Just put your lips together and blow?
The whistled fricatives of Southern Bantu

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Abstract. *Phonemically, whistled fricatives /s͎ z͎/ are rare, limited almost entirely to Southern Bantu. Reports differ as to whether they are realized with labial protrusion and/or rounding. Phonetically, whistled sibilants are common; they are regarded as a feature of disordered speech in English. According to the clinical literature, unwanted whistled fricatives are triggered by dental prosthesis and/or orthodontics that alter the geometry of the incisors—not by aberrant lip rounding. Based on aeroacoustic models of various types of whistle supplemented with acoustic data from the Southern Bantu language Tshwa (S51), this paper contends that labiality is not necessary for the production of whistled fricatives.*

1. Introduction

1.1. Typology

Few phonemes are as typologically restricted as the so-called whistled, whistling, or whistly fricatives / s͎ z͎ /.[1] They are said to occur in only a handful of languages: the Shona (S10) and Tshwa-Ronga (S50) groups of Southern Bantu (Bladon et al., 1987; Sitoe, 1996; Ladefoged and Maddieson, 1996; Maddieson, 2003), Tabassaran (North Caucasian,

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[1]The vertical subscript arrows are used for whistled fricatives in the clinical literature (ICPLA, 1994). Ladefoged and Maddieson (1996, 171) choose not to represent the sound symbolically in their discussion of whistled fricatives. Later, they use the symbols [s̫ z̫] to refer to "a pair of rounded fricatives," in Shona, with no mention of the whistle (358). Bladon et al. (1987) use /s̫ z̫/ but this seems unsatisfactory since the diacritic [̫] elsewhere signifies only labialization (IPA, 1979). Sitoe (1996) uses /ʂ ʐ/, signifying retroflexion. This may represent the whistling 'gesture' better than [s̫], which is really just an alternative form of [s^{w}] (IPA, 1949). Contemporary orthographies of Shona and Tshwa-Ronga languages use the digraphs *sv* and *zv*.

Lezgic) (Maddieson, 2003), and Sheḥri or Jibbāli (South Arabian) (Johnstone, 1984). Virtually nothing is known about the acoustics or articulation of the Tabassaran sound. As for the whistled sibilants of Seḥri, I have listened to an audio recording of the phonemes of this language (Al-Šaḥrī, 2000) and find no evidence of a sibilant with the distinctive tone characteristic of Bantu whistled fricatives. This paper will focus on the fricatives of Southern Bantu, for which audio recordings and numerous published accounts are available.

1.2. Labial whistling, whistled languages, and whistled fricatives

Generated by moving air, the human whistle is an oscillation whose characteristic frequency is determined by the resonance of the oral cavity. Unlike many common speech sounds, including vowels and other voiced continuants, the oscillation of a whistle is achieved *without* the vibration of the vocal folds. The aeroacoustics of whistling will be reviewed in Section 3.

At this point, it will be useful to distinguish recreational labial whistling, whistled languages, and whistled fricatives. Recreational labial whistling is the familiar whistle used to produce a melody or serve any number of paralinguistic functions; here, the lips must protrude. In whistled languages, a spoken language (e.g. Pirahã, Yupik, or Spanish) is reduced to its suprasegmental features like duration and tone, then these are whistled as distinct notes (Busnel and Classe, 1976). Whistled fricatives[2] are less well-known. Sibilants are frequently accompanied by whistling in English (and presumably in many other languages). This condition is is exacerbated when speakers use dental prostheses or undergo orthodontics (Cohen, 2006). The whistle is sometimes treated as a disorder, but lip rounding is never the focus of therapy (see Section 5). While allophonic whistling of sibilants is ubiquitous, it is phonemicization of whistled sibilants that is rare.

My recordings of phonemic whistled sibilants in Tshwa (S51) indicate that they are accompanied by a spectral peak narrower than that of non-whistled sibilants (see Section 4). I argue that whistled fricatives are not necessarily produced with labial protrusion, i.e. they are akin to a non-labial form of recreational whistling referred to as ‘palatal’ or ‘roof’ whistling.

2. Disputed claims in Bantu

A few examples of words containing the the whistled fricatives in various Southern Bantu languages are presented in Table 1.

Reports conflict regarding whether and to what extent the whistled fricatives of Bantu are characterized by lip rounding. In Shona (S10), it has been reported that the main difference “between [s] and [[s̪]] is. . . the raising of the lower lip and general rounding of the lips in such a way as to lessen materially the opening” (Doke, 1931, 47–48). Of Shona and Kalanga (S16) it has been said that, “Unlike ‘ordinary labialization’ which involves rounding or protrusion of the lips accompanied by a raising of the tongue back. . . labialization [of [s̪ z̪]] involves primarily a vertical narrowing of the lips with *little or no protrusion* and no accompanying back tongue raising” (emphasis added) (Maddieson, 2003, 27). Of Karanga (S14) it has been observed that for the whistled fricatives

[2]More precisely they are sibilants: only /s̪/ and /z̪/ have been reported.

