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Place uniformity and drift in the Suzhounese fricative and apical vowels

Abstract

Suzhounese exhibits an unusual place anteriority contrast between rounded and unrounded dorso-palatal high front vowels, postalveolar fricative vowels, and apicoalveolar apical vowels. This arrangement is vulnerable to loss under intensifying contact with Standard Chinese. Using acoustic and tongue ultrasound data, we investigated the phonetic implementation of place in the Suzhounese fricative and apical vowels and the similarity of place targets with the apicoalveolar and alveolopalatal fricative consonants /s/, /ɕ/ and the front vowel /i/. Two age cohorts differing in their acquisition history and usage of Standard Chinese were investigated. The younger cohort, which had earlier and likely more intense exposure to Standard Chinese, exhibited a subphonemic shift in the fricative vowels toward less anterior, more /i/-like constrictions. Due to this shift, implementation of place targets among vowels and consonants was less uniform for the younger cohort, particularly in acoustic terms, but articulatory target uniformity among the vowels at each place was robust for both cohorts regardless of the degree of shift. We discuss possible contact-based mechanisms for the observed changes, as well as implications of the observed interactions between L1-L2 transfer and L1-internal structural cohesion.

Keywords

Contact-induced change, L1 drift, ultrasound, fricative vowels, target uniformity

1 Introduction

Multilingual speakers associate L1 phonemes with L2 phonemes (Best 1994; Best and Tyler 2007; Chang 2015; Flege 1995); these mappings and the resulting mutual influence of L1 and L2 speech production routines (Flege et al. 2003; Fowler et al. 2008; Fricke et al. 2019; Kartushina et al. 2016; Sundara et al. 2006) have been implicated in contact-induced language change (Thomason 2013; Thomason and Kaufman 1988). Although research has often focused on L1 transfer to L2, L2 transfer to L1 is also well-established (Chang 2012 and 2013; Guion 2003; Mora and Nadeu 2012; Sancier and Fowler 1997; Sleeper 2020; Yao and Chang 2016).

Less studied are details of within-language subphonemic structure in contact situations. In this study, we focus on TARGET UNIFORMITY, a constraint operating on the phonetic implementation of distinctive features which maximizes similarity among phonemes sharing a given feature valuation (Chodroff and Wilson 2017). Target uniformity is established early in L1 acquisition (Ménard et al. 2008), applies to L2 production (Chodroff and Baese-Berk 2019), and is maintained during sound change, resulting in parallel shift of featurally related sets of segments (Fruehwald 2013 and 2019; Oushiro 2019). While target uniformity has primarily been treated as a constraint on similarity of acoustic outputs, it is sometimes instead formulated as a constraint on articulatory implementation (Ménard et al. 2008; Faytak 2018).

This study examines contact-induced sound change and changes to acoustic and articulatory target uniformity in bilinguals' L1. At issue are the unusual front vowel contrasts in Suzhounese, a language in intense contact with Standard Chinese, and whether transfer from L2 Standard Chinese affects the production of L1 Suzhounese phones. We also examine whether L1 target uniformity for place of articulation is disrupted more under more intense contact.

1.1 Suzhounese vowels

Suzhounese is a Wu Chinese (ISO 639-3: wuu) dialect spoken in the city of Suzhou, immediately west of Shanghai, by two to three million speakers (Eberhard et al. 2020; Zhengzhang 1988). In spite of its historical prestige – in Chinese linguistics, it is the canonical Wu dialect (Chao 2017 [1928]) – it is vulnerable to encroachment from Standard Chinese (ISO 639-3: cmn), which is nearly universally used as an L2 (Wang 2003).

Suzhounese contrasts high front vowels /i/, /y/ with unrounded and rounded FRICATIVE VOWELS /iʑ/ and /yʑ/,[1] which are known from prior articulatory studies to have a more anterior constriction than /i/, /y/ (Hu and Ling 2019: 9–10; Ling 2009). Both sets contrast with unrounded and rounded APICAL VOWELS, /ɿ/ and [ʮ][2] (Figure 1), which have a still more anterior apico-alveolar constriction (Faytak and Lin 2015; Lee-Kim 2014; Shao 2020; Zhou and Wu 1963), and also occur in Standard Chinese. Unlike apical vowels, which co-occur only with homorganic fricative or affricate onsets (Duanmu 2007; Wiese 1997), Suzhounese fricative vowels co-occur with a wider range of non-fricative onsets. Fricative and apical vowels in Suzhounese and beyond involve production of postalveolar frication (Hu and Ling 2019; Ling 2009) or alveolar frication (Faytak and Lin 2015; Shao, 2020; Wu, 2017).

The vowel anteriority contrast among high front, fricative, and apical vowels can be characterized with place features also used for onset consonants (Table 2), but this account may mask interspeaker variability in phonetic implementation of place. Ling (2009) reports two strategies for producing fricative vowels: dorso-postalveolar, similar to [i] with a prepalatal constriction; and lamino-postalveolar, similar to [ɕ] with a bunched, postalveolar constriction. Li (1998) also comments that younger Suzhou speakers produce /iʑ/ perceptually closer to /ɿ/ than their elders. Thus, speakers' constrictions for /iʑ/, /yʑ/ may be more anterior (more /s/-like), or less anterior (more /i/-like), than Table 2 depicts, with accordingly stronger or weaker target uniformity for place across vowels and consonants.

[1] These digraphs indicate simultaneous, not sequenced, articulation of the written elements.
[2] Phonemic contrast between [ʮ] and the other rounded vowels cannot be established on distributional grounds: *[sy] and *[syʑ] sequences are disallowed.

