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# An acoustic study of fricated vowels in Nuosu Yi: an exploratory study

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**ABSTRACT**

Fricated nuclei in Nuosu Yi were found to be more correctly described as fricated vowels, rather than syllabic fricatives due to the presence of clear formant structures typical of front vowels. In this exploratory study, two types of fricated nuclei were examined: retroflex "yr" and non-retroflex "y." The retroflex nucleus "yr" had higher F1 and lower F3 than non-retroflex "y", indicating a lower tongue height. On the other hand, F2 was found to correlate not with nucleus retroflexion, but instead with onset consonant retroflexion: F2 was higher following retroflex onsets, in both vowels. This effect was persistent through the entire vowel, suggesting a phonological effect, rather than a coarticulatory one. Interpretation of the F2 results require accompanying articulatory data since the usual coupling of F2 and tongue backness does not always hold for retroflex vowels. Examining the articulation of the fricated nuclei in Nuosu Yi is a direction for future research.

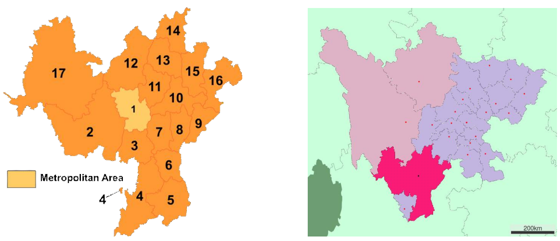
**Keywords: Nuosu Yi, fricated vowels, retroflexion, formant values.**

## 0. Introduction

Nuosu Yi, a Tibeto-Burman language, has syllabic nuclei that have been described as apical vowels or syllabic fricatives in the literature. The goal of this paper was to examine acoustic properties of these fricated nuclei and to report the interaction of these nuclei with retroflex onsets in Nuosu Yi.

Fricated nuclei commonly known as apical vowels, fricative vowels, or fricativized vowels in the literature are reported in Shanghai Chinese (Svantesson 1989), Beijing Mandarin (Lee 2005), Suzhou Chinese (Feng 2007), Lower Xumi (Chirkova & Chen 2013) and Upper Xumi (Chirkova et al 2013). Connell (2000) also identifies fricated vowels in Mambila (a Bantoid language) based on clear formant patterns of front vowels. Fricated vowels in Suzhou Chinese have lowered F2 (Feng 2007), but articulatory evidence shows fronting of the tongue. This type of mismatch between acoustic and articulatory data is also found in Beijing Mandarin (Lee 2005). Thus, lowered F2 is somehow consistent with tongue fronting, but not tongue backing for fricated vowels.

Nuosu Yi, a northern Ngwi branch in the Tibeto-Burman language family, is mainly spoken in the Liangshan county in the Sichuan province; thus it is also called Liangshan Yi. According to the 2010 census, there were about 2.2 million Yi people (49% of the population) in the Liangshan Yi prefecture. As one of the officially recognized ethnic groups in the Republic of China, the Yi language has its own orthography and is used




Liangshan prefecture Sichuan province

Figure 1. Map of Liangshan prefecture and its location in Sichuan (#12 in the Liangshan Yi autonomous prefecture is the Mianning county)

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as a medium of instruction in schools. There have been few studies investigating Nuosu Yi grammar (Chen & Wu 1998, Gerner 2013). The data in this paper was collected in the Mianning County (#12 in Figure 1) in the Sichuan province in 2011.

The phonological background of Nuosu Yi is shown in Section 1. Methods related to data collection and analysis are presented in Section 2. Before the discussion in Section 4, results of an acoustic analysis are shown in Section 3. Section 5 is the conclusion.

## 1. Nuosu Yi phonology and the syllabic nuclei

Nuosu Yi has a large number of consonants and numerous vowels. The segmental inventory in Table 1 and 2 is based on the description in Chen & Wu (1998) and Gerner (2013). The consonants and the vowel [ɿ] in the shaded cells were the focus of the current study. The vowel [ɿ], which is not a standard IPA symbol but used in the description of fricated vowels, is spelled as ‘y’ in the Nuosu Yi romanization system (called ‘Nuosu Yi pinyin’). As an exploratory study, the ‘y’ symbol is used for representing the fricated vowel.

