

AN ACOUSTIC AND ARTICULATORY STUDY OF DRENJONGKE FRICATIVES

Céleste Guillemot¹, Seunghun J. Lee^{1,2}, Fuminobu Nishida³

International Christian University¹ University of Venda² Tohoku University³
celeste.guillemot@gmail.com, seunghun@icu.ac.jp, nishidafuminobu@gmail.com

ABSTRACT

Drenjongke (Bhutia) is a Tibeto-Burman language spoken in Sikkim, India. Previous impressionistic descriptions of Drenjongke report a three-way laryngeal contrast in fricatives: voiceless, voiced and devoiced, but how this contrast is phonetically implemented has not been investigated. This study reports phonetic analyses of Drenjongke fricatives based on acoustic recordings and Electroglottograph data from five (1 female, 4 male) Drenjongke speakers. Our data is consistent with previous studies in that Drenjongke fricatives have a three-way laryngeal contrast. However, we found that the laryngeal contrast in Drenjongke manifest itself both in terms of voicing and f_0 , as voiceless fricatives are followed by high f_0 , and voiced and devoiced fricatives by low f_0 . We found a gender-based variation in voicing contrast as well; while the female speaker produced clear glottal vibration at the onset of the frication noise, male speakers did not do so.

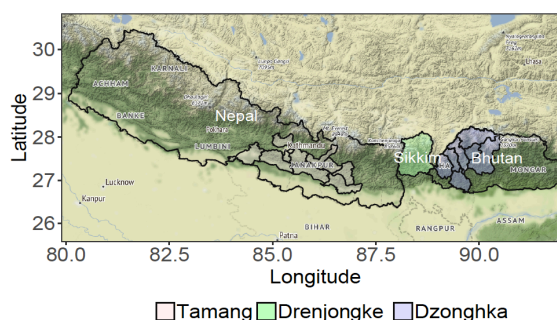
Keywords: Drenjongke, fricatives, voicing, tone, EGG.

1. INTRODUCTION

Drenjongke, also called “Bhuthia”, “Hloke” or “Sikkimese”, is a Tibeto-Burman language spoken in Sikkim, India (see Figure 1). Currently spoken by about 80,000 speakers, it is endangered, as the official languages in Sikkim are Nepali and English. Moreover, Drenjongke does not have its own orthographic system; speakers instead use a script based on classical Tibetan, although it does not reflect the current state of the vernacular language [7].

The phonological system of Drenjongke has been described in previous studies (see [3], [4] or [13] for example), but these were based on impressionistic observations. There is a need for more acoustic studies, in order to provide a more objective description of the language. The present paper investigates the acoustic and articulatory characteristics of the laryngeal contrast in Drenjongke fricatives.

Figure 1: Languages of the Himalaya



Previous impressionistic descriptions point out a four-way laryngeal contrast in Drenjongke plosives, but a three-way laryngeal contrast for fricatives [3, 4, 13]. These studies posit three fricative types: voiceless, voiced and devoiced fricatives. The term “devoiced” designates a specific type of fricatives, which used to be voiced but historically underwent devoicing. This is clearly reflected in the loss of a voiced prefix observed in the Uchen Tibetan writing system.

What these studies also suggest is the existence of an interaction between voicing and tone in the fricative contrast, as Drenjongke has a two-way tonal contrast (high and low), realized as a function of voicing.

2. THEORETICAL AND EMPIRICAL BACKGROUND

2.1. Fricatives and tone

Cross-linguistically, the voiceless-voiced contrast for fricatives is commonly found. There are languages where voicing is contrastive in fricatives (e.g. Japanese, English, French), and some other where it is not (e.g. Korean [2]). However, the two types of fricative are not equally common; i.e. voiceless fricatives are more frequent than voiced fricatives [8]. Indeed, voiced fricatives are articulatorily more challenging to produce: in order to create frication, the intraoral airpressure needs to be kept high, which makes it hard to sustain transglottal airpressure drop to maintain voicing. As a consequence, they are less frequent than voiceless ones.