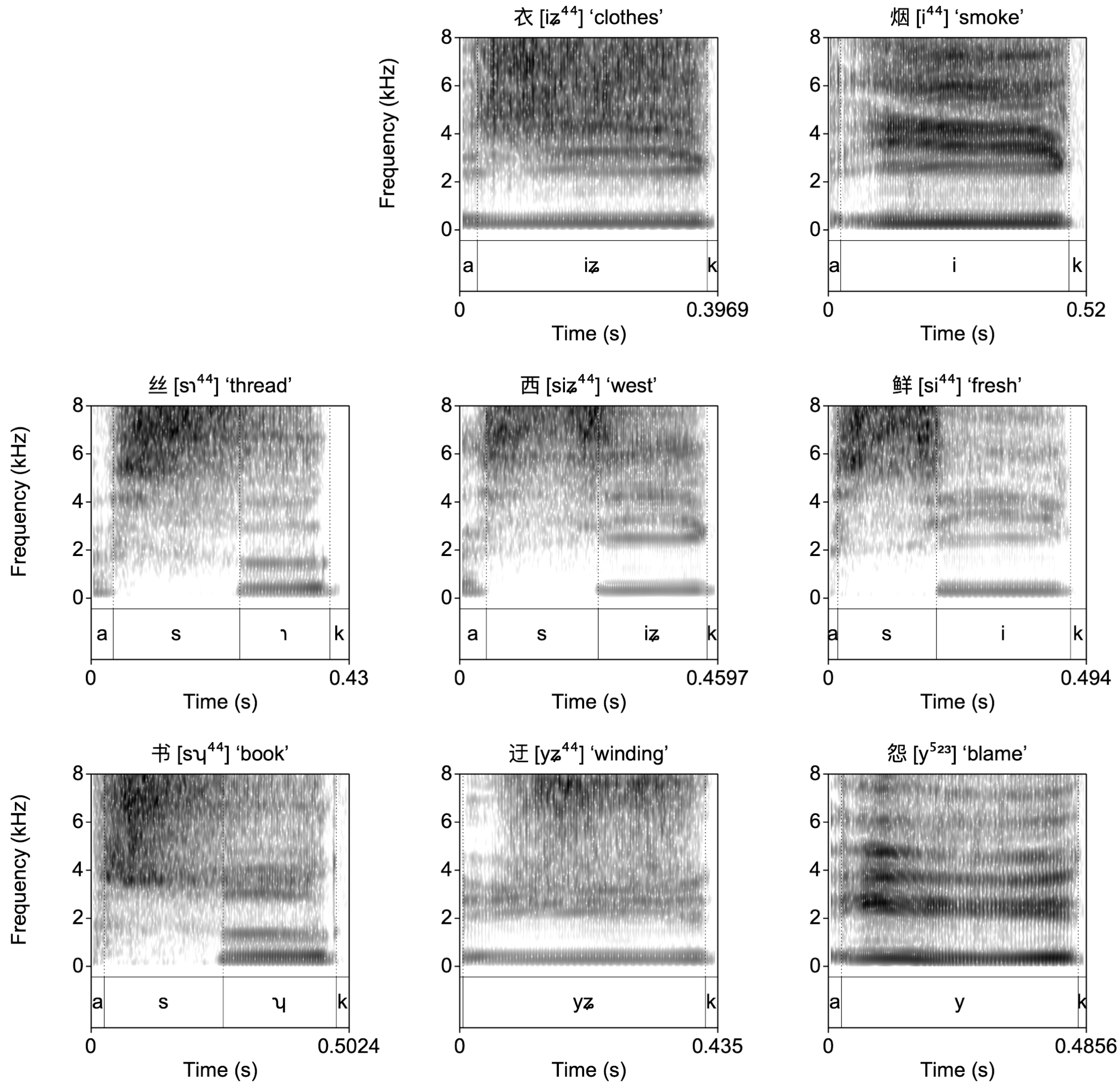

Figure 1. Near-minimal set of Suzhounese apical, fricative, and high front vowels (speaker S44); audio in supplemental materials.

Table 2. Fricative consonants and front vowels in Suzhounese, after Wang (2011); major allophones in parentheses.

	COR +ant	COR -ant	DOR
	Apico-alveolar	Alveolopalatal	High front vowels
V [-round]	ɿ	iʑ	i
V [+round]	(ʮ) < /y/ or /yʑ/	yʑ	y

C	s ts tsʰ	ɕ tɕ tɕʰ	

Table 3. Fricative consonants and front vowels in Standard Chinese, after Duanmu (2007); major allophones in parentheses.

	COR +ant	COR -ant	COR, DOR +ant	DOR
	Apico-alveolar	Retroflex	Alveolopalatal	High front vowels
V [-round]	(ɿ) < /i/	(ʅ) < /i/	-	i
V [+round]	-	-	-	y
C	s ts tsʰ	ʂ tʂ tʂʰ	ɕ tɕ tɕʰ	

1.2 Study aims

We aimed to gauge the effect of contact-induced change in the Suzhounese vowel place contrast. Speakers' increasing Standard Chinese dominance (Duanmu et al. 2016; Wang 2003) has been argued to drive contact-induced convergence (Chirkova and Gong 2019; Evans 2001; Ratte 2011; Yao and Chang 2016). In Suzhounese, loss of the three-way vowel place contrast may result due to transfer from Standard Chinese, which lacks contrastive COR, [-ant] vowels (Table 3). Furthermore, Suzhounese words containing /iʑ/, /yʑ/ are cognate with Standard Chinese words containing /i/, /y/, e.g. 比 'compare' read as Suzhounese /piʑ^{51}/ vs. Standard /pi^{213}/; 虛 'weak' read as Suzhounese /ɕyʑ^{44}/ 'weak' vs. Standard /ɕy^{55}/. An effect of cognacy, as observed in other language pairs (Amengual 2012; Mora and Nadeu 2012; Wu 2015; Yao and Chang 2016), may facilitate L1 drift toward /i/, /y/, though fronting towards /s/ is also a possibility (Li 1998).

We also aimed to examine uniformity among place targets and whether it changes under intensifying contact. L1-internal target uniformity and contact-induced L1 drift may put competing demands on place implementation: drift due to L2 transfer may disrupt target uniformity; conversely, target uniformity may constrain the scope and possible outcomes of L2 transfer. To address the possible competition of these forces, we investigated acoustic and articulatory correlates of place in the apical and fricative vowels for two cohorts of speakers differing in age and language experience.

Articulatory implementation of place was assessed using correlates of place obtained from lingual ultrasound. These allowed for comparisons based on similarity of tongue shape among fricative vowels, fricative consonants, and the high front vowels, the latter of which lack a deliberately produced aperiodic noise source and cannot be assessed with CoG.

Comparison of acoustic correlates of place is more indirect: acoustic implementation of place was assessed using spectral center of gravity (CoG). CoG is modulated by constriction anteriority, rounding, and voicing (Jongman et al. 2000), all involved in the contrasts at issue. Acoustic target uniformity as laid out in Chodroff (2017: 24–28) holds if the effect of [±anterior] on CoG is substantially larger than those of cross-cutting features and interactions. This is schematized in Figure 4A: if no additive segment-specific effects are required to model CoG, then uniformity holds; however, if place is more or less anterior for a given valuation of [±anterior] under the influence of a cross-cutting feature, then uniformity cannot be said to constrain implementation of [±anterior]. In this study, the cross-cutting feature is varied among three sets of segments (Figure 4B): fricative consonants and unrounded vowels ($\text{C-V}_{[\text{-rd}]}$) across [±voice][3]; fricative consonants and rounded vowels ($\text{C-V}_{[\text{+rd}]}$) across [±voice] and [±round]; and in rounded and unrounded vowels ($\text{V}_{[\text{-rd}]}\text{-V}_{[\text{+rd}]}$) across [±round].