Table 1. Consonant inventory of Nuosu Yi

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| p | p$^h$ | b | $^m$b | m̥ | m | f | v |
| t | t$^h$ | d | $^n$d | n̥ | n | ɬ | l |
| ts | ts$^h$ | ʣ | $^n$dz | | | s | z |
| tʂ | tʂ$^h$ | dʐ | $^n$dʐ | | | ʂ | ʐ |
| tɕ | tɕ$^h$ | dʑ | $^n$dʑ | | ȵ̥ | ɕ | ʑ |
| k | k$^h$ | g | $^ŋ$g | | ŋ | x | ɣ |
| | | | | | | h | |

Table 2. Vowel inventory of Nuosu Yi

| | | | | | | |
|---|---|---|---|---|---|---|
| i | | | | ɯ | | u |
| | ɿ | | | | | |
| | | e | | | o | |
| | | | | ɔ | | |
| | | | a | | | |

Nuosu Yi also has three lexical tones and one sandhi tone. The lexical tones are low (21), mid (33) and high (55). The sandhi tone is slightly rising (34). The numbers in parentheses are a tonal system following Chao (1930); the lower the number is, the lower the pitch level is, and the numbers are divided into 5 levels.

Chen & Wu (1998: 271-273) report two “fricativized” nuclei (“y” and “yr” in their notation) that can co-occur with many consonants in Table 1. These two types of nuclei require an onset and cannot form a syllable by themselves. Lama (2002) labels these vowels “fricativized vowels,” making a distinction between them and consonantal “fricative vowels.” It is argued that the “y” and “yr" sounds have sonority and duration profiles more similar to vowels, rather than fricative consonants, a position which our results support. Impressionistically, the “yr” nucleus has louder and higher frication noise than the “y” nucleus. The “yr” nucleus is a retroflex version of the “y” nucleus.

Gerner (2013) reports the difference between “y” and “yr” to involve creakiness, rather than retroflexion. Edmondson et al. (2001) presents laryngoscopic evidence for a distinction between lax (“y” vowel) and tense phonation (“yr” vowel) in vowels in Yi. These authors further note that the tense vowels involve reinforcement in the tongue root of the posterior movement of the epiglottis that results in raised F1 and lowered F2. While no correlates of laryngeal constriction are measured here, the acoustic findings were in accordance with Chen & Wu (1998), who conclude that there is a difference in retroflexion.

Co-occurrence restrictions show that alveolars (except the liquids), velars, [ɳ], [w] and [h] do not co-occur with these nuclei. Additionally, the “yr” nucleus does not co-occur with [b], [m], [f] and [dʑ], but these restrictions might be accidental gaps. There are no tonal restrictions with the “y” nucleus, which occurs in all three lexical tonal contexts. The “yr” nucleus, however, only occurs in the mid tone (33) context.

## 2. Methods

### 2.1 Data collection

Data analyzed in this paper was a part of a larger study on the phonetics and phonology of Nuosu Yi. The larger study examines detailed characteristics of sounds and their patterns, tone sandhi as well as prosodic patterns. Speech data was collected in the Mianning county in the Liangshan Yi autonomous prefecture, located in southern Sichuan (see Figure 1). One native male speaker of Nuosu Yi participated in the recording sessions.[5] He wore a heard-worn Shure WH-30

5) A reviewer pointed out that it is difficult to make generalizations from data obtained from a single speaker. We are fully aware of this shortfall and do not claim that the

microphone to minimize the change of distance from his mouth to the microphone. The microphone was connected to a Marantz PMD-661 field recorder. The sampling rate of the .wav recordings was 44.1 KHz with a 16-bit quantization level. Recordings were done in a quiet room where all the electronic devices were switched off during the time of the recordings.

Stimuli of the recordings came from a syllabary table in Chen & Wu (1998). The male consultant read the Yi orthography, and not the alphabetic representation of the syllables, with five repetitions. For example, the "y" nucleus with the [p] onset is ꀲ in high tone (55), ꀴ in mid tone (33) and ꀵ in low tone (21). The sandhi tone (34) version of each syllable was not included in the recordings. The stimuli were presented in the Nuosu Yi orthography to the speaker who produced each target syllable five times in isolation. This method ensured that there was no effect on F0 from varying the prosodic position of the stimuli.

