Production and perception of dental vs. alveolar contrast in Tshivenda

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ABSTRACT

Tshivenda, a southern Bantu language, has a contrast between dental and alveolar nasals, also distinguished in the orthography. This study reports results from analyses of this nasal place contrast produced by eight speakers. Video recordings show that dental nasals are produced with the tongue protruding interdentally, while alveolar nasals do not have such protrusion. The production difference is also found in the measurement of locus equation, where the onset and the midpoint of F2 is measured. Perception results reveal that native listeners perceive the difference between dental and alveolar nasals.

Keywords: Tshivenda, nasal, alveolar, dental, locus equation, perception

1. INTRODUCTION

Tshivenda (S20, [4]) is a southern Bantu language spoken as an official language in Limpopo, South Africa. Tshivenda is also spoken in the southern part of Zimbabwe. The contrast between dental and alveolar in Tshivenda coronals (nasals, liquids, plosives) is reflected in the Tshivenda orthography by adding a circumflex below the alveolar symbol: alveolar [n] vs. dental [n̪]. This type of place contrast in the coronal region is rare and only few other languages (e.g. Mapudungun [1], an Araucanian language spoken in central Chile) are reported to have this contrast.

While the Tshivenda sound system is documented impressionistically in a dictionary [10] as well as a grammar [7], there is a gap in detailed phonetic studies except [7] and [8]. This paper explores the details of the place contrast in coronal nasals: dental versus alveolar. Three minimal pairs are shown below in (1), where dental nasals are shown with a circumflex:

(1) Minimal pairs (from [10])

[n̪aŋga] 'flute'	[nanga] 'choose'
[n̪eŋga] 'sneak away'	[nenga] 'sneak'
[n̪iŋga] 'punch'	[niŋga] 'hit sideways'

Warmelo's dictionary mark the contrast quite clearly, but it has not been clear what acoustic properties are part of this contrast. The current study thus explored how the two types of coronal categories are distinguished acoustically, articulatorily and perceptually.

2. METHOD

The data reported is based on the fieldwork in Thohoyandou, Limpopo, South Africa, which was conducted in July and November of 2018.

2.1. Speakers

Eight native speakers (5 female and 3 male) of Tshivenda participated in the recording session. They were all university students majoring in the Tshivenda language. All the speakers spoke English in addition to Tshivenda. Some speakers had basic knowledge of Isizulu, Sepedi or Xitsonga. The age ranged from 21 years old to 27 years old. Before the recording session, consent forms and demographic questionnaires were collected from each speaker. Each participant was compensated for their time (100 South African Rand).

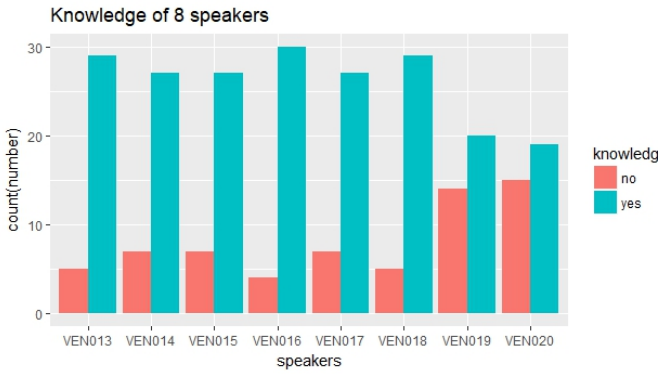
2.2. Recording

Within each recording session, each speaker read (i) target words in a frame sentence *ndi a vhala X hafha* 'I read X here.', and (ii) each nasal in intervocalic position. The acoustic recording session was also accompanied by a video recording of the area surrounding the mouth. After the recording session, participants were asked to validate a list of stimuli and identify the words that they actively use with other Tshivenda speakers. The validation test tells us about the effect of lexical knowledge, and the video recordings shows the presence of the protrusion of the tongue. Acoustic analyses proceed after this validation because the similarity in the acoustic signal makes it difficult to assess the acoustic characteristics of the contrast without visually examining the contrast from the video recordings. The order of the target words was randomized, and the speakers repeated the list seven times. All the recording was made using a TASCAM recorder (DR100-MK). The stimuli were presented in the Alphabetic script using Powerpoint on a Macintosh computer. The target of the recording session included 18 dental nasals and 16 alveolar nasals. The current analysis pools data from across different vowel context.