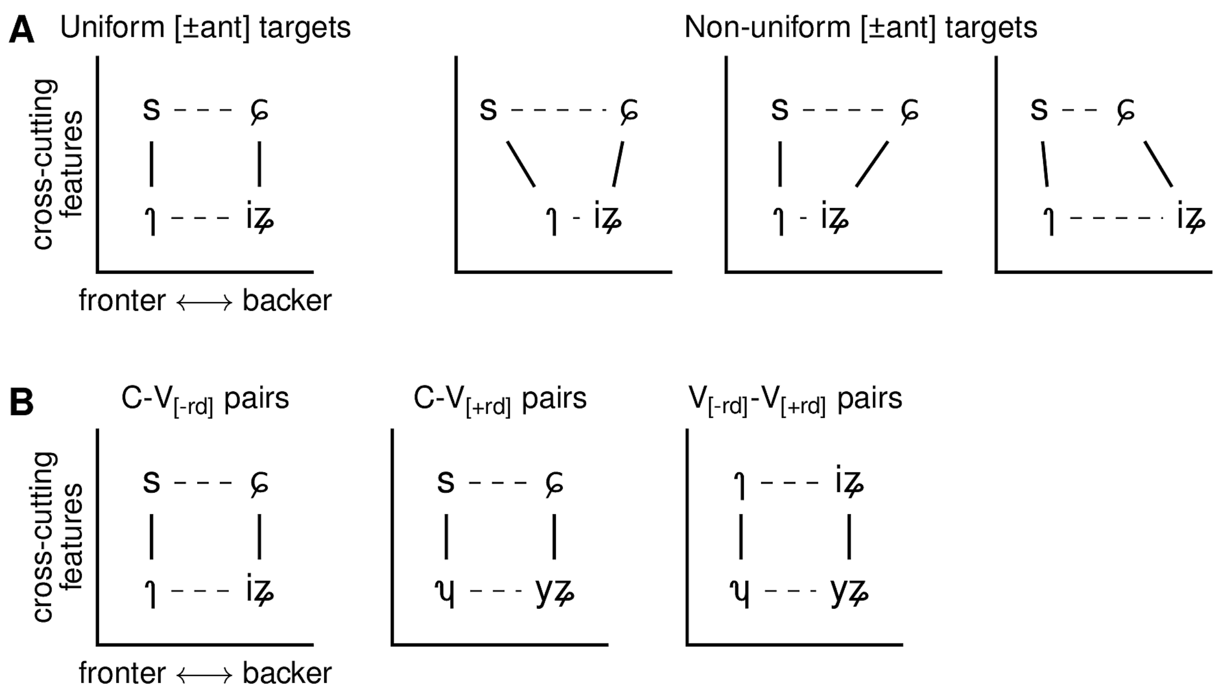

Figure 4. A: Schemas for target uniformity and non-uniformity, after Chodroff (2017); B: phone sets analyzed in this study.

2 Methods

2.1 Participants

[3] We use [±voice] to denote the fricative consonant-fricative vowel distinction, but this may best be viewed as a bundle of consonantality and voicing.

Forty-four Suzhounese-speaking participants (29 F, 15 M)[4], all residents of urban Suzhou for fifteen or more years, completed a questionnaire on language usage, residential history, and demographic characteristics. Competency in Standard Chinese and Suzhounese was self-rated on seven-point Likert scales for verbal and writing ability (1: no ability; 7: fluent). Speakers sorted into two age cohorts (Figure 5A): 22 participants (17F, 5M) were born before 1985, and 22 (11F, 11M) were born after 1985.[5] The cohorts diverge in the number of years between age of acquisition (AoA) of Suzhounese and Standard Chinese (Figure 5B): the positive number for the pre-1985 cohort indicates acquiring Suzhounese three to nine years before acquisition of Standard Chinese. Post-1985 participants score at or slightly below zero, indicating near-simultaneous acquisition. Per discussion with participants, an AoA gap larger than 3 indicates that speakers learned Standard Chinese in primary school.

Ratios of speakers' self-rated Suzhou and Standard Chinese competencies were calculated; ratios greater than one indicate higher self-ratings in Suzhounese, while ratios less than one indicate higher self-ratings in Standard Chinese. Most participants rated themselves equally competent in Suzhou and Standard Chinese (Figures 5C–5D), but younger speakers skew towards higher self-ratings for Standard Chinese and older speakers towards higher self-ratings for Suzhounese.