Table 1. Whistled sibilants in three Southern Bantu languages

Shona	Gloss	Language	Guthrie Code
zvakuga	food	Tshwa	S51
svanyi	ruminated grass	Tshwa	S51
-svìnyà	close the eyes	Tsonga	S53
-svìgònyò	dried crabs	Tsonga	S53
-vázvá	make bitter	Zezuru	S12
svàvìkè	shrivelled object	Zezuru	S12

the lips are closely rounded (Pongweni, 1977). According to a speaker of Zezuru (S12), "The chief feature distinguishing [s͎ z͎] from [s z] is the bringing forward of the lower jaw; some lip rounding may also be observed. . . [T]here may be some slight curling upward of the tongue in [s͎ z͎]" (Bladon et al., 1987, 40). As mentioned earlier, the whistled sibilants of Tsonga (S53) are transcribed as retroflexes, i.e., [ʂ ʐ] (Sitoe, 1996). Finally, video recordings of Zezuru indicate *no lip rounding* in the whistling sibilants (Bladon et al., 1987, 44).

Despite the disagreement, synchronic and diachronic analyses still proceed based on the supposition that the whistled sibilants are somehow inherently labial (see, e.g. Downing, 2004). Bantuists agree that the whistled Class 8 prefix *svi-* [s͎i]- or *zvi-* [z͎i]- in Shona and Tshwa-Ronga derives from either *βî-* or *bį́-*[3] (Maho, 1999). For Shona verbs, [s͎ì] ← [pì̝] and [z͎í] ← [bì̝] (see Table 2, based on (Hannan, 1987)).[4] Maddieson has remarked that the "so-called 'whistling' fricative reflexes of */pį bį/ in Kalanga and some Shona varieties" are "particularly unusual" because they "reduce the original [labial] consonant to a secondary feature" (2003, 19). I argue that the posited correspondence between labials and whistled sibilants is not only unusual but unwarranted, since labiality is not a necessary condition for the articulation of whistled sibilants.

Table 2. Shona whistled reflexes of Proto-Bantu roots.

Shona		Proto-Bantu	Gloss
svìkà	←	**pį̀k*	arrive
svìnà	←	**pį̀n*	squeeze
zvíná	←	**bį́n*	dance for joy
zvímbá	←	**bį́mb*	swell

3. The mechanics of whistling

According to Wilson et al. (1971, 366), the term 'whistle' is used to describe "all types of aerodynamic sound-generating devices which depend in some way for their operation on the formation of vortices and the interaction of these vortices with some other part of

[3]The vowel is 'super-high', usually written as *į*; it is transcribed here as IPA [i̝].

[4]Note that the whistled fricatives now occur in various vocalic environments.

the device.” Chanaud (1970) classifies all whistles into three types, two of which will be discussed here: hole tones and edge tones.

3.1. Hole tones

A hole (or ‘orifice’) tone is produced by a fast-moving cylinder (or ‘vena contracta’) of air that interacts with the slow-moving anulus of air surrounding it. Instability in the boundary layer leads to perturbations that increase in size until a feedback path is established whereby specific frequencies of the resonance chamber are emphasized (Shadle, 1983, 149). Labial whistling is regarded as a hole tone (Wilson et al., 1971). The phenomenon requires a resonant cavity and two smooth, non-vibrating orifices. During labial whistling, the first orifice is formed by raising the back of the tongue close to the roof of the mouth, or by rolling up the edges of the tongue, while the lips form the second orifice (Wilson et al., 1971, 366). Tongue tip position alters the pitch of the tone. Wilson et al. (1971) report that the geometry of the human labial whistle acts as a Helmholtz resonator, where the frequency is inversely proportional to the square root of the chamber volume, larger for a larger orifice diameter, and lower for a larger orifice thickness.

3.2. Edge tones

Unlike hole tones, edge tones are generated by a thin jet of air that strikes an obstacle. Vortices are shed near the point of disturbance in the flow, alternating on each side of the obstacle or ‘wedge’. In a flute or organ, each side of the obstacle is provided with a set of air pulsations at the frequency of the initial disturbance. According to Coltman (1968, 983), “These pulsations can maintain acoustic oscillations in a resonator to which the wedge is properly affixed, and these oscillations in turn provide the initial disturbance for the jet. Subject to certain phases and loop-gain conditions, the entire system will then maintain itself in oscillation.” This is the proposed mechanism for whistled fricatives, wherein “the tongue form[s] the jet-producing constriction and the teeth serv[e] as the edge” (Shadle, 1997, 54). The production of an oral edge tone whistle is independent of the lips, though certainly the lengthening of the chamber (through labial protrusion) would change the frequency of the oscillation. So, whereas the lips are crucial to the production of an oral hole tone, they are ancillary in the production of an oral edge tone.

4. Measurements from Tshwa

A male speaker of Tshwa (S51) was recorded at 44.1 kHz in an audiometric booth, uttering nonsense VCV syllables where C = [s z ʃ s̥ z̥] in alternating vocalic environments (e.g. [as̥i as̥e as̥a]). Spectral peak frequency and bandwidth were measured using 14th-order LPC analysis. The results are presented in Tables 3 and 4.

