

The phonetic structure of Dzongkha: A preliminary study*

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Abstract

Dzongkha is the national language of Bhutan, but its phonetic nature has not been studied instrumentally in depth. This research note thus explores the phonetic structure of this language, focusing on three aspects: (i) the vowel quality, (ii) the tonal contrast, and (iii) the four-way laryngeal contrast. The results show (i) that the first three formants are necessary to distinguish the eight vowels of this language, (ii) that the tonal contrast most clearly manifests itself at the onset of syllables, and (iii) that the laryngeal contrast is acoustically differentiated in terms of both VOT and F0 of the following vowels. Although the current analysis is limited in that it is based on the data from a single speaker, it is hoped that it provides a stepping stone toward further analyses of Dzongkha, and comparative phonetic studies of other related languages.

1 Introduction

Dzongkha (a.k.a. Butanese) is a Tibeto-Burman language, and is the national language of the Kingdom of Bhutan. According to Ethnologue, it is spoken by about 226,000 speakers.¹ Despite becoming designated as the national language, however, Bhutan's political situation is such that parents tend to encourage their children to learn English instead of Dzongkha for socio-economic

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¹<https://www.ethnologue.com/language/dzo>

6 reasons (Nishida, 2004). Because of this socio-political situation, Dzongkha is being endangered,
7 and it is important that we document its linguistic properties as soon as possible.

8 While there is an impressionistic description by Tshering and van Driem (2015), itself a re-
9 vised version of van Driem and Tshering (1998), and a brief phonetic analysis by Watters (2002),
10 Dzongkha’s phonetic structure has not been studied in depth using recent instrumental technolo-
11 gies. From the previous studies (Tshering and van Driem, 2015; Watters, 2002), we know that
12 Dzongkha has eight contrastive vowels, a two-way tonal contrast (H(igh) and L(ow)), and a four
13 way laryngeal contrast, each category being referred to as “aspirated”, “voiceless”, “voiced,” and
14 “devoiced” (cf. Nishida 2016). Our aim in this research note is to systematically explore the
15 acoustic realizations of these three contrasts.

16 The tone is contrastive in vowel-initial syllables and syllables with sonorant onsets. However,
17 there are tone-consonant restrictions such that obstruents can be followed by only particular types
18 of tones. Concretely, syllables with aspirated and voiceless onsets predictably bear H-tones, and
19 “devoiced” and voiced onsets predictably bear L-tones (Tshering and van Driem 2015: 39-40).²

20 One general caveat is in order. The phonetic analysis presented in this paper is lim-
21 ited in that it is based on the data from a single speaker, whose speech is made available in
22 van Driem and Tshering (1998); therefore, the findings of this paper should be interpreted with
23 caution, and should be replicated with a larger number of speakers in future research. Meanwhile,
24 it is hoped that we can situate this study as a stepping stone for future research of this language, as
25 well as comparative phonetic studies of other related Tibeto-Burman languages, such as Tamang
26 and Dränjongke.

27 **2 Method**

28 **2.1 Vowel quality and the tonal contrast**

29 All the recordings came from van Driem and Tshering (1998). The speaker is Tshering himself,
30 who is a male, native speaker of Dzongkha. He was about 30 years old at the time of recording. He
31 worked as the broadcaster of the national TV program in Bhutan. He was born in Thimphu, and
32 raised in Gaselô, in Wangdi Phodrang district. His dialect of Dzongkha would thus be characterized
33 as “Gasebi-kha.” All the sound samples were digitized at 44.1k Hz sampling rate.

34 Dzongkha has eight vowels, transcribed by Tshering and van Driem (2015) as /a/, /ä/, /e/,
35 /i/, /o/, /ö/, /u/, and /ü/. Among those, five of them have a short-long length contrast

²Watters (2002) (p.17) provides a near-minimal pair /jii/ ‘field’ vs. /ji/ ‘die’, in which the first word has L-tone and the second word has H-tone. We have consulted Karma Tshering, a native speaker of Dzongkha, and also the speaker who provided the data for the current study. He informed us that he does not know how to pronounce the first word (i.g. /jii/ with L-tone). There are two possibilities for this discrepancy. One is that Watters (2002) is dealing with a different dialect of Dzongkha. The second is that this is simply a typo.