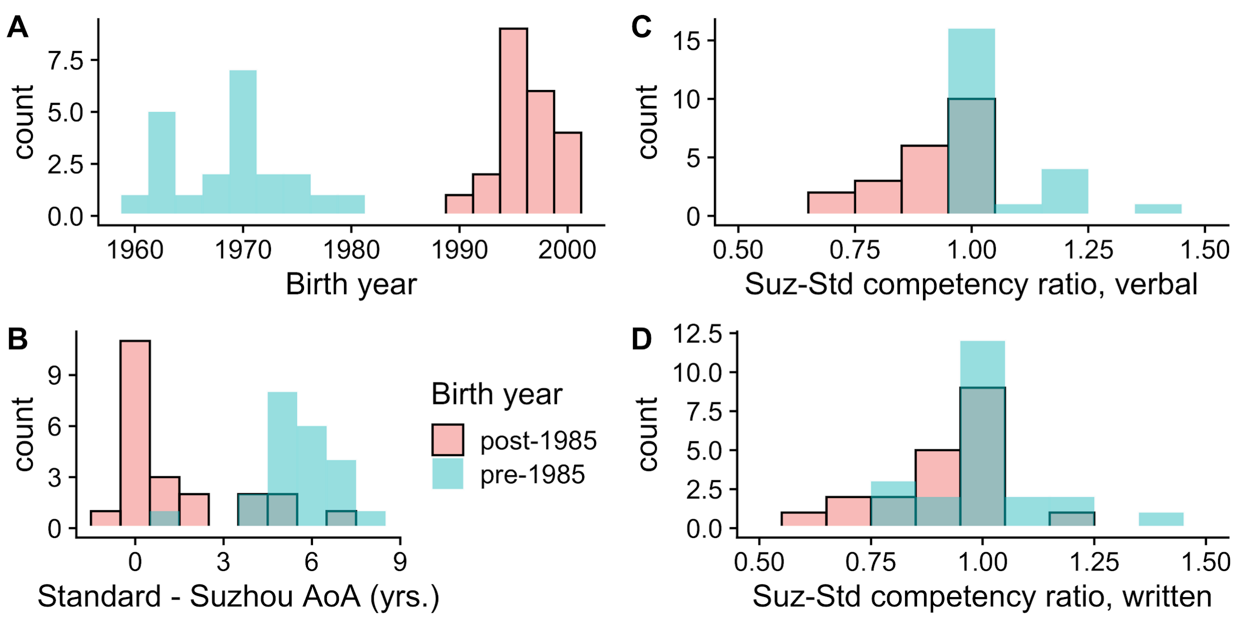

Figure 5. Birth year by cohort (A), Standard-Suzhounese AoA gap (B), and ratios of self-rated Suzhounese to Standard competency in verbal (C) and written (D) domains.

2.2 Procedure and materials

[4] All recruitment and experimental procedures described here were approved by the Committee for Protection of Human Subjects at the University of California, Berkeley.
[5] S19 (male, post-1985), who misinterpreted the self-rating questions, is excluded from Figure 5.

Except for four speakers recorded in a sound-attenuated room in the Department of Chinese Language and Literature at Fudan University, recordings were made in a quiet hotel room in Suzhou. Ultrasound (54Hz frame rate) was recorded using a Telemed EchoB, Telemed PV6.5-10-128 convex probe, and aluminum stabilization headset (Scobbie et al. 2008). Synchronized audio (44.1kHz sampling rate) was recorded using a Sony ECM-77B electret condenser microphone attached to the stabilization headset.

Monosyllabic CV stimuli containing consonants /s/, /ɕ/ and vowels /i/, /ɿ/, /ʮ/, /iʑ/, /yʑ/ were presented as simplified Chinese characters in the frame in (1):

(1)	我	看	到	——	该	个	字	哉。
	ŋəu^{24}	k^{h}ø^{51}	ta^{35}	___	kɛ^{44}	kəʔ^{5}	zɿ^{33}	tsɛ^{21}
	I	see	arrive	___	DEM.DIST	CLS	character	PERF

‘I see __, that character.’

[associatedaudio-1-faytak.wav with example (1)]

Ten blocks presenting each item once in pseudorandom order were recorded, totaling ten tokens of each item. Four speakers recorded twelve or thirteen blocks (S32, S20, S3, S4), and one eight blocks (S19), due to technical problems. Excluding tokens affected by disfluencies and accounting for variable readings of the logographic stimuli,[6] 11,008 target segments were collected (1,662 /i/, 1,725 /iʑ/, 472 /ɿ/, 877 /yʑ/, 438 /ʮ/, 2,756 /s/, and 3,078 /ɕ/) in 7,138 stimulus tokens. With the exception of S35, who merged /yʑ/ into /y/, speakers contributed roughly equally to these totals. A list of stimuli can be found in the supplemental materials.

2.3 Acoustic and ultrasound analysis

Segment boundaries were obtained using the Penn Forced Aligner (Yuan and Liberman 2008), with an English acoustic model (DiCanio et al. 2013). Acoustic implementation of place in the fricated segments (i.e., excluding /i/) was assessed using CoG, measured in Praat (Boersma and Weenink 2019) for the middle 80% of each segment using time-averaging (DiCanio 2013; Shadle 2012). While more complex methods – e.g. multitaper analysis (Blacklock 2004) – are more precise for time-varying fricative spectra, we deem time-averaging sufficient here since the spectra at issue do not appear to exhibit substantial dynamicity. Data were Hann stop-band filtered below 3 kHz, a higher cutoff than usual for voiced fricatives (Chodroff 2017; Jongman et al. 2000), to remove both low-frequency voicing energy and excitation of harmonics up to F3-F4.

Articulatory implementation of place was assessed more directly, using an index of tongue shape derived from ultrasound data. Ultrasound frames at force-aligned segment midpoints were submitted to principal components analysis (PCA) to produce a low-dimensional representation of tongue posture (Hueber et al. 2007, Mielke et al. 2017). Each speaker’s first six principal components (explaining about 75% of variance) were submitted to linear

[6] Unexpected readings were retained for analysis if they were phonotactically licit in Suzhou. For details, see Faytak (2018).

discriminant analysis (LDA), which maximized separation of three *training segments* (/i/, /s/, and /ɕ/) in a two-dimensional space consisting of linear discriminants LD1 and LD2. PCA data for fricative and apical vowels were then embedded in this space to characterize the tongue postures of these segments in terms of similarity to the training segments.

To explore relationships between cohort, cross-cutting features, and phonetic implementation of place, CoG and articulatory measures were submitted to linear mixed-effects models carried out in R (R Core Team 2019) using lme4 (Bates et al. 2014), with *p*-values estimated using lmerTest (Kuznetsova et al. 2017). Pearson's product-moment correlations were also calculated and *p*-values were determined using the corrplot package (Wei and Simko 2017). R code and data used for all analyses are included in the supplementary materials.

3 Results

3.1 Acoustic analysis

Recall that CoG is used here as an acoustic measure of anteriority. The [+anterior] segments /s/, /ɿ/, and /ʮ/ were found to exhibit higher CoG than the [-anterior] segments /ɕ/, /iʑ/, and /yʑ/ (Figure 6). As expected, vowels, particularly the rounded vowels, exhibit lower CoG compared to voiceless consonants. Although not shown in Figure 6, female speakers also exhibit higher CoG than male speakers for each phone, though this is reversed for [ʮ] and /yʑ/.

Linear mixed-effects models were carried out to explore the relationship between CoG and place, rounding, and voicing/consonantality. One model assessed uniformity of place across voicing (C-$V_{[-rd]}$), excluding rounded [ʮ] and /yʑ/; another assessed uniformity of place across rounding ($V_{[-rd]}$-$V_{[+rd]}$), excluding voiceless /s/ and /ɕ/. Models included fixed effects of cohort, gender, the relevant pair of features, and their interactions, with random slopes for speaker given place. Reference levels (female, anterior, unrounded, and voiceless) were selected to create a high-CoG intercept; for cohort pre-1985 was baseline. Full fixed effects tables are provided in the supplementary materials; the discussion below focuses on featural main effects and their interaction, the magnitudes of which can be used to identify target uniformity (see Section 1.2).