### 2.2 Annotation

The target sounds were separated from longer sound files using a Praat script. The target sounds were manually segmented for their onset and their nucleus by opening the .wav files with another Praat script. The beginning of the nucleus was determined by two criteria: (a) the beginning of regular and periodic voicing in the waveform, and (b) a sharp decrease in amplitude at the higher frequencies. Figure 2 shows an example of an annotation of the syllable "shy."

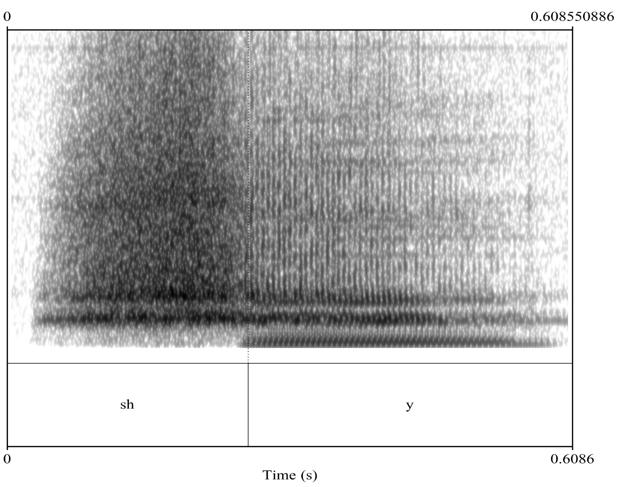


Figure 2. An example of an annotation of the onset and the nucleus for "shy"

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findings here are necessarily generalizable over the whole Nuosu Yi population. We plan to collect speech data of multiple speakers in future fieldwork.

### 2.3 Targets and measurements

Syllables with onsets of six coronal fricatives and affricates [s, z, ʂ, ʦ, ʣ, tʂ] and the target sounds (the "y" nucleus and the "yr" nucleus) in the mid tone context were selected for analysis because the target sounds usually appear after these onsets. Nuosu Pinyin notation was used for representing fricatives and affricates in this paper (see the appendix for the Nuosu orthography version of the target sounds). Five tokens of each onset-nucleus combination were analyzed yielding a total of 60 tokens (5 tokens each of [s, z, ʂ, ʦ, ʣ, tʂ] + y; 5 tokens each of [s, z, ʂ, ʦ, ʣ, tʂ] + yr). A complete list appears in the appendix.

The middle 3rd of the target sounds were extracted for formant measurements in order to ensure the minimized influence of coarticulation. Formant frequencies (F1, F2 and F3) and pitch (F0) were measured. F0 was measured through the entire vowel duration, unlike F1 and F2.

### 2.4 Statistical Analysis

A statistical analysis was conducted in order to check the relationship between retroflexion in the onset consonant and the nucleus. The null hypothesis was that there is no relationship between retroflexion in onset and retroflexion in nucleus in terms of the formant value.

Separate linear regressions for F1, F2 and F3 as dependent variables were performed. The model included onset retroflexion, nucleus retroflexion and onset continuancy as potential factors. Onset continuancy was simply nested because onset continuancy was not expected to interact with retroflexion. However, onset and nucleus retroflexion may interact with each other since they involve the same articulatory feature on adjacent sounds. As a result, onset and nucleus retroflexion were crossed in the linear regression model. The same model was used for F2 and F3. Statistical results of linear regression are listed in the appendix.

## 3. Results

### 3.1 Acoustic properties of "y" and "yr"

In the "y" nucleus, the presence of high frequency frication was observed over the course of the nucleus. In particular, the peak frequency of fricatives continued into F2 (Soli 1981) as shown in Figure 2. Compare the spectrograms of the "y" nucleus in Figure 2 with that of the high vowel [i] in Figure 3; the high frequency frication is absent in Figure 3.