36 (Tshering and van Driem, 2015, p.45) (cf. Nishida 2004: p.20). The vowels with an umlaut sign
37 (/ä/, /ö/ and /ü/) are always long, and these vowels are indeed noticeably longer (ca. 300 ms) than
38 the other vowels (ca. 150 ms) in the recording. Each vowel was read with H-tone and L-tone.

39 Both F0 and spectral properties of these vowels were analyzed using Praat (Boersma 2001).
40 The first three formant values, averaged across the entire vowel intervals, were extracted. In addi-
41 tion to these vowels read in isolation, the recording included syllabary readings, which included 34
42 H-tone tokens and 33 L-tone tokens. The F0 patterns of these syllables were analyzed. We also ad-
43 dressed one consonant-tone interaction in Dzongkha by examining 18 syllables with a voiced onset
44 and 16 syllables with what has been referred to as “devoiced” consonants (Tshering and van Driem,
45 2015). The motivation of this analysis came from their impression that “devoiced” consonants are
46 distinguished from other categories in terms of the F0 of the following vowel.

47 **2.2 The laryngeal contrast**

48 The syllabary readings of the recording in van Driem and Tshering (1998) included the obstruents
49 of the four laryngeal types, all followed by a vowel [a]. To analyze the acoustic differences be-
50 tween the four classes of obstruents, the lag between the release of the consonant and the onset of
51 the following vowel is annotated using Praat (Boersma, 2001). These intervals are taken to rep-
52 resent VOT of different types of obstruents (see Figure 1). The onset of the vowels was aligned
53 with the point where the vocalic formants started (especially those higher than F1), together with
54 clear periodic energies in the waveform display.³ Voiced consonants showed clear voicing during
55 closure, despite being word-initial (Figure 1(c)). The closure voicing interval was taken as a neg-
56 ative VOT. Based on Praat annotations such as those illustrated in Figure 1, the durations of these
57 intervals were automatically extracted using a script.

³An anonymous reviewer raised a potential concern to the effect that the onset of the vowels should have been aligned with the onset of voicing, rather than the onset of higher formant structure, the latter of which comes slightly later. The rationale is that we should follow the original definition of VOT by Lisker and Abramson (1964). This difference between the onset of voicing and the onset of higher formant structure often occurs in natural languages because superlaryngeal gestures and laryngeal gestures are not perfectly synchronized, although they are undoubtedly coordinated (i.e. articulatory binding: Kingston 1985, 1990; Silverman 1995; Shaw and Kawahara 2018). Thus, while we appreciate this reviewer’s comment, we would like to point to the fact that it is not uncommon to identify the onset of vowels using formant structures higher than F1. For example, Davidson (2010) defines vocalic intervals as “a period of voicing...with formant structure containing a *visible second formant* that ended with abrupt lowering of intensity at the onset of [the following consonant]” (p.276: emphasis added). Kawahara (2006) likewise states “[t]he onset of [the preceding vowel] was set where *F3* becomes visible” (p.552: emphasis added). In this sense, our estimates of VOT may be longer than what we would have obtained if we set the onset of the vowels to the onset of vocalic voicing (Lisker and Abramson, 1964). Ultimately, however, we believe that what is more important is consistency within the analysis, rather than arguing how we decide where the vowels start. It is most likely that thanks to articulatory binding, the onset of voicing and the onset of higher formant structure should be highly correlated after all.