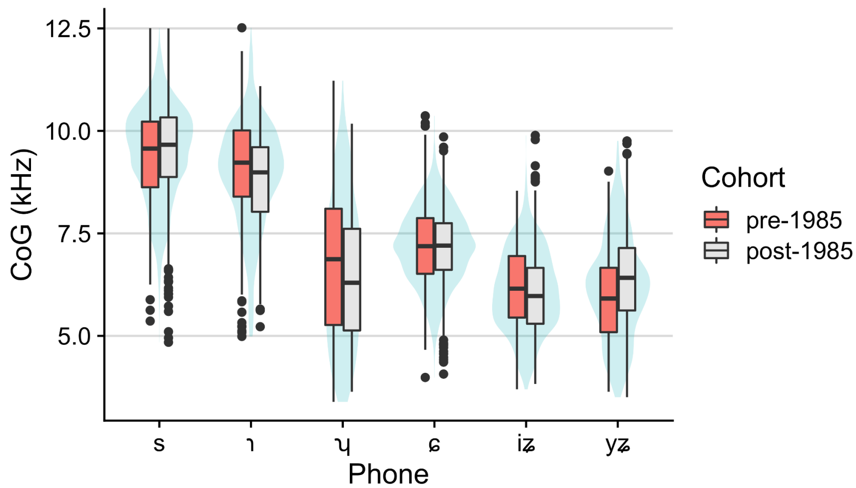

Figure 6. CoG by phone and cohort.

In the place-voicing model, main effects of place (β = -2451.04, *SE* = 151.09, $p < 0.001$) and voicing (β = -210.48, *SE* = 65.22, $p < 0.01$) demonstrate expected CoG-lowering effects, with a much larger effect of place than voice. The interaction of voicing and place (β = -682.06, *SE* = 75.79, $p < 0.001$) suggests segment-specific CoG lowering for /iʑ/, though of a smaller magnitude than either main featural effect. While the main effect of cohort did not reach significance, the interaction of cohort and voicing (β = -485.09, *SE* = 101.12, $p < 0.001$) did, suggesting that the younger cohort's vowels have still lower CoG.

In the place-rounding model, main effects of place (β = -3134.12, *SE* = 228.17, $p < 0.001$) and rounding (β = -2885.54, *SE* = 101.04, $p < 0.001$) again show expected CoG-lowering effects. However, the large magnitude of the interaction between place and rounding (β = 2407.55, *SE* = 118.47, $p < 0.001$) suggests reduced CoG lowering for /yʑ/. The main effect of cohort does not reach significance; however, cohort's interaction with rounding (β = -333.07, *SE* = 161.33, p = 0.039) and the three-way interaction of cohort, place, and rounding (β = 408.21, *SE* = 156.08, $p < 0.001$) suggest that the CoG-lowering effect is further reduced for the post-1985 cohort's /yʑ/.

To further explore place implementation within-cohort, correlations were calculated for 43 of 44 speaker median CoGs. Speaker S35 (post-1985, male) is excluded for lacking tokens of [yʑ]. Selected segment CoG pairs are plotted in Figures 7–8 with simple linear smoothing (see correlogram in supplemental material). The pre-1985 cohort's C-$V_{[-rd]}$ pairs show strong positive correlations (/ɕ/-/iʑ/: R^2 = 0.375, $p < 0.01$; /s/-/ɿ/ R^2 = 0.521, $p < 0.001$). The $V_{[-rd]}$-$V_{[+rd]}$ pair /iʑ/-/yʑ/ also exhibits a strong positive correlation (R^2 = 0.313, $p < 0.01$). However, correlations for same-place pairs of consonants and rounded vowels fail to reach significance. In the post-1985 cohort, this pattern holds, but the /ɕ/-/iʑ/ correlation also fails to reach significance; only /s/-/ɿ/ does (R^2 = 0.550, $p < 0.001$). As in the older cohort, no correlations involving rounded segments reached significance.

3.2 Ultrasound analysis

Recall that LD1 and LD2 are compact representations of tongue posture. Range-normalized median LD1 and LD2 for representative speakers are shown in Figure 9 (data for all speakers are provided in the supplemental materials). Apical vowels cluster about /s/ in LD1-LD2 space, as expected since they are always preceded by onset /s/. Fricative vowels vary in location: while many speakers' /iʑ/ and /yʑ/ cluster tightly with /ɕ/ (e.g. speakers 3, 16, 40) regardless of onset type, others' /iʑ/ and /yʑ/ are intermediate in LD2 value between /ɕ/ and /i/ (e.g. speakers 13, 44). A few post-1985 speakers show speaker S1's pattern, with productions between /ɕ/ and /s/.

