Formant frequencies and frication of the 'fricative vowel' [ʐ̩] in Mandarin

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Mandarin [ʐ̩]. Fricative vowels (or syllabic fricatives (Ladefoged & Maddieson, 1996)) are uncommon in the world's languages. Mandarin, however, has an uncertain retroflex fricative vowel [ʐ̩], which has drawn opposing views. Some researchers have postulated that [ʐ̩] is a phonetic variant of the high front vowel /i/ in Mandarin (e.g., Howie, 1976) because they are in complementary distribution (Xu, 1980). This [ʐ̩] appears only after the retroflex affricates or fricatives [tʂ, tʂʰ, ʂ, ʐ] (e.g., [tʂʐ̩] 'know', [tʂʰʐ̩] 'eat', [ʂʐ̩] 'poem', and [ʐʐ̩] 'sun' (Duanmu, 2007:34)), whereas the vowel [i] does not. Other researchers have argued that [ʐ̩] is a consonant distinct from [i] (e.g., Pulleyblank, 1984; Wiese, 1997), claiming that it is "a voiced prolongation" of the preceding onset (Duanmu, 2007:35).

Goal. Evidence of high frication noise in fricative vowels was reported in some studies (e.g., Faytak, 2013) but absent in other studies (e.g., Lee-Kim, 2014). This study investigated the formant frequencies and spectral mean frequency of [ʐ̩] with a recent group of speakers to determine its vowel and fricative characteristics.

Methods. The corpus comprises 1024 [i, a, u, ʐ̩] vowel-final utterances recorded at 44.1 kHz from 16 (8 male, 8 female) native adult Mandarin speakers who were born and raised in east and central China. In this corpus, [ʐ̩] occurs in the syllable [ʂʐ̩] only. Formant frequencies (F1 and F2) of the four vowels were estimated with linear predictive coding analysis and were normalized for each speaker using Lobanov's (1971) z-score transformation. The [ʐ̩] tokens were plotted with the [i], [a], and [u] tokens using F1 and F2 values from the stable part of the vowel (Watson & Harrington, 1999) in order to determine its position relative to these three corner vowels in F1/F2 space. To examine its spectral mean frequency (CoG), [ʐ̩] was analyzed with the retroflex fricative [ʂ] using Fast Fourier Transform in Praat (Boersma & Weenink, 2019) at three different temporal locations: the onset, middle, and offset of the segment (Jongman et al., 2000). The speech signal was high-pass filtered at 300 Hz to remove any voicing below 300 Hz.

Results. Figure 1 displays the distributions of [i, a, u, ʐ̩] in z-normalized F1/F2 space. The vowel-like [ʐ̩], positioned within Mandarin's triangular vowel space, is clearly separate from [i] and is fairly central, similar to a typical [ɨ]. T-tests performed on F1 and F2 show significant differences between all pairs of vowels ($p < .0001$). Figure 2 displays the CoGs of [ʂ] (~4000 Hz) and [ʐ̩] (below 1000 Hz). Although voicing may have somewhat lowered the CoG of [ʐ̩], this large gap in CoG between the tautosyllabic [ʂ] and [ʐ̩] suggests that the speakers did not produce [ʐ̩] as a voiced prolongation of [ʂ]. The CoG rises in the middle window of [ʂ], where [ʂ] is less affected by the adjacent vowels than elsewhere. For [ʐ̩], the CoG remains fairly flat throughout the segment and there is no clear evidence that its frication was affected by the offset of [ʂ].

Discussion. The formant frequency values of [ʐ̩] suggest a high central vowel. However, the ultrasound images in Lee-Kim's (2014) study revealed that [ʐ̩] is homorganic with the preceding fricative ([ʂ] in this case); a plain vowel would not exhibit such characteristic. Yet, the low frication noise of [ʐ̩] versus [ʂ], as indicated by their CoGs only, does not support the claim that [ʐ̩] is a (syllabic) fricative. Other spectral analyses between fricative vowels and their plain counterparts (e.g., harmonics-to-noise ratio) and comparisons with other languages (e.g., Sūzhōu Chinese in Faytak, 2018) will provide further insight. It has been suggested that [ʐ̩] would be better explained as a retroflex approximant (Lee-Kim, 2014; Mok, 2013): this analysis needs a supportive account for the phonological distribution of [ʐ̩]. The current study has focused on the retroflex fricative vowel. It has a dental counterpart [z̩] which will be included in future analyses.

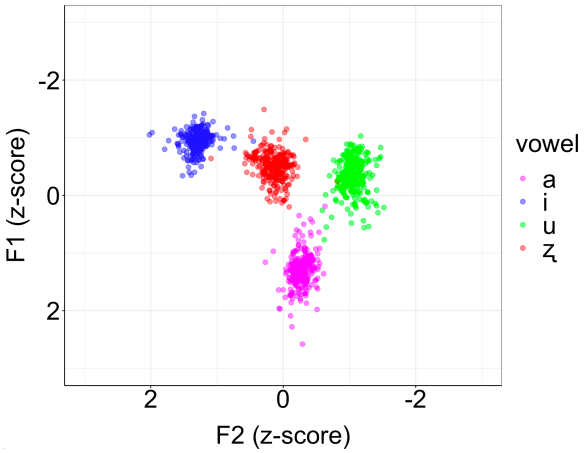

Figure 1. Comparison between [ʐ̩] and the corner vowels [i], [a], and [u] in z-normalized F1/F2 space.

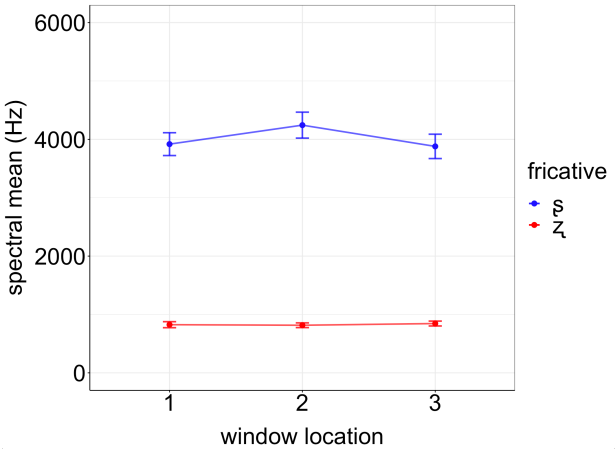

Figure 2. Comparison of the spectral mean frequency between [ʐ̩] and the fricative [ʂ] at the onset (1), middle (2), and offset (3) of the segment.

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