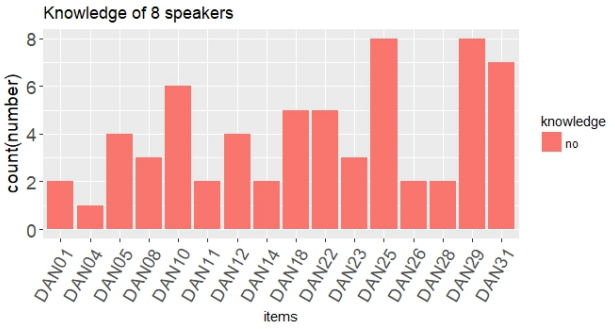
2.3. Validation test and video results

We conducted item validation test based on a self-report by asking whether a participant actively uses a

particular word with other Tshivenda speakers. The results in Figure 1 show that not all words were known to participants (see Appendix for list). For an item to be included in further analyses, we used two inclusion criteria: (a) a participant actively uses more than 25 items in the stimuli set, and (b) an item is actively used by more than half of the participants (i.e. four). Since lexical knowledge may affect phonetic realization (cf. [2], [3]), the validation test was important to know the effect of unknown words simply read based on spellings.



(a)



(b)

Figure 1: Results of the validation test, which were used to set exclusion criteria (a) by speakers and (b) by items.

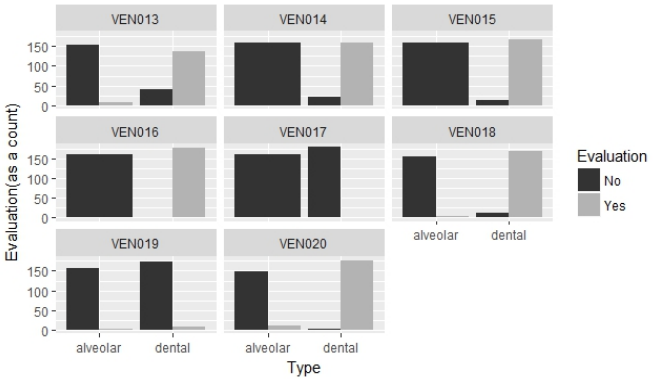


Figure 2: Results of the video evaluation. Black bars indicate the absence of tongue protrusion, and gray bars indicate the presence of it. In each panel, left bar(s) are for alveolars and right bars are for dentals.

The feature of dental nasals in Tshivenda is tongue protrusion between the teeth. Two trained annotators recorded whether tongue protrusion was present or not using visual examination. Figure 2 shows results of the video analysis. A black bar means no tongue protrusion and a gray bar means that a token is produced with tongue protrusion. As expected, most alveolar tokens are produced with no tongue protrusion (see VEN014, VEN015, VEN016, and VEN017). Six speakers produced majority of the dental nasals with tongue protrusion (the interrater reliability was high (over 96%)). VEN017 and VEN019 do not use tongue protrusion in the production of dental nasals, so their results were excluded from further acoustic analyses. Coupled with the results of the validation test, the rest of this paper analyzes data from four participants who knew more than 25 words from the list, and who consistently protruded tongue for dental nasals in the video recording.

2.4. Perception test

The place contrast in nasal coronals is hard to disthinguish. As such, we also conducted a perception test with eleven listeners of Tshivenda, which was designed to investigate meta-linguistic awareness of the dental vs alveola contrast. Participants were asked to judge (i) whether a word in a frame sentence begins with a dental or an alveolar (120 trials), and (ii) whether the onset of a syllable begins with a dental or an alveolar (120 trials). The perception test was run using Superlab 5 on a Macintosh Computer with two keys on the keyboard as input method. Listeners wore a noise-reducing Sennheiser headphone.

