V_1	C_2	V_2
s ʂ ɕ	ɿ ʅ u i	s ʂ ɕ	a

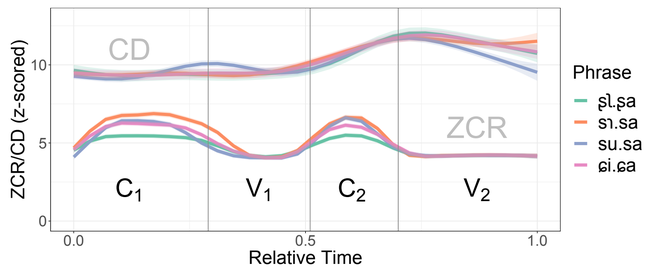
Analysis:

1. **Zero-crossing rate (ZCR)**: measure of frication
2. **Constriction degree (CD)**: distance between tongue front and hard palate
3. **Smoothing-spline ANOVAs (SSANOVAs)**: visualize tongue posture during target segments

Hypotheses

1. Frication noise targets → little/no lingual adjustment and no change in frication
2. Lack frication noise targets → tongue front lowering and sizeable drop in frication

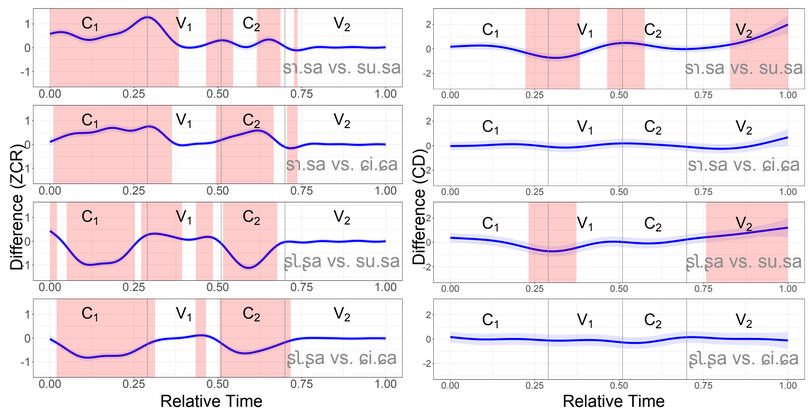
Combined ZCR & CD GAMMs



ZCR. Consistently much lower during V_1, suggesting that each V_1 has a much lower aperiodicity in the acoustic signal than the flanking sibilants.

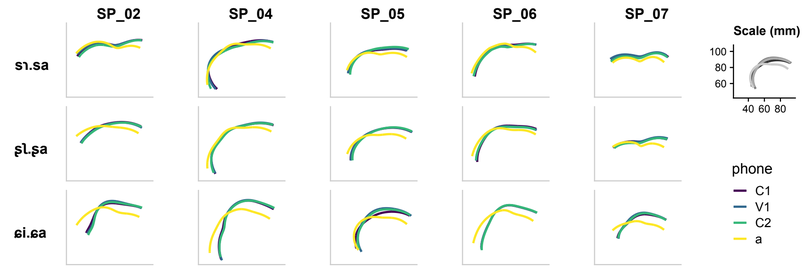
CD. Little to no perceptible change during the transition from initial sibilants to the apical vowels and [i], while during [u] there is a clear sudden increase in channel size.

Difference plots for ZCR & CD GAMMs



ZCR.Significant differences (in red) exist between sibilant pairs during C_1 and C_2, with no significant difference at the V_1 midpoint. **CD**. No significant difference between apical vowels and [i]; a period of significant difference exists during [u].

SSANOVAs



In the apical vowel targets, the tongue blade does not visibly differ in position between the first onset fricative, the apical vowel, and the second onset fricative. The same is true for [i].

Findings

1. There is a considerable drop in frication during both apical vowels, comparable to [i u].
2. Little to no adjustment was seen in lingual posture and CD in the transition from onset sibilant to apical vowel (also for [i]).

How do we explain the results?

1. Some *non-lingual* adjustment suppresses frication e.g. directly manipulating the rate of airflow.
2. The onset of voicing cessates frication.
3. Velic leakage may contribute to the reduction in frication (predicts trace amount of nasalization) [3].
4. Lingual adjustment occurs at regions not fully captured by ultrasound tongue imaging [6] (replication with real-time MRI needed).

Implications

1. If speakers are manipulating the airflow velocity, this is indicative of airflow velocity targets *separate* from CD targets.
2. Results suggest clearly that both apical vowels lack frication noise targets.

Acknowledgements

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