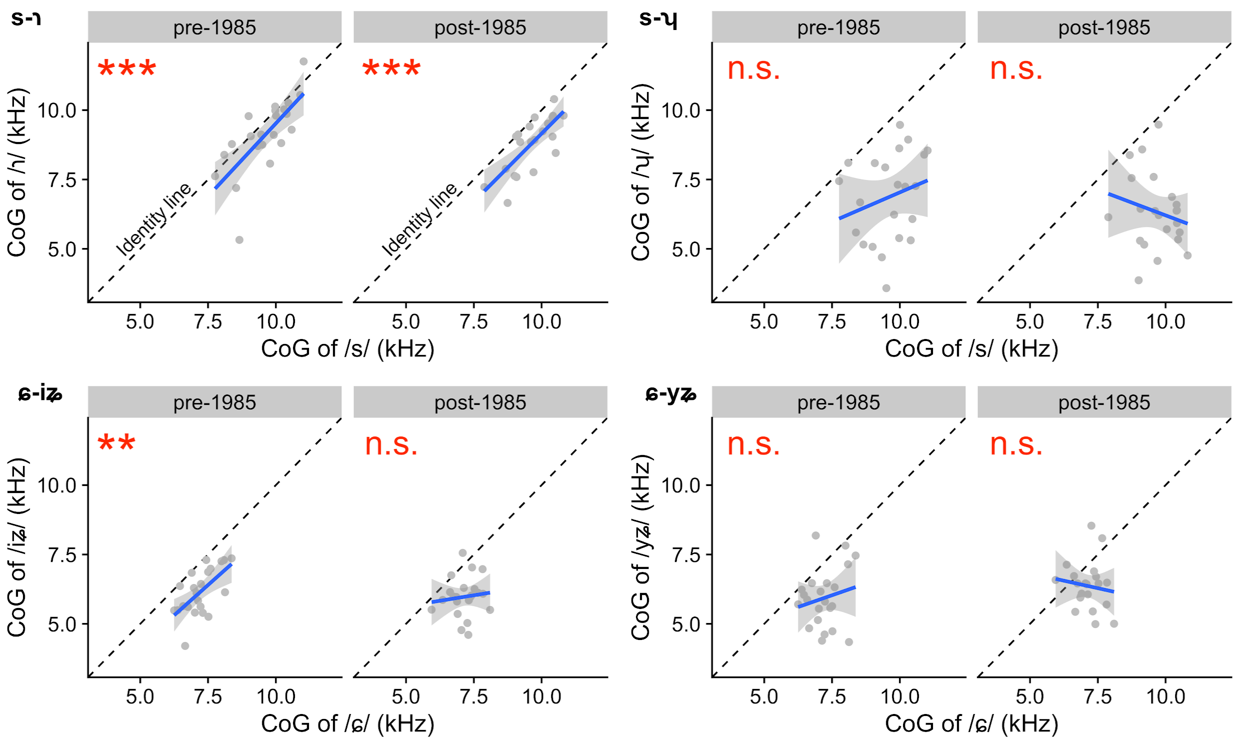

Figure 7. By-speaker median CoGs for C-V$_{[-rd]}$ (left) and C-V$_{[+rd]}$ pairs (right). Asterisks indicate significance for *r*.

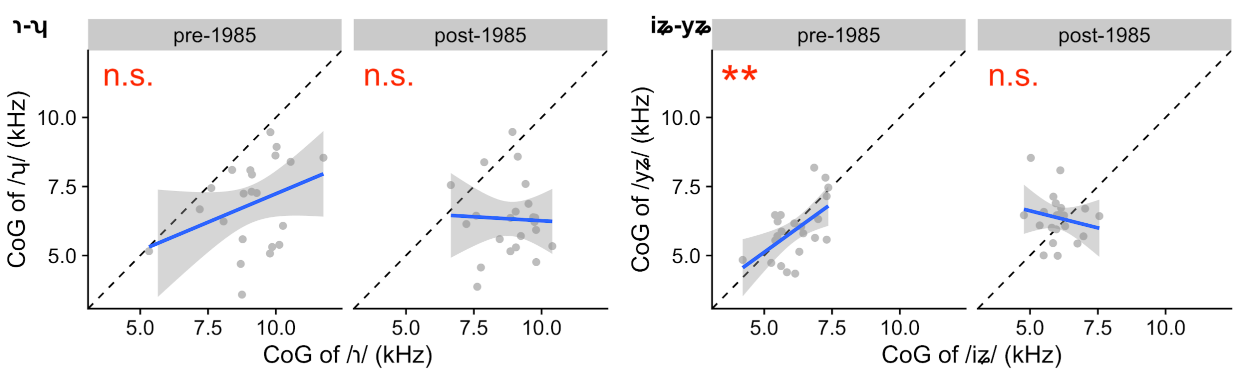

Figure 8. By-speaker median CoGs for V$_{[-rd]}$-V$_{[+rd]}$ pairs. Asterisks indicate significance of *r*.

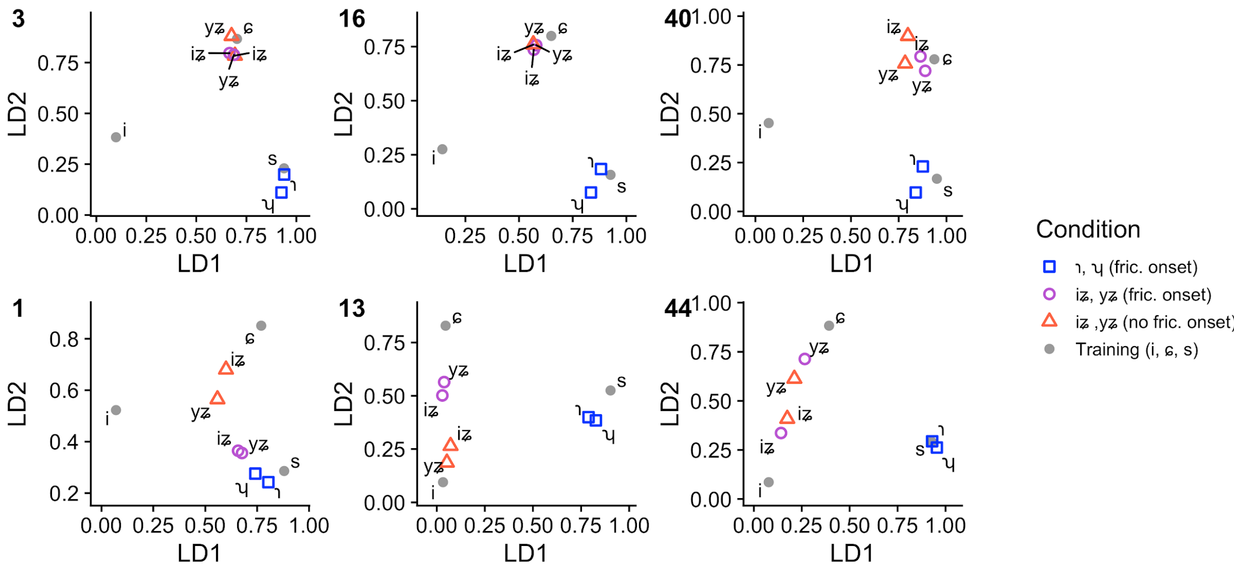

Figure 9. Median scores in LD1-LD2 space for representative speakers. Top row: fricative vowels show target uniformity with /ɕ/. Bottom row: fricative vowels show weaker target uniformity. Speakers 16 and 40 in pre-1985 cohort; others in post-1985 cohort.

Due to speaker-specific rotations of LD1-LD2 space, we use Euclidean distance from training segments /i/, /s/, and /ɕ/ to characterize articulation (Figure 10). Forty-three speakers' fricative and apical vowel Euclidean distances from median /ɕ/, /s/, and /i/ values were submitted to linear mixed-effects regression. Speaker S35 is again excluded, due to loss of /yʑ/. The maximal effects structure with which all models converged was used: distance with respect to vowel, cohort, and their interactions, with random slopes by speaker. Apical /ɿ/ and pre-1985 cohort served as reference levels. Unlike the CoG models, speaker gender is not included as a fixed effect, since LD1-LD2 values are in normalized, speaker-specific articulatory spaces.