2.5. Acoustic analysis

Acoustic analysis for the nasal place contrast was conducted with locus equation [6], a measurement reported to distinguish small difference in place contrast. Locus equation plot the F2 at the onset of a post-nasal vowel against the midpoint of the post-nasal vowel. In Mapudungun [1] and other Austronesian languages [9], locus equation is shown to distinguish the contrast between alveolars and dentals.

3. RESULTS

3.1. Acoustic results

Figure 3 shows the locus equation of dental vs. alveolar by six speakers. Locus equations (LEs) are represented based on the F2 value of a vowel following the target nasal. LE plots the F2 value at the onset against the midpoint of a vowel following the target sound. A comparison of locus equations of alveolar and dental nasals demonstrates that dental

nasals have lower F2 onset values than alveolar nasals compared to a F2 value at the mid-point of the vowel. The effect of dental on LEs is greater in speakers in the left two columns, but to a lesser degree in the speakers in the rightmost column.

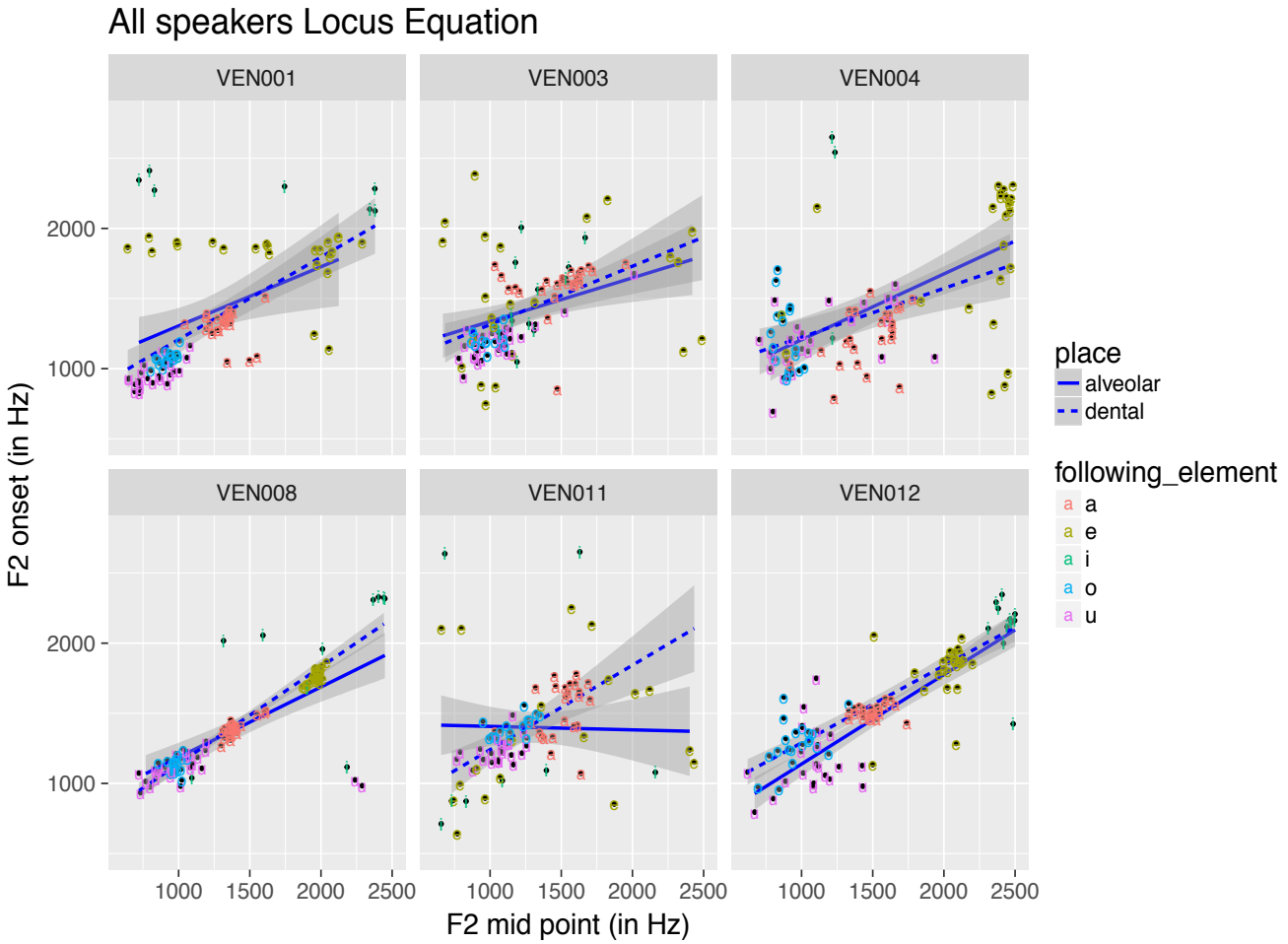


Figure 3: Locus equation of dental and alveolar nasals. Different panels show different speakers.

3.2. Perception results

Results from two perception tests from 11 listeners are reported in table 1, using d-prime values (sensitivity to a difference) and c values (response bias). Higher d-prime values suggests that participants discriminate the difference between dental and alveolar. The first perception task was identifying dental versus alveolar onset of a target word embedded in a frame sentence. Although two listeners have negative values, suggesting that they may not have understood the task, when a t-test was run against the null hypothesis, there was a significant difference between d-prime and the null hypothesis: $t(10)=3.23$, $p<0.01$. The listeners were able to perceive the difference between dental and alveolar place of articulation, with most of them showing a bias toward dental (as the negative c values show).