One-way ANOVA illustrates the differences in spectral peak frequency and bandwidth among the fricatives. Significant differences emerge in terms of spectral peak frequency. For /s/ vs. /ʃ/ vs. /s̥/ $F(2,77) = 58.15$, $p < 0.0001$; for /z/ vs. /z̥/ $F(1,50) = 55.82$, $p < 0.0001$. In terms of spectral peak bandwidth, differences are also evident. For s̥ vs. [s] $F(2,51) = 18.25$, $p < 0.001$ and for [z̥] vs. [z]: $F(2,51) = 13.98$, $p < 0.001$.

This suggests that spectral peak bandwidth and spectral peak frequency play significant roles in the distinctive acoustics of the Bantu whistled fricative. Bladon et al.

Table 3. Spectral peak frequency for Tshwa sibilants.

SP Frequency (kHz)		
	M	SD
[s]	2.81	0.83
[s͎]	1.55	0.09
[ʃ]	1.47	0.26
[z]	2.71	0.80
[z͎]	1.50	0.09

Table 4. Spectral peak bandwidth for Tshwa sibilants.

SP Bandwidth (Hz)		
	M	SD
[s͎]	130.00	91.72
[s]	679.00	661.13
[z͎]	110.4	84.47
[z]	448.00	405.55

(1987, 61) claim that "an overriding perceptual cue to the whistling/non-whistling distinction is the Bark-scaled slope of the energy fall-off on the high frequency side of the peak." This may be correlated with narrow spectral peak bandwidth. The distinctive spectral envelopes of Tshwa /s s͎/ are presented in Figure 1.

5. Whistled fricatives and disordered speech

Those who experience unintended or unwanted whistling during the production of /s/ often attribute the 'disorder' to dental prostheses or orthodontia (Cohen, 2006). In conversation with two speech pathologists, one of whom has dealt with the issue among older patients, neither suggests modification of lip position to deal with the whistle (Andrea Schindler and Maren Crickmore, p.c.).

Dentures are known to alter the articulatory and acoustic character of speech, especially when the vertical dimension of occlusion[5] is modified by the prosthesis (Petrovic, 1985). Changes in different maxillary central incisor positions influenced the articulation of the alveolar fricative /s/. The lower bound of the noise band was raised significantly and the upper bound was lowered significantly when the prosthesis was angled labially (Runte et al., 2001, 490). This could be said to relate to narrowing of spectral peak bandwidth.

[5]The vertical dimension of occlusion is the distance between the mandible and maxilla when the opposing teeth are in contact (Sharry, 1968).

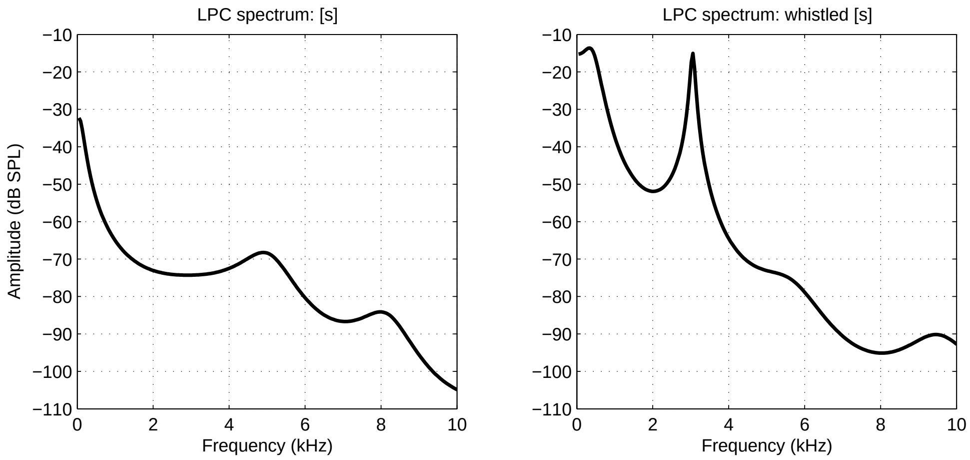

Figure 1. LPC spectra of Tshwa sibilants.

6. Conclusion

From what we know about the aeroacoustics of whistling, it should not be surprising that reports differ on the labiality of whistled fricatives in Southern Bantu. The reported variation is allophonic in all but a few cases.[6] While lip rounding as a secondary feature will lower the pitch of an edge-tone whistle by lengthening the resonator, lip rounding is not fundamental to the production of a whistle. An edge-tone whistle can be generated by channeling a thin, flat jet of air towards the incisors or alveolar ridge. This can be accomplished with a raised tongue tip. The vortex shedding and subsequent acoustic resonance occurs independently of lip geometry. Thus, diachronic analyses of whistled fricatives as reflexes of labial consonants are flawed, insofar as their basis is articulatory. Based on the aeroacoustics of whistling, it cannot be presumed that a labial stop is more likely to become a whistled fricative than an alveolar stop. In terms of lingual configuration, alveolar edge-tone whistles have more in common with coronals than with labials.

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[6] Shona apparently uses distinctive labialization for a further phonemic contrast, e.g. /s̺^{w}/ vs. /s̺/ (Ladefoged and Maddieson, 1996, 358).

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