Model effects tables are provided in the supplemental materials. Here, we limit discussion to main effects of cohort and interactions of cohort and vowel, which reveal inter-cohort differences in /ɕ/ distance and /i/ distance. Distance from /s/ shows no significant inter-cohort differences, and is not discussed further. Unlike the acoustic analysis, where place must be inferred through CoG, low distance from /ɕ/ or /i/ may be directly interpreted as uniform lingual articulatory implementation of place with that segment. Intercepts for /ɿ/ and main effects for other vowels reach significance and indicate expected similarity of apical vowels to /s/ and variable positioning away from /s/ for /iʑ/ and /yʑ/.

The /ɕ/ distance model suggests that the post-1985 cohort articulates the fricative vowels less similarly to /ɕ/ than the pre-1985 cohort. The main effect of cohort (β = -0.12, *SE* = 0.029, $p <$ 0.001) indicates that younger speakers produce all apical and fricative vowels closer to /ɕ/, possibly driven by a slight shift in the apical vowels. However, interactions of cohort and vowel suggest greater distance of the fricative vowels from /ɕ/ for the post-1985 cohort (/iʑ/: β = 0.26, *SE* = 0.014; /yʑ/: β = 0.23, *SE* = 0.016; *p*s < 0.001). The interaction of cohort with /ʮ/ fails to reach significance. Likewise, the /i/ distance model suggests that the post-1985 cohort articulates the fricative vowels more similarly to /i/ than the pre-1985 cohort. While the main effect of cohort fails to reach significance, all cohort-phone interactions do, suggesting movement of /iʑ/ and /yʑ/ towards /i/ (/iʑ/: β = -0.090, *SE* = 0.013; /yʑ/: β = -0.10, *SE* = 0.014; *p*s < 0.001).

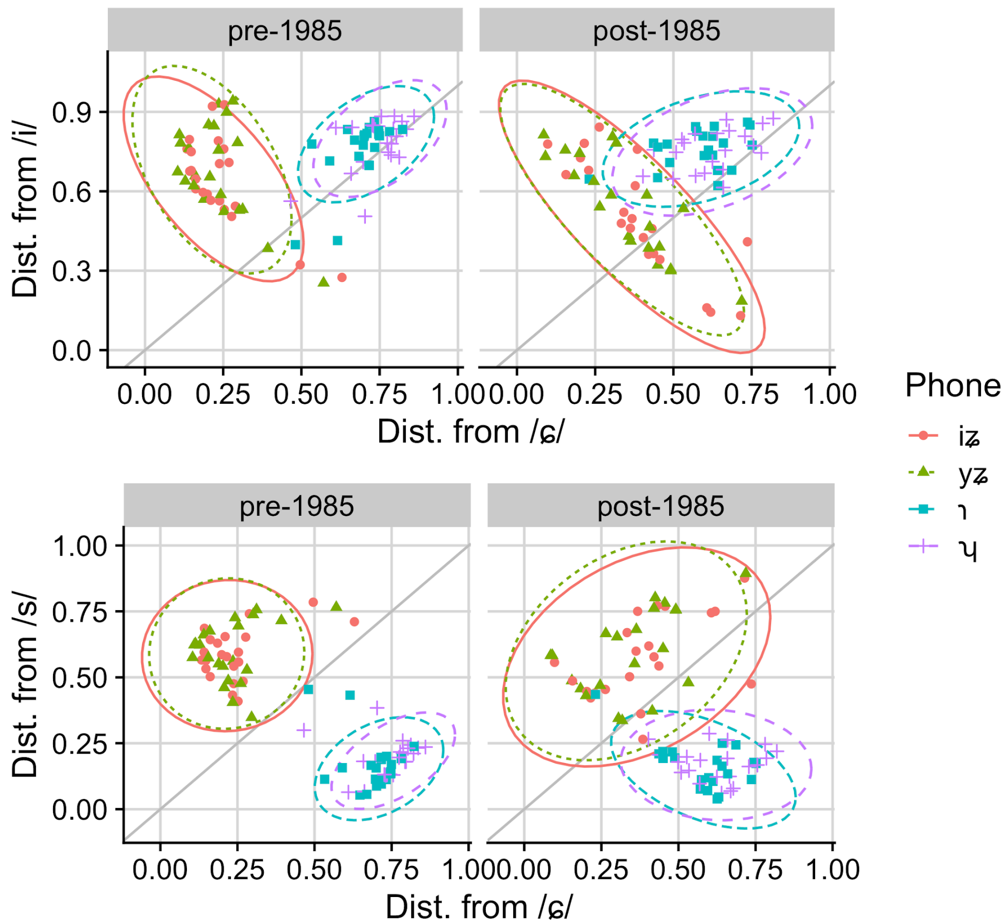

Figure 10. By-speaker median Euclidean distance from median /ɕ/, /s/, and /i/ with 95% confidence ellipses for all tokens.

To assess articulatory target uniformity among vowels across [±round], correlations of by-speaker median distance scores for $V_{[-rd]}$-$V_{[+rd]}$ pairs were carried out (Figure 11; see correlogram in supplemental materials). These suggest that, unlike CoG, both cohorts' *lingual articulation* of place is uniform across rounding within vowels. For the pre-1985 cohort, positive correlations (*p*s < 0.001) were observed for all pairs in distance from /ɕ/ (/iʑ/-/yʑ/ R^2 = 0.80; /ɿ/-/ʮ/ R^2 = 0.60), /s/ (/iʑ/-/yʑ/ R^2 = 0.65; /ɿ/-/ʮ/ R^2 = 0.56), and /i/ (/iʑ/-/yʑ/ R^2 = 0.85; /ɿ/-/ʮ/ R^2 = 0.87). The post-1985 cohort *also* exhibits positive correlations (*p*s < 0.001) for these pairs for distance from /ɕ/ (/iʑ/-/yʑ/ R^2 = 0.84; /ɿ/-/ʮ/ R^2 = 0.60), /s/ (/iʑ/-/yʑ/ R^2 = 0.59; /ɿ/-/ʮ/ R^2 = 0.86), and /i/ (/iʑ/-/yʑ/ R^2 = 0.88; /ɿ/-/ʮ/ R^2 = 0.76).