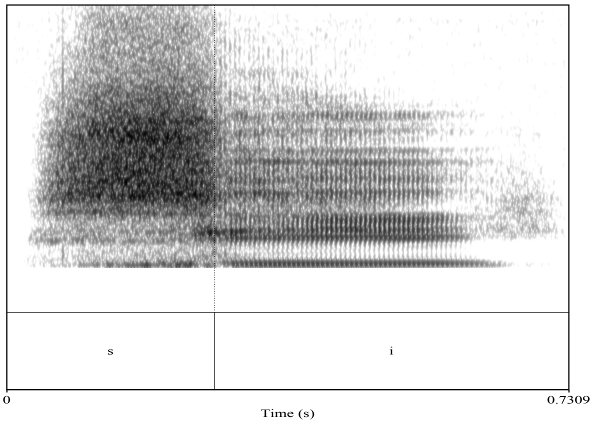


Figure 3. A spectrogram of the [i] vowel with the absence of high frequency frication

An examination of acoustic properties showed a relationship between retroflexion in onset and retroflexion in nucleus. This relationship is captured in Figure 4.

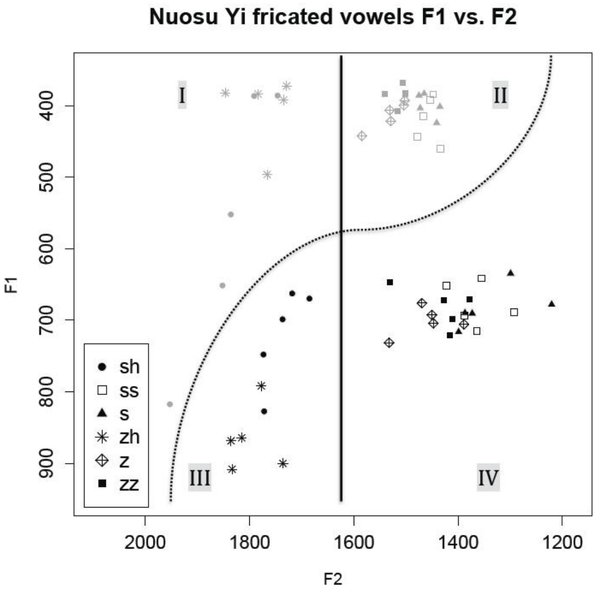


Figure 4. Acoustic properties of “y” and “yr” with different onsets (the plot is produced with the algorithm in Thomas & Kendall 2007). Areas I and II have tokens with the non-retroflex nuclei (“y”) and areas III and IV have tokens with retroflex nuclei (“yr”); areas I and III have tokens with retroflex onsets (sh, zh) and areas II and IV have tokens with non-retroflex onsets (s, ss, z, zz).

Figure 4 shows four major findings. First, retroflex nuclei (“yr”, dark-colored; III and IV) were consistently lower in height and have lower F2 than non-retroflex nuclei (“y”, light-colored; I and II). Second, when the retroflex onsets appeared together with a fricated nucleus, the nucleus had a higher F2 (i.e. more fronted; I and III). Third, there was a greater range of variability in F1 when a retroflex onset appeared together with a fricated nucleus (area I vs. area II and area III vs. area IV); there was less clustering with non-retroflex onsets. Fourth, tokens with affricate onsets usually had higher F2 in comparison to tokens with fricative onsets (see both areas II and IV).

### 3.2 F1 and F2

The linear regression models examined the relationship of retroflexion and F1 as well as F2. First, F1 was raised for “yr” relative to “y” ($\beta$ = 282 Hz, $p < 0.001$). Second, F2 was raised in vowels following retroflex onsets ($\beta$ = 315 Hz, $p < 0.001$). Third, F2 was slightly lowered for “yr” compared to “y” ($\beta$ = -92 Hz, $p < 0.001$). Lastly, F2 was also slightly lowered in vowels following fricatives compared to affricates ($\beta$ = -53 Hz, $p < 0.001$).

### 3.3 F3 and retroflexion

The linear regression model for F3 and retroflexion suggested that there was an interaction between types of onsets and the retroflexion of the nucleus ($\beta$ = 179 Hz, $p < 0.01$) as shown in Figure 5. This interaction was in addition to the main effects of the retroflexion of the nucleus ($\beta$ = -137 Hz, $p <.001$) and the retroflexion of the onset ($\beta$ = 117 Hz, $p < .01$).