Among the few studies on voiced fricatives, [11 et seq.] provide some insightful findings on their articulatory and acoustic characteristics. In terms of production, voiced fricatives have extended glottal vibration at the onset and offset of the frication noise. Additionally, voiced fricative exhibit extensive F1 transitions at boundaries in both VC- and CV-transitions. [11] also found out some perceptual cues for voicing in fricatives; they argue that the perception of voicing is largely based on the duration and amplitude of the glottal vibration during the frication noise. Namely, a fricative is perceived as voiced if there is frication noise without glottal vibration that is 60 ms or shorter. Similar results were observed in a study investigating Dutch by [6].

Interactions between consonant voicing and tone are not uncommon cross-linguistically. It is often observed that some types of consonants impose some phonological restrictions on tonal distributions, and this is not only true for tonal languages. [5 et seq.], for example, claims that the voicing of an obstruent affects the following vowel in terms of f0. Voiced obstruents are immediately followed by a low f0, while a high f0 is usually associated with voiceless obstruents. From [5], it is expected that fricatives should also follow this pattern: to a voiceless fricative a high f0 and to a voiced one a lower f0.

2.2. Drenjongke fricatives

Drenjongke is a language with a two-way tonal contrast (high and low) and a three-way laryngeal contrast in fricatives [7]. Previous descriptions of the fricatives contrast [7] are summarized in Table 1.

Table 1: Drenjongke fricatives

	Voiceless	Voiced	Devoiced
Voicing	No	Yes	No
Tone	High	Low	Low

Previous findings indicate that tonal contrasts in fricatives are realized as a function of voicing: voiceless fricatives are followed by a vowel with a high tone and voiced ones by a low one. However, the devoiced category appears to be unique, as, it should involve both absence of voicing and low tone; this association is something that is unexpected from the typological observation made by [5].

The present study investigates experimentally the phonetic characteristics of Drenjongke fricatives in order to test whether findings from phonological descriptions hold in actual speech.

3. METHODOLOGY

The acoustic and articulatory data was collected in the summer of 2017 by the second author in Sikkim, India. Native speakers of Drenjongke were asked to take part in a reading task where stimuli were presented in the Uchen Tibetan script on slides using Keynote and a Macintosh computer. Recordings were conducted using a Shure WH30XLR head-worn microphone and a TASCAM recorder (DR100-MK). The participants were all primary or secondary school teachers that were also fluent in English and Nepali.

Stimuli were all the possible syllables containing fricatives from the Drenjongke syllabary followed by the vowel /a/: /sa/, /ʃa/ (voiceless), /za/, /ʒa/ (voiced) and /ɬa/, /ʈa/ (devoiced). Each syllable was produced five times. The results of this study present the data recorded from 5 speakers (1 female, 4 male). After removing disfluent tokens, we analysed a total of 144 tokens. Annotation and acoustic measurements were conducted using Praat (version 6.0.23) [1], and statistical comparisons were made with R (version 3.4.1) [10].

In addition, laryngeal activity was recorded using an Electroglottograph (EGG), a non-invasive device which measures the impedance between the vocal folds, reflecting the degree of contact between vocal folds. This is quantified as the “open quotient” in voice production. EGG data was collected using a Glottal Enterprises EG2PCX2 Electroglottograph.

4. RESULTS

4.1. f0

A summary of the results of the acoustic analysis for f0 (for male ‘m’ and female ‘f’ speakers) is presented in table 2. F0 measurements were conducted using a Praat [1] script.