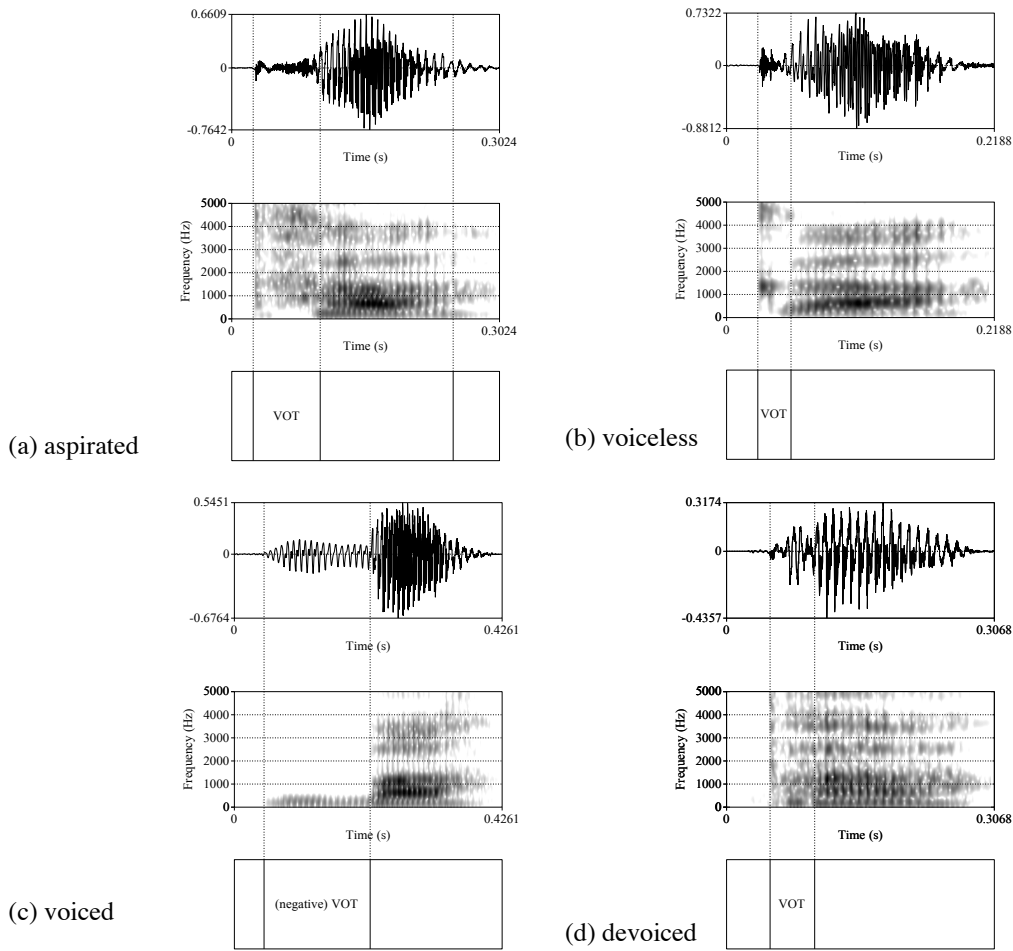


Figure 1: The four laryngeal categories in Dzongkha. Top left (a) = aspirated (= [t^h]); top right (b) = voiceless (= [ka]); bottom left (c) = voiced (= [ba]); bottom right (d) = “devoiced” (= [ba] (?)).

58 A 20 ms analysis window was created at the onset of the following vowel, and the average
 59 F0 within that analysis window was calculated for each type of consonant. The analysis is based
 60 on a small number of tokens produced by a single native speaker (aspirated = 5; voiceless = 7;
 61 devoiced= 11; voiced = 13). We thus did not attempt to apply statistical analyses to the results of
 62 the syllabary reading.

63 While the syllabary reading tokens may offer “clear” information about the phonetic struc-
 64 ture of Dzongkha, as syllabary readings are arguably free from lexical factors that may influence
 65 speech production (e.g. Baese-Berk and Goldrick 2009; Gahl 2008; Munson and Solomon 2004;
 66 Scarborough 2012, 2013; Wright 2004), they may be “artificial” in the sense that they are not
 67 produced as meaningful units in Dzongkha. To overcome this limitation, since the recording in

68 van Driem and Tshering (1998) also included pronunciation of basic vocabulary in Dzongkha, we
69 analyzed the VOT and the F0 in the following vowel using these real words, in the same way that
70 we used for the syllabary readings. The *N*s analyzed using these real words are: aspirated = 26;
71 voiceless = 49; “devoiced” = 9; voiced = 57. We conducted statistical analyses based on these
72 tokens.

73 **3 Results**

74 **3.1 The formant characteristics of the vowels**

75 We first started by exploring the acoustic nature of each vowel in Dzongkha (/a/, /ä/, /e/, /i/, /o/, /u/,
76 /ö/, /ü/). This first analysis is based on vowel-only readings, each vowel produced with H-tone and
77 L-tone. Figure 2 plots the standard F1 and F2 chart of these eight vowels, which shows that for
78 those vowels without umlaut signs (/a/, /e/, /i/, /o/, /u/), their F1 and F2 distribute in the expected
79 F1-F2 regions (except that perhaps, the F1 values of mid vowels distribute closer to those of high
80 vowels than halfway between high and low vowels). We also observe that umlauted versions have
81 lower F1—and, more clearly, higher F2—compared to non-umlauted versions, which suggests that
82 they are likely to be fronted versions of the corresponding non-umlauted vowels (i.e. umlaut rep-
83 resents frontness, as in German⁴); i.e. /ä/= /æ/, /ö/= /ø/, /ü/= /y/ (Johnson, 2003; Reetz and Jongman,
84 2008; Stevens, 1998). The lowering of F1 in umlauted vowels can potentially be understood as
85 a consequence of an additional palatal gesture associated with the fronting of vowels. Finally we
86 observe that in Figure 2, four types of vowels are clustered in the left-top region (/i/, /e/, /ö/, /ü/).