In the second perception task that was more challenging, listeners were asked to identify the contrast intervocalically in the absence of any lexical cue. Listeners were able to perceive the difference between dentals and alveolars ($t(10)=3.81$, $p<0.01$). The response bias results were mixed because some showed bias toward dentals and other showed bias toward alveolars.

Table 1: D-prime and C scores of eleven listeners

	Experiment 1		Experiment 2	
Listeners	Dprime	C	Dprime	C
1	1.421754	-0.32556	1.389128	0.033349
2	0.210428	-0.10521	0.063901	-1.06838
3	0.227663	-0.41057	0.715053	-0.35753
4	0.777748	-0.13553	0.620456	0.030467
5	1.34898	0	1.142847	0.46501
6	-0.34353	0.213555	0.366956	0.247249
7	1.377128	-0.34787	1.067787	-0.23716
8	1.124195	0.221403	0.160907	0.542472
9	-0.17489	0.297874	0.234153	-0.07529
10	0.083652	0.041826	-0.15057	0.117076
11	1.622246	-0.47043	1.498452	0.287207

4. CONCLUSION

The current paper was set out to explore how dental and alveolar place contrast in Tshivenda nasals is produced using acoustic and articulatory data. We also reported results from two identification tasks where Tshivenda listeners judged the place of articulation of a nasal. The video validation showed that speakers differed in how they produce a dental nasal; two speakers showed no tongue protrusion, while other six speakers had the protrusion of the tongue tip between teeth. Acoustic analyses of these six speakers suggest that difference in the place of articulation may be captured with locus equation.

An informal comment during the perception test by a Tshivenda speaker noted that dental nasals are slightly longer than alveolar nasals. In [5], however, no durational difference in the nasal signal between dentals and alveolars was found, suggesting duration may not be a reliable cue for distinguishing the place contrast.

Our results show that speakers produce the difference between dentals and alveolars when they are prompted with written stimuli. Even so, when acoustic analyses using locus equations were conducted, no distinct pattern across speakers were found. The results of identification tasks demonstrated that most listeners are able to distinguish dentals from alveolars, but the bias was not