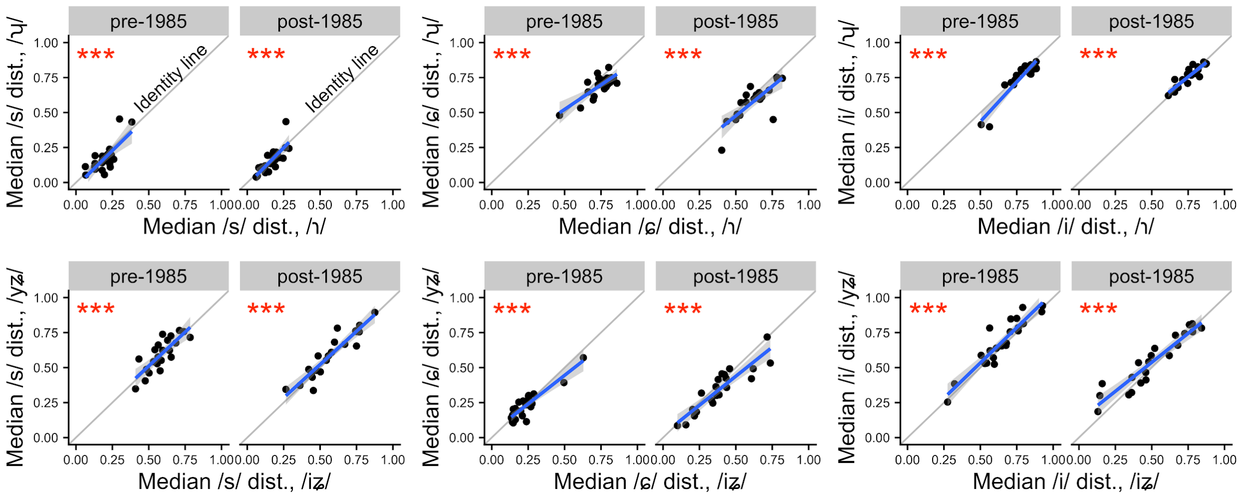

Figure 11. Distance measure correlations for $V_{[-rd]}$-$V_{[+rd]}$ pairs. Asterisks indicate level of significance of *r*.

4 Discussion and conclusions

4.1 Summary of sound changes

Two cohorts of Suzhounese speakers were examined to determine the range of articulations used for the fricative vowels /iʑ/ and /yʑ/, and to gauge the degree of target uniformity present in speakers' articulations. Speakers born after 1985 tended to acquire Suzhou and Standard Chinese simultaneously from home caregivers before entering primary school; this group has higher self-rated confidence in, and likely frequency of, Standard Chinese usage relative to Suzhounese.

Regression analysis of ultrasound data suggested uniform articulatory targets for $V_{[-rd]}$-$V_{[+rd]}$ pairs in both cohorts. However, the younger cohort exhibited reduced uniformity for C-$V_{[-rd]}$ and C-$V_{[+rd]}$ pairs due to a wider range of more /i/-like, less /ɕ/-like lingual articulations for both fricative vowels. Correlation analysis confirms that, even as fricative vowel articulation shifts away from /ɕ/, uniformity for $V_{[-rd]}$-$V_{[+rd]}$ pairs persists, suggesting parallel shifting of both vowels (Fruehwald 2019; Oushiro 2019). These articulatory data suggest that the tendency to regularize language-internal structure can be superseded by cross-language transfer; further research may help determine why this occurs for C-V uniformity to a greater extent than V-V uniformity.

Looking to the acoustic analysis, both cohorts exhibited similar effects of place, voicing, and rounding on CoG. However, the magnitude of main effects in linear regression, as well as correlation analysis within cohorts, yielded evidence only for weak acoustic uniformity. It is especially striking that C-$V_{[+rd]}$ pairs in both cohorts completely lacked strong correlations for CoG, in contrast to the articulatory uniformity suggested by the ultrasound data. Since the ultrasound data provide evidence for *articulatory* target uniformity in both cohorts, these findings should be interpreted with caution. We suspect that reduced acoustic uniformity is due to interference from lip rounding, which in front vowels is typically accompanied by adjustments to tongue position relative to the analogous unrounded vowel (Wood 1986). Joint tongue and lip adjustments in fricative vowels may have complex effects on the fricative noise spectra produced. Use of time-averaging to calculate CoG may also not have accounted for time-varying coarticulation in cases where rounded vowels followed fricatives (Shadle 2012), though limiting measurement to the middle 80% of target segments is likely to have reduced the influence of segmental transitions.

We highlight two additional implications of these findings for future research. First, the mismatch between acoustic and articulatory uniformity, especially for $C\text{-}V_{[+rd]}$ pairs, suggests that target uniformity may constrain *articulation*, rather than *acoustic outputs* as typically modeled (Faytak 2018, cf. Chodroff 2017). Second, the interspeaker variation shown here for fricative vowel place, which is not reported in the existing literature, suggests that existing descriptions of apical and fricative vowels gloss over variability in frication intensity, timing, and other properties (Lee-Kim 2014; Shao 2020).

4.2 Internal or external motivation?

Although we have suggested that the shift of both fricative vowels towards /i/ is contact-related, internal motivations are difficult to rule out (see Thomason 2013). For instance, a shift of /iʑ/ and /yʑ/ toward /s/-like articulations, and even eventual merger with apical vowels, has been cast as internally and functionally motivated in a range of Chinese topolects (Hu and Ling 2019; Wu 1995; Zhao 2007; Zhu 2004) in that it increases acoustic distance of /iʑ/, /yʑ/ from /y/ (Zhu 2004). However, the shift toward /i/-like articulations in Suzhounese happens to be toward the Standard Chinese cognate vowels, and foreshadows a different merger: into /i/, /y/, as attested in Shanghainese (Qian 1992; Zhu 2006), which can also be attributed to contact with Standard Chinese.[7]

Contact thus remains a plausible explanation for the observed changes. A possible mechanism lies in associations between L1 and L2 phonemes (Best and Tyler 2007; Chang 2015; Flege 1995). Since Standard Chinese lacks fricative vowels, speakers likely associate /iʑ/ with Standard Chinese /i/, and /yʑ/ with /y/, facilitated by the cognacy of these pairs. Increased transfer along these lines in the post-1985 cohort would follow from increased activation of Standard Chinese (Sancier and Fowler 1997), and possibly associated changes in stance toward the languages (Law et al. 2019). Future research could strengthen this contact-based account by controlling for usage, stance, and other factors such as the nature of variability in the linked phonemes (Harrington and Schiel 2017; Johnson and Babel 2021) while demonstrating that place implementation in a wider variety of lexemes is mediated by the frequency of Standard Chinese cognate lexemes (Mora and Nadeu 2012; Yao and Chang 2016).

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[7] One speaker, S35, appeared to merge /yʑ/ into /y/, in line with this change.

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