⁴Tshering and van Driem (2015) state that “[t]he Dzongkha vowel ö has no English counterpart. The Dzongkha vowel ö is like the vowel [œ] in French *oeuf*, German *plötzlich* or Dutch *lus* (p. 52).” This impressionistic statement is compatible with the result of the acoustic analysis.

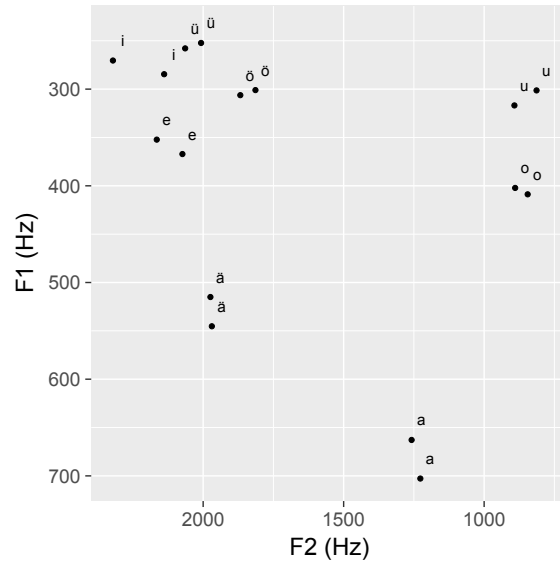


Figure 2: The F1-F2 vowel chart of Dzongka vowels. The analysis is based on the vowel-only reading tokens. Each vowel is produced twice, once with H-tone and once with L-tone.

87 In order to explore how these four vowels (/i/, /e/, /ö/, /ü/) are distinguished acoustically, we
 88 examined their F3, which is known to distinguish unrounded front vowels from rounded front
 89 vowels (Reetz and Jongman 2008: p. 184). The results appear in Figure 3, which plots F3 values
 90 on the y-axis and F2 values on the x-axis. As expected, F3 distinguishes unrounded front vowels
 91 (/e/, /i/) and rounded front vowels (/ö/, /ü/), in that the latter group has much lower F3.

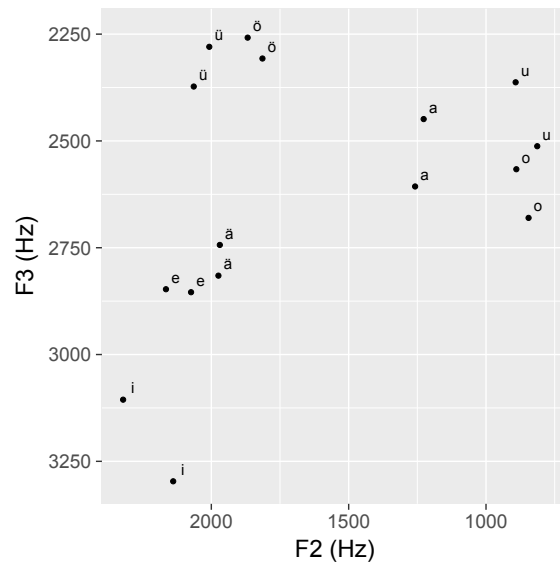


Figure 3: The F2-F3 vowel chart of the Dzongka vowels.

92 By way of summary, Table 1 shows the first three formants of the eight vowels in Dzongkha
93 (the values are based on the H-toned tokens).

Table 1: The first three formant values of the eight vowels (averaged over the entire vocalic intervals) in Dzongkha (Hz). The values are based on H-toned tokens.

vowel	F1	F2	F3
/a/	703	1227	2449
/e/	367	2074	2854
/o/	409	845	2680
/i/	285	2139	3297
/u/	317	892	2363
/ä/	545	1969	2743
/ö/	306	1868	2258
/ü/	252	2007	2280

94 3.2 Tonal realizations

95 Figure 4 shows F0 curves of H-toned and L-toned syllables, based on the vowel-only readings, the
96 same dataset that was used in Figures 2 and 3. The F0 contours were obtained by dividing the
97 vocalic intervals into five equally-timed windows, and taking the average F0 values within each
98 window.⁵ It shows that H-toned and L-toned syllables are separated clearly at the onset of syllables,
99 and the differences are neutralized toward the end for some vowels (see also Watters 2002 for a
100 similar finding). The tonal difference seems to persist throughout the syllables for /e/, /i/, and /u/.⁶

⁵This process was automated using a scripting function in Praat.