Table 2: Acoustic results of the following vowel f0

Voiceless	Voiced	Devoiced
High f0	Low f0	Low f0
avg.	avg.	avg.
m: 140.2Hz	m: 130.2Hz	m: 129.1Hz
f: 185.4Hz	f: 174.9Hz	f: 176.7Hz

The analysis of the acoustic data confirms the observations in previous descriptions of the language. The vowels following voiceless fricatives were observed with a higher f0 than for the voiced and devoiced categories. An independent samples t-test reveals a significant difference for f0 between the voiceless and voiced categories for male ($t(73)=-2.04$,

$p=.04$) and female ($t(18)=-3.21$, $p<.01$) speakers and between the voiceless and devoiced categories for male ($t(76)=-2.3$, $p=.02$) and female ($t(18)=-2.32$, $p=.03$) speakers. On the other hand, no differences were observed between the voiced and devoiced categories for both male ($t(73)=-.30$, $p=.76$) and female ($t(18)=.42$, $p=.67$) speakers. What these results suggest is that f_0 is a crucial predictor for the devoiced category as it allows to make a distinction between voiceless and devoiced categories. This is illustrated in Figures 2 and 3 where f_0 contours appear as blue lines. In Figures 2 and 3, two spectrograms of the productions of the same speaker, we can observe a higher f_0 contour for the voiceless fricative /ʃa/ than for the devoiced one /ʂa/.

Figure 2: f_0 after a voiceless fricative

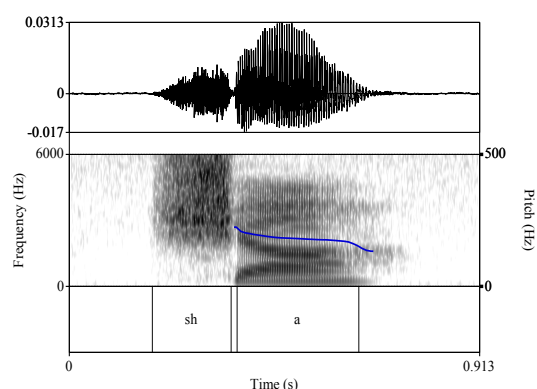
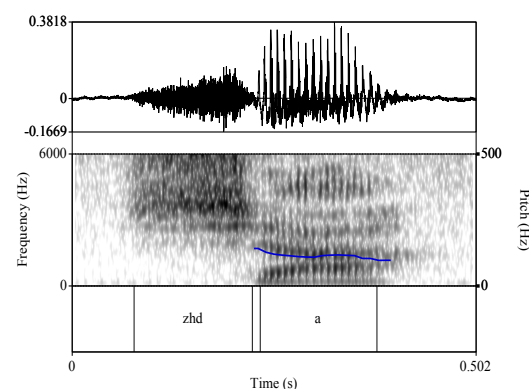


Figure 3: f_0 after a devoiced fricative



4.2. Voicing

The presence of voicing during frication was assessed via inspection of waveforms and spectrograms. The results were consistent with previous studies for voiceless and devoiced fricatives—no voicing was observed. However, while our results indicate a clear voicing contrast for voiced fricatives in female speech, as illustrated in Figure 4, the same contrast was not observed in male speakers (Figure 5). In Figure 4, a clear glottal vibration was observed at the onset of frication up to the mid-point of the fricative

for the female speaker while for the same syllable in male speech, voicing was absent.

Figure 4: Voiced fricative of a female speaker

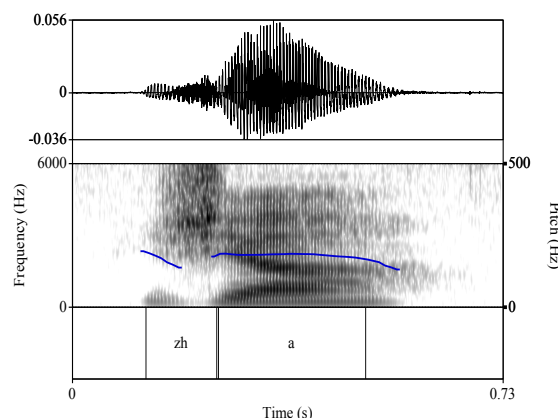
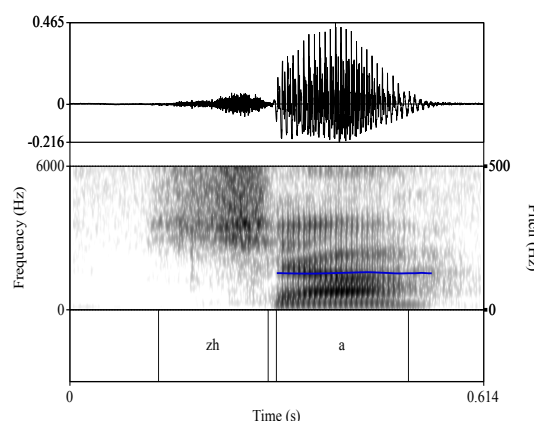


