Vowel coarticucation with alveopalatal sibilants in Mandarin

Ivy Hauser (University of Texas at Arlington)

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Abstract and full references list available here.

Introduction

- Vowels following [ɕ] typically exhibit raised second formant (F2) values (e.g. Stevens, 2004)

- **Main finding:** Raised F2 continues through entire vowel following [ɕ].

- **Proposal:** Vowel fronting is phonologized, as it affects the whole segment, regardless of vowel duration.

Background

- /s ʂ ɕ/ occur before [a] and [u]/[əu], neutralize to [ɕ] before [i̯] (e.g. Duanmu, 2007; Li, 2008).

- [a] and [u] / [ɕ]_ sometimes also described as diphthongs [ia] and [iu], placing [ɕ] in complementary distribution with [s ʂ] (e.g. Lee & Zee, 2003)

- Persistent fronting through entire vowel is notable under either analysis.

Methods

- Laboratory speech production task
- **Participants**: 11 native Mandarin speakers (6F, 5M)
- **Stimuli**: words with initial /s ʂ ɕ/ and vowels /a u/ in carrier phrase "wǒ bǎ X dú yī biàn" ('I read X once').
- Crossed according to: sibilant (levels: s ʂ ɕ) × vowel (levels: a u) × word status (levels: high frequency, low frequency, non-word) × number of syllables (levels: 1, 2) × tone (4 levels)
- All factors not fully crossed because of limitations of the lexicon

Results

- F2 following [ɕ] consistently raised for entire vowel duration of [u] and at least 50% of vowel duration for [a].

  - Formants estimated in Praat (Boersma et al., 2001) using the Burg method and extracted at 10ms intervals throughout vowel duration.
  - Excludes formant excursions of >1000Hz over 10ms.
  - Results below show time-averaged trajectories for a representative speaker with Loess smoothing.
  - Averaged results include ~30 tokens in each condition (sibilant context).
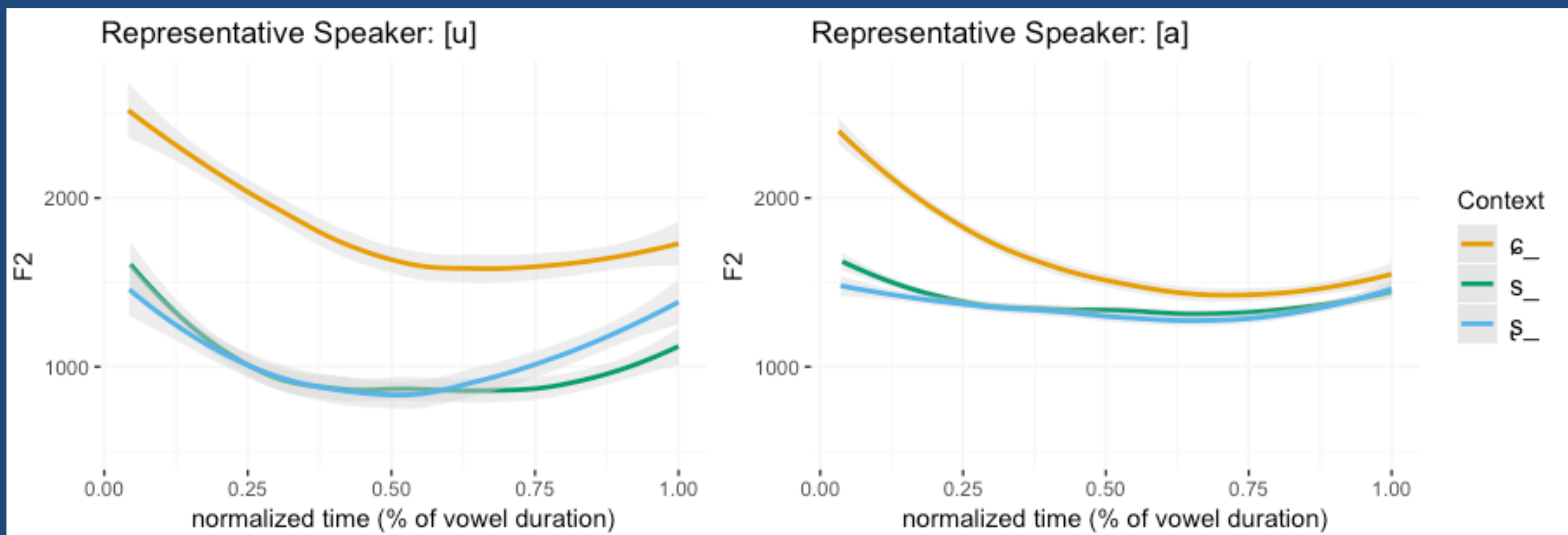
Analysis

- Mixed effects linear regression predicting F2 at vowel _offset_ (as RQ is whether raising extends through the entire vowel).
- Speaker and item were included as random effects. Post-hoc analysis showed no effect of tone, talker gender, # syllables, or word status; these factors not included in best-fit model.

Key Results

- F2 offset significantly lower following /s ʂ/ relative to /ɕ/.
- F2 offset following [ɕ] _increases_ with vowel duration.

Effect	Estimate	t value	p
(Intercept)	1534.62	14.505	***
C-s	-616.55	-3.435	**
C-ʂ	-435.79	-2.599	*
V-a	-21.40	-0.120	
vowel.dur	1085.71	3.950	***
C-s × V-a	333.60	1.311	
C-ʂ × V-a	258.98	1.094	
C-s × vowel.dur	1738.41	4.307	***
C-ʂ × vowel.dur	996.73	2.429	*

Main effect table for mixed effects linear regression predicting F2 at vowel offset. Model intercept is /ɕu/. Speaker and stimulus item included as random effects.

Discussion and conclusion

- **Main finding:** Mandarin vowels following [ɕ] exhibit prolonged acoustic effects of coarticulatory fronting, differing from previous descriptions of coarticulation affecting only vowel onset/transition.

- Phonological implications: Solé (2007) proposes mechanical effects should have fixed temporal extensions. We find that duration of raised F2 is not fixed; F2 is raised throughout the vowel regardless of speech rate, and F2 offset actually _increases_ in longer vowels.

  - Suggests Mandarin speakers may actively use F2 to enhance sibilant contrast in longer vowels.

- Perceptual implications: Previous work shows use of F2 vowel onset as a primary cue for distinguishing [ɕ] from [s ʂ]. Our results suggest the potential for a stronger perceptual effect–Mandarin speakers may be able to identify the preceding sibilant from the following vowel alone, or even only the offset of the following vowel.