⁶In all syllables, tones fall toward the end. This may be due to the fact that they were read in isolation, and declarative sentences in Dzongkha have sentence-final low tones (Nishida, 2004). Future research should use a frame sentence to address this issue of whether the observed fall in pitch is due to phrasal/sentential tones.

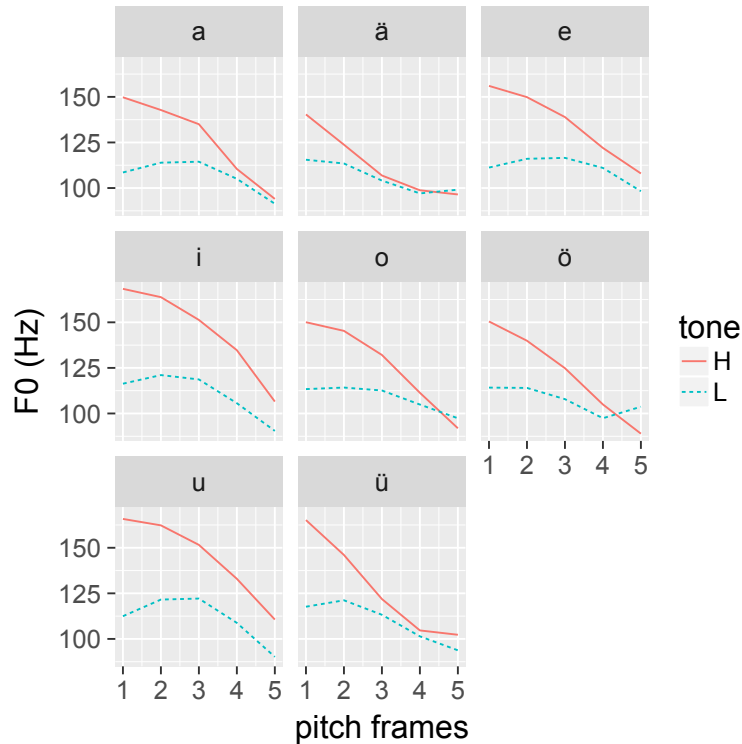


Figure 4: F0 movement of two types of tones, separated by vowel. The analysis is based on the vowel-only reading. H-tones=solid lines; L-tones=dotted.

101 Since the tonal patterns are comparable—if not identical—across different vowel qualities,
 102 Figure 5 shows the average F0 plots of H-toned and L-toned syllables, based on all syllabary
 103 reading tokens, most of which had an onset consonant. Figure 5 is based on an analysis that is
 104 the same as that of Figure 4, although it targets only vocalic intervals. On average, at the onset of
 105 the syllables, H-toned and L-toned syllables differ by 30-40 Hz; the differences in F0 get smaller
 106 toward the end of the syllables, and are not observed in the fifth and final frame. What is emerging
 107 through our analysis is that tonal differences in Dzongkha most clearly manifest themselves at the
 108 onset of vowels.

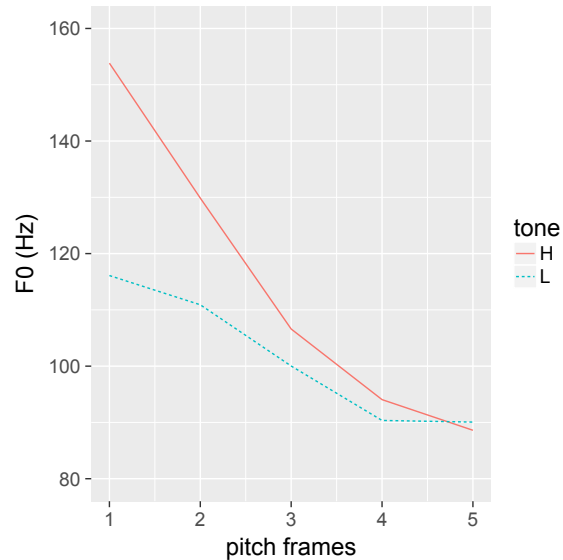


Figure 5: F0 differences of all syllables. The analysis is based on the syllabary readings.