Figure 5: Voiced fricative of a male speaker



What the results suggest for fricatives is that male speakers might have a two-way laryngeal contrast, based on f_0 distinction only; i.e. they no longer contrast between voiced and devoiced fricatives. Indeed, no contrast can be observed in male speakers' production, as long as the presence of voicing is concerned, since no glottal vibration is produced for either category. In terms of f_0 , while voiceless fricatives are immediately followed by vowels with higher f_0 which distinguish this category from the other two, this is not the case for the voiced and devoiced categories. We analysed further acoustic cues in order to investigate whether the contrast between the voiced and devoiced category manifests itself in some other phonetic dimensions. To this end, other acoustic cues such as duration, center of gravity (COG) and intensity of the frication noise were assessed. However, statistical testing of these factors showed no significant differences between the two categories, even though there was a tendency to have a lower COG for the voiced category (realized as voiceless).

Electroglottography data confirmed the findings above regarding the voiced category for male speakers. This is illustrated in the differences in

laryngeal activity in Figures 6 and 7 obtained from the Matlab based program Eggnog [12] version 0.5.1.

Figure 6: EGG results of a voiced fricative for a female speaker

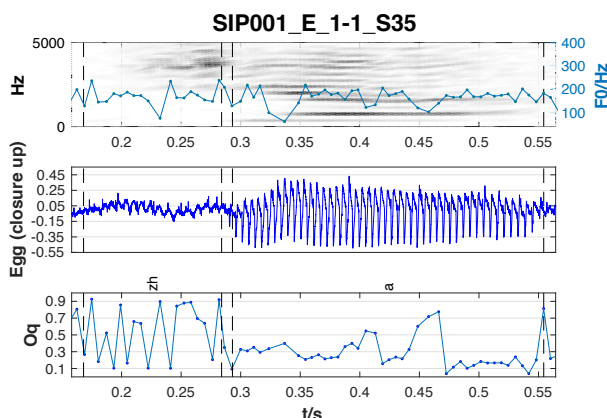
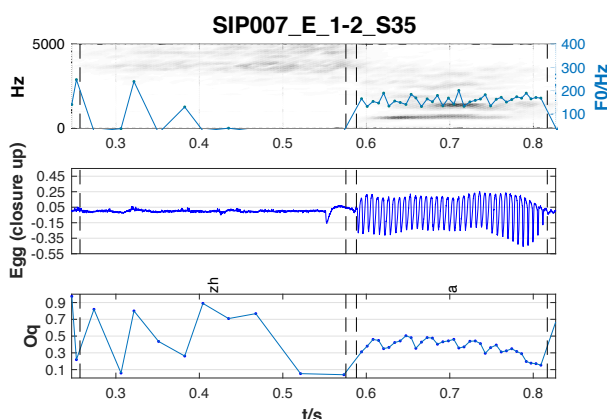