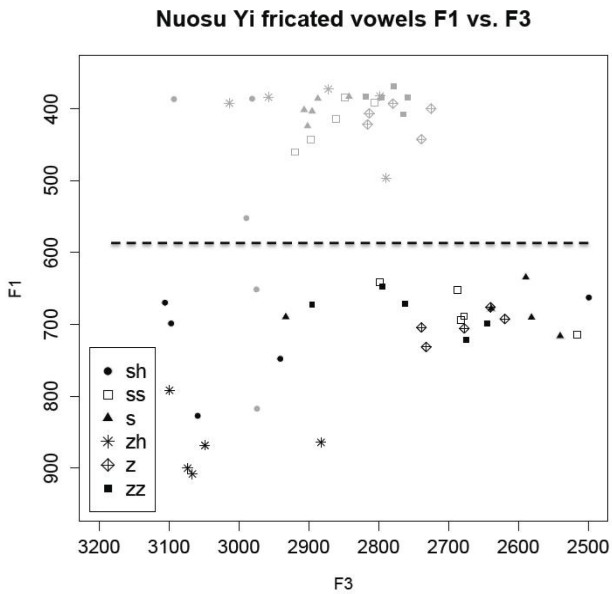


Figure 5. F3 and retroflexion. Light-colored tokens above the dotted line are syllables with the non-retroflex nucleus “y”; dark-colored tokens below the dotted line are syllables with the retroflex nucleus “yr”.

For the retroflex nucleus “yr”, F3 was higher in nuclei following retroflex onsets compared with other onsets; however for the non-retroflex nucleus “y,” there was no such onset effect on F3.

### 3.4 Lowered F0 in the “yr” nucleus

All analyzed tokens belonged to mid tone. An analysis of F0, however, showed that the “yr” nucleus had lowered F0. The range of F0 values in the middle third of the “y” nucleus was from 160 to 173 Hz, and the corresponding range in the “yr” nucleus was from 155 to 165 Hz. Figure 6 below illustrates the F0 profiles converted to semitones for all tokens of each vowel. The semitone scale used a reference F0 of 160 Hz, which was the median F0 of all tokens. The dark and light regions illustrate the 95% confidence intervals of the F0 data, using SS Anova.

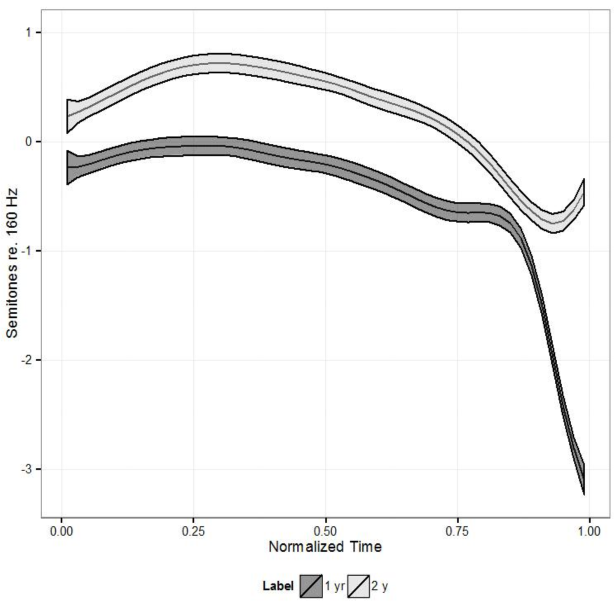


Figure 6. Time-Normalized Pitch in Semitones by Vowel. The light-colored pitch track is for the “y” nucleus and the dark-colored pitch track is for the “yr” nucleus.

## 4. Discussion

### 4.1 F1 and F2

Nuclei with retroflexion had higher F1, indicating that the nuclei were produced with lower tongue-height than non-retroflex nuclei. This height distinction provides the basic phonological contrast between the two nuclei.

F2 was also higher when a nucleus followed a retroflex onset. This effect of F2 was large and persisted to the middle of the nucleus. Therefore, this effect is interpreted to be a phonological one. The variation of F2 in the nucleus can be characterized as allophonic variation rather than as a coarticulatory effect. These results are similar to those reported by Lama (1998), who also found raised F1 and lowered F2 among “tense” vowels (“yr” vowels) in Yi.

### 4.2 F3 and retroflexion

When the onset was retroflex, there was a larger variance in the F3 values of the retroflex nucleus. It was possible that our speaker had less reason to enhance the retroflexion in the nucleus due to the coarticulatory effect of the onset.