109 In addition to the analysis of these F0 differences due to lexical H-tone vs. L-tone contrast,
 110 we also analyzed one type of consonant-tone interaction. Specifically, we examined 18 syllables
 111 with a voiced onset consonant and 16 syllables with what Tshering and van Driem (2015) and
 112 Watters (2002) referred to as a “devoiced” onset consonant. Recall that the lexical tone of these
 113 syllables was generally limited to L-tones (Tshering and van Driem, 2015) . The result, which
 114 appears in Figure 6, shows that the F0 is higher after voiced consonants than after “devoiced”
 115 consonants, the pattern that is opposite from what is expected if “devoiced” consonants were
 116 voiceless, as voiceless consonants usually raise F0 of the surrounding vowels (e.g. Hombert et al.
 117 1979; Kingston and Diehl 1994; Lee 2008). Our conjecture at this point is that these consonants
 118 are actually breathy consonants, which are known to lower F0 of the surrounding vowels cross-
 119 linguistically (e.g. Baumbach 1987; Lee 2008; cf. Halle and Stevens 1971). This conjecture is
 120 supported by the impressionistic description offered by Tshering & van Driem (2015: 56) “In ar-
 121 ticulatory terms, devoiced consonants are unvoiced, but, in contrast to the voiceless consonants,
 122 they are followed by a murmured or ‘breathy voiced’ vowel.”

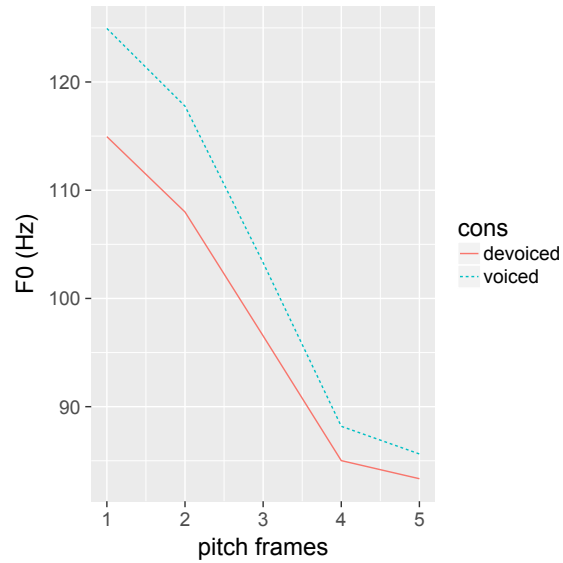


Figure 6: Effects of “devoiced” consonants on F0. The y-axis scale is identical to that of Figure 5.

123 3.3 Laryngeal contrast

124 Figure 7 is a violin plot which shows the VOT values of the four laryngeal categories, based on
 125 all the syllabary readings. We observe that voiced consonants are separated from the remaining of
 126 the three categories in that they all have negative VOT values (i.e. closure voicing); their closure
 127 voicing is usually longer than 100 ms. Among the other three categories, aspirated consonants
 128 show the largest VOT values, which are close to or slightly shorter than 100 ms. Voiceless and
 129 “devoiced” consonants show intermediate values (around 50 ms). One important question that
 130 arises is thus how these two categories are phonetically distinguished, which we turn to next.

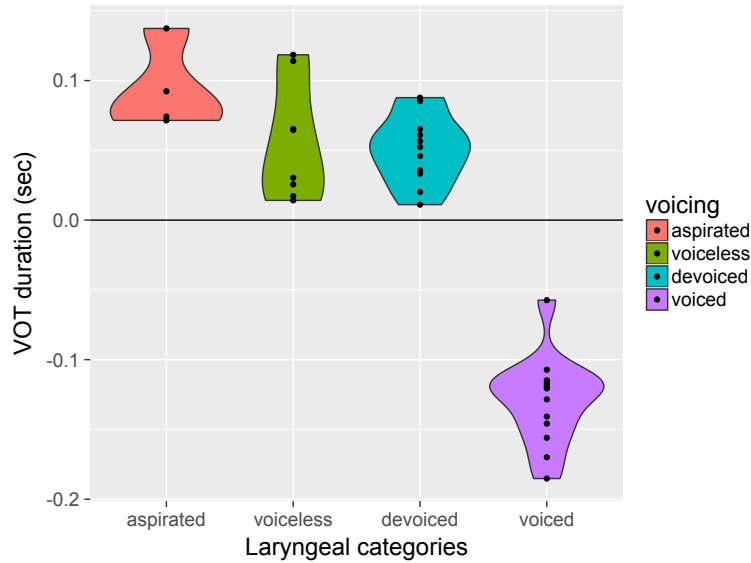


Figure 7: VOT of the four laryngeal categories (based on the syllabary reading). The first two types of categories are generally H-toned, and the last two types are generally L-toned.