Figure 7: EGG results of a voiced fricative for a male speaker



5. DISSCUSSION AND CONCLUSION

This study investigated the acoustic characteristics of Drenjongke fricatives. Our findings were only partly consistent with previous impressionistic descriptions of the language [7]. For the female speaker only, we could confirm the three-way laryngeal categories. Voiceless fricatives are characterized by an absence of glottal vibration and are immediately followed by high-pitched vowels. Voiced and devoiced categories are both followed by low-pitched f0, and can be distinguished in terms of the presence/absence of glottal vibration. For male speakers, the current data seems to suggest that they have only two distinct laryngeal categories. Indeed, the contrast between voiced and devoiced fricatives appears to be neutralized, as both were realized as voiceless and followed by low-toned vowels. Furthermore, this phenomenon is not limited to the syllabary reading, as preliminary investigation of a word list read by the same speakers shows the same

tendency. However, the observations above are based on a production data from a few speakers only and we need to conduct analysis of the production data on a larger population. Moreover, in order to investigate whether the neutralization of the voicing contrast observed in male speech is complete or incomplete [9], further research is necessary. Namely, we will conduct perception tests to identify potential perceptual cues allowing Drenjongke speakers to distinguish the two categories.

The gender-based nature of the observed neutralization phenomenon is of interest. One possible explanation to account for this neutralization of the voicing contrast is the influence of education. Indeed, in Nepal and Sikkim, many of the men are monks or receive monastic education using Tibetan, and in the current study the stimuli were presented to the participants using Tibetan script. As Lhasa Tibetan phonology, for example, has no voicing contrast but does have a tonal distinction in fricatives (see Table 3), we can postulate that exclusively male speakers might have been influenced by their linguistic knowledge of Tibetan.

Table 3: Contrast in Lhasa Tibetan fricatives: Tibetan script followed by transliteration in italics and IPA

L tone (voiced)	H tone (voiceless)
ཞ <i>zha</i> [ʃà]	ཤ <i>sha</i> [ʃá]
ཞ <i>za</i> [sà]	ཤ <i>sa</i> [sá]

Another finding of this study concerns the interaction between voicing and tone. We found that a low tone can occur after a devoiced fricative, contrary to previous studies' results pointing out the influence of consonant voicing on tone (i.e. absence of voicing in obstruents triggers a high tone) [9]. This suggests that the acoustic influence of consonants on tone can be overridden by a phonological grammar that demands a particular tonal classification (manifested in f0).

6. REFERENCES

- [1] Boersma, P. 2001. Praat, a system for doing phonetics by computer. *Glott International* 5 (9/10), 314–345.
- [2] Chang, C.B. 2007. Korean fricatives: Production, perception and laryngeal typology. *UC Berkeley Phonology Lab Annual Report*, 20–70.
- [3] van Driem, G. 2001. *Languages of the Himalayas: An Ethnolinguistic Handbook of the Greater Himalayan Region, containing an Introduction to the Symbiotic Theory of Language*. Leiden: Brill.
- [4] van Driem, G. 2016. The phonology of Dränjoke. Ms.
- [5] Hombert, J-M., Ohala, J., Ewan, W.G. 1979. Phonetic explanations for the development of tones. *Language* 55, 37–58.

- [6] Kissine, M., Van de Velde, H., van Hout, R. 2003. An acoustic study of standard Dutch /v/, /f/, /z/ and /s/. *Linguistics in the Netherlands* 2003, 93–104.
- [7] Lee, S., van Driem, G., Kawahara, S. 2017. Drenjongke. ms.
- [8] Maddieson, I. 1984. *Patterns of Sounds*. Cambridge University Press.
- [9] Port, R. F., O'Dell, M. 1985. Neutralization and syllable-final voicing in German. *J. of Phonetics* 13, 455–471.
- [10] R Core Team. 2017. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. Vienna, Austria. <http://www.R-project.org>.
- [11] Stevens, K. N., Blumstein, S., Glicksman, L., Burton, M., Kurowski, K. 1992. Acoustic and perceptual characteristics of voicing in fricatives and fricative clusters. *J. of the Acoustical Society of America* 91 (5), 2979–3000.
- [12] Villegas, J. 2019. Eggnog: ElectroGlottography Not Obligatory Guidance. Version 0.5.1. Available from <http://onkyo.u-aizu.ac.jp/software/eggnog/>
- [13] Yliniemi, J. 2005. Preliminary phonological analysis of Denjongka of Sikkim. MA Thesis, University of Helsinki.