

Different Acoustic Realisations of Standard Mandarin Retroflex Sibilants:

A Preliminary Production Study

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Background: Although traditional descriptions often associate retroflex segments with a set of specific articulatory properties (apicality, posteriority, sublingual cavity and tongue retraction), previous research has shown that Standard Mandarin retroflexes lack the property of posteriority characteristic of prototypical retroflex sounds and are therefore better characterised as marginal or non-prototypical members of the broader retroflex category [5]. Prior studies have also documented substantial variability in the acoustic realisation of the Standard Mandarin alveolar-retroflex contrast across speakers and speech communities [2, 3]. However, existing work has typically emphasised a small set of cues (notably COG) as diagnostics of retroflexion, leaving open the question of what distinct implementation patterns emerge when multiple acoustic dimensions are considered jointly.

Method: This study uses recorded speech data to examine individual variation in the acoustic realisation of the Standard Mandarin alveolar-retroflex sibilant contrast. Speech data were collected from ten female native speakers of Standard Mandarin producing 46 alveolar-retroflex minimal pairs (/s-ʂ/, /ts-tʂ/, /tsʰ-tʂʰ/) in frame sentences. All stimuli were real lexical items, chosen to cover as many attested alveolar-retroflex × rhyme combinations as possible. Acoustic measures included spectral moments (COG, variance, skewness, kurtosis) extracted from the frication portion, as well as vowel-onset formants (F₁-F₃), motivated by previous acoustic studies of sibilants and retroflex consonants [1, 4, 5, 6, 7, 10]. Linear mixed-effects models with speaker-specific random slopes, together with principal component analysis (PCA) and hierarchical clustering, were used to examine speaker-specific implementation patterns.

Result: In the linear mixed-effects models, the alveolar-retroflex contrast showed significant effects on COG, skewness, and vowel-onset F₁-F₃ (all $p < .05$), indicating that the contrast is supported by a stable acoustic basis and anchored by a set of cues shared across speakers. In contrast, effects were not significant for kurtosis or spectral variance, suggesting that these dimensions are not reliable shared anchors of the contrast.

Building on the LMM results, PCA results revealed that speaker differences were primarily organised along dispersion-related patterns, while other measures contributed less to between-speaker separation. Loadings further indicated that the first principal component (PC1) was primarily driven by spectral centroid and spectral variance, with additional contributions from skewness and F₃ (Figs. 1 and 2), suggesting that this component may reflect variation in constriction geometry and posterior vocal-tract shaping.

Hierarchical clustering yielded three implementation clusters with distinct multi-cue profiles (Fig. 3). The first group showed relatively moderate and coherent effects, with small-to-moderate shifts in COG/skewness, limited change in variance, and modest vowel-onset differences in F₂/F₃. The second group showed stronger dispersion-related effects, with larger variance changes accompanied by clearer shifts in COG/skewness and F₂/F₃. The third group exhibited the greatest cross-measure variability, with weaker coordination among COG, variance, skewness, and F₂/F₃, indicating a more variable multi-cue implementation pattern.

Summary: The results support a shared acoustic basis for the Standard Mandarin alveolar-retroflex contrast while revealing multiple speaker-specific implementations, with variation organized mainly along dispersion-related dimensions. This underscores the need for a multi-cue characterisation beyond single diagnostics (e.g., COG). Future work will test the stability of these patterns in larger samples and across more diverse contexts and link the acoustic profiles to articulatory mechanisms (e.g., ultrasound) to build a generalisable typology of Standard Mandarin retroflex implementation.

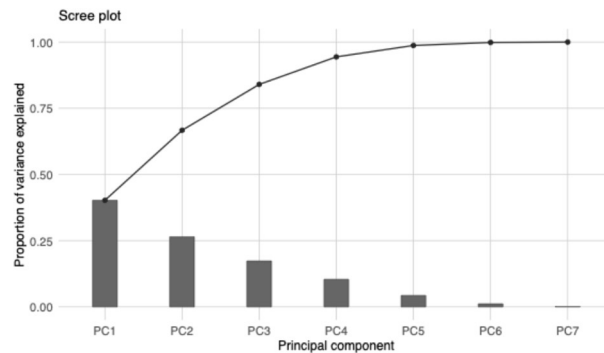


Fig. 1. Scree plot of PCA on speaker random-slope profiles. The solid line indicates cumulative variance explained.

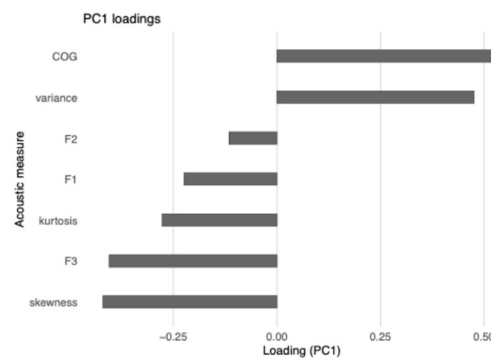


Fig. 2. PC1 loadings for acoustic measures (PCA of random slopes)

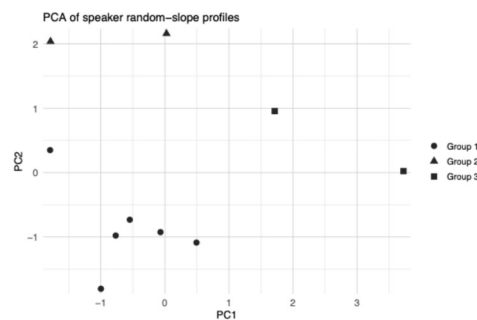


Fig. 3. Speaker clustering in PCA space (PC1–PC2)

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