131 Figure 8 is a violin plot which shows the results of the F0 analyses; recall that what has been
 132 measured are the average F0 values of the 20 ms analysis windows, placed at the onset of the
 133 following vowels. Figure 8 shows that voiceless and “devoiced” consonants, which showed com-
 134 parable VOT profiles, are separated out in terms of this measure. In addition, voiced consonants
 135 show lower F0 than voiceless consonants, an observation that is compatible with cross-linguistic
 136 observations (e.g. Hombert et al. 1979; Kingston and Diehl 1994; Lee 2008).

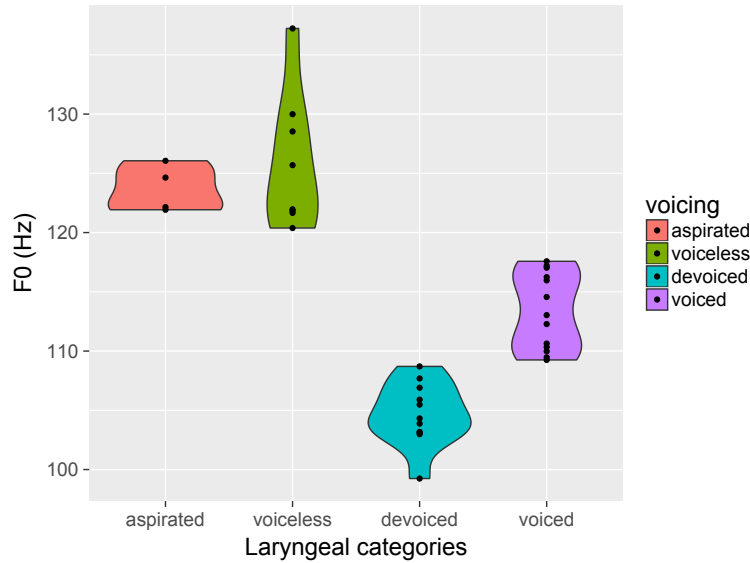


Figure 8: F0 of the four laryngeal categories (based on syllabary reading). The first two types of categories are generally H-toned, and the last two types are generally L-toned.

137 Since the number of syllabary reading tokens was limited, to the degree that we were not able to
 138 apply statistical analyses, we analyzed the real words recorded in van Driem and Tshering (1998).
 139 Figure 9 shows the results of the VOT analysis based on these real word tokens. It turned out
 140 that the results look very similar to what we observed in syllabary readings (Figure 7), except that
 141 we observe several tokens of positive VOT values for the voiced category. This may be related
 142 to the fact that all of these consonants were pronounced word-initially in isolation, and hence
 143 initiating closure voicing was particularly challenging (Hayes, 1999; Kingston and Diehl, 1994;
 144 Westbury and Keating, 1986).⁷ To statistically assess the differences between the four laryngeal
 145 categories, a one-way ANOVA with VOT duration as the dependent variable and the four laryngeal
 146 categories as the independent variable, was found to be significant ($F(3, 137) = 101.4, p < .001$).
 147 Multiple post-hoc comparisons using Tukey Honest Significant Difference (HSD) tests show that
 148 all the differences but the difference between voiceless and “devoiced” are significant, all at the
 149 $p < .001$ level.

⁷Some important remaining questions include whether these voiced consonants with positive, rather than negative, VOT would be appropriately perceived as voiced, and if so, how. A perception experiment is necessary to address these questions.