The lowering of F3 in a retroflex nucleus was expected and observed. However, the lowering occured to a greater degree when the onset was not retroflex because it is necessary to enhance acoustic cues since there is less contribution from the coarticulation with the onset.

### 4.3 Lowered F0 in the “yr” nucleus

The observed difference in F0 values between “y” and “yr” has two possible sources. First, this difference could have been due to the difference in the height of the two nuclei. The nucleus “yr” had lower height (i.e. F1 is higher) than the nucleus of “y.” This intrinsic height difference might, in turn, lead to a difference in F0 between “y” and “yr” (cf. Whalen & Levitt 1995). Second, as other authors have pointed out (Gerner 2013, Edmondson et al. 2001), “yr” and “y” differ in that the former vowel is creaky while the latter is not. Creakiness has commonly been associated with lowered F0, and so the effect could have originated as a result of this reported creakiness difference (Stevens 1977, Gordon & Ladefoged 2001).

It is unlikely that the F0 difference between these two nuclei was phonological (i.e. it is not a tonal difference). For this to have been the case, a larger difference in F0 would have been expected; the measured difference was small and likely imperceptible. Future work could be conducted to determine whether and to what extent the F0 effect was due to intrinsic vowel height or due to creakiness.

## 5. Conclusion

In conclusion, vowel retroflexion raised F1, lowering the vowel. Additionally, retroflexion in a preceding onset consonant raised F2 in the vowel. Future work should explore whether this is in agreement with Feng’s (2007) and Lee’s (2005) findings in which raised F2 corresponded to tongue backing.

The nuclei under inspection in this paper were consistent with an analysis of fricated vowels, rather than syllabic fricatives. As in Connell's (2000) study of Mambila, clear formant structures for a front vowel are seen.


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## Appendix

List of target sounds with their corresponding Yi orthography

| Yi | Spelling | IPA | Yi | Spelling | IPA |
|---|---|---|---|---|---|
| ꌦ | sy | [s] | ꌩ | syr | [s] |
| [illegible] | ssy | [z] | [illegible] | ssyr | [z] |
| [illegible] | shy | [ʂ] | [illegible] | shyr | [ʂ] |
| [illegible] | zy | [ʦ] | [illegible] | zyr | [ʦ] |
| [illegible] | zzy | [ʣ] | [illegible] | zzyr | [ʣ] |
| [illegible] | zhy | [tʂ] | [illegible] | zhyr | [tʂ] |

F1 Linear Regression Results

($R^2$ = 0.81, $F(4,55)$ = 62.13, $p < 0.001$)

| | Estimate (β) | *t* | *p-value* |
|---|---|---|---|
| Intercept | 404 Hz | 20.9 | < 0.001 |
| Onset (Retroflex) | 78 Hz | 2.69 | < 0.01 |
| Vowel (Retroflex) | 282 Hz | 11.9 | < 0.001 |
| Ons. Continuancy (Fricative) | 0.7 Hz | 0.034 | 0.973 |
| Onset: Vowel | 29.9 Hz | 0.728 | 0.469 |

F2 Linear Regression Results

($R^2$ = 0.91, $F(4,55)$ = 148.2, $p < 0.001$)

| | Estimate (β) | *t* | *p-value* |
|---|---|---|---|
| Intercept | 1515 Hz | 110 | < 0.001 |
| Onset (Retroflex) | 315 Hz | 15.2 | < 0.001 |
| Vowel (Retroflex) | -92 Hz | -5.42 | < 0.001 |
| Ons. Continuancy (Fricative) | -53 Hz | -3.84 | < 0.001 |
| Onset: Vowel | 56 Hz | 1.92 | 0.061 |

F3 Linear Regression Results

($R^2$ = 0.50, $F(4,55)$ = 15.54, $p < 0.001$)

| | Estimate (β) | *t* | *p-value* |
|---|---|---|---|
| Intercept | 2818 Hz | 98.2 | < 0.001 |
| Onset (Retroflex) | 117 Hz | 2.71 | < 0.01 |
| Vowel (Retroflex) | -137 Hz | -3.88 | < 0.001 |
| Ons. Continuancy (Fricative) | 18 Hz | 0.643 | 0.523 |
| Onset: Vowel | 179 Hz | 2.95 | < 0.01 |