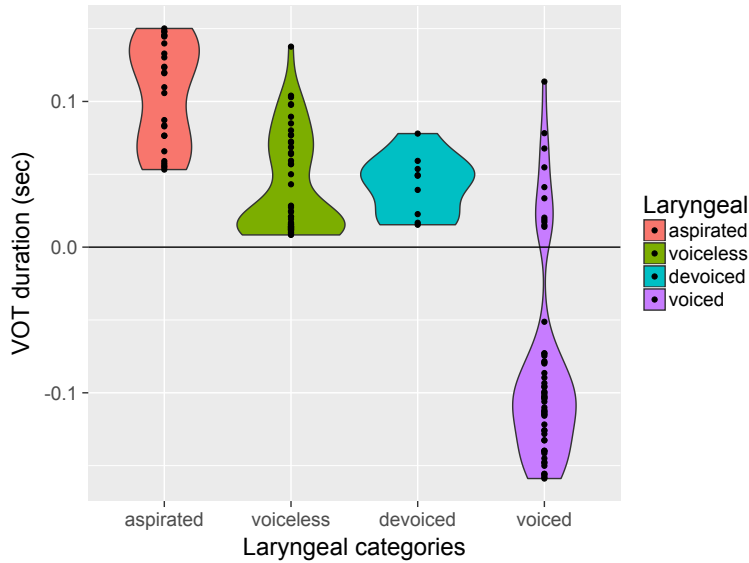


Figure 9: VOT of the four laryngeal categories (based on real words).

150 The patterns of F0 in Figure 10 more or less follow the same pattern that we observed in
 151 syllabary reading (Figure 8): aspirated and voiceless consonants show high F0 in the following
 152 vowels; “devoiced” consonants show the lowest F0 and voiced consonants show slightly higher
 153 F0.

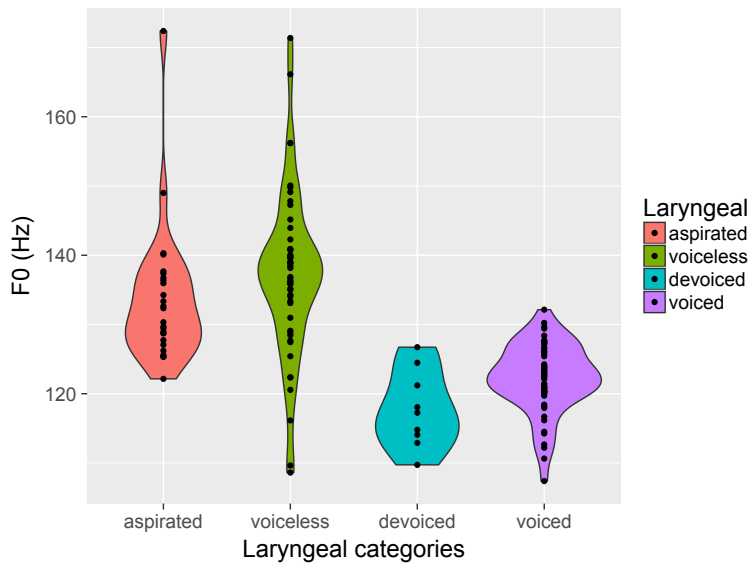


Figure 10: F0 of the four laryngeal categories (real words).

154 Statistically, one way ANOVA shows that there is a significant effect of the laryngeal cate-

155 gories on F0 ($F(3, 137) = 31.12, p < .001$); Tukey HSD tests show that there are no significant
 156 differences between aspirated and voiceless categories; both aspirated and voiceless consonants
 157 show higher F0 than devoiced and devoiced consonants, all at the $p < .001$ level. No statistical
 158 differences were observed between voiced and “devoiced” consonants.

159 Table 2 summarizes how the four laryngeal categories are distinguished in Dzongkha.

Table 2: How the laryngeal contrast is differentiated in Dzongkha.

	VOT	F0
aspirated	long	high
voiceless	short	high
“devoiced”	short	low
voiced	negative	low

160 4 Conclusion

161 The aim of this research note was to explore the basic phonetic structure of Dzongkha. Our prelim-
 162 inary analyses have revealed that (i) Dzongkha’s eight vowels are distinguished in terms of F1, F2,
 163 and F3, (ii) the lexical H-tone vs. L-tone contrast manifests itself at the onset of syllables, and (iii)
 164 the four-way laryngeal contrasts are distinguished in terms of both VOT and F0 of the following
 165 vowels. As declared at the outset of this paper, these conclusions have limitations in the sense that
 166 they are based on speech produced by a single speaker. We are working to seek other speakers of
 167 Dzongkha to examine the generality of the current findings. We also aim to compare the current
 168 findings with related Tibeto-Burman languages, including Dränjongke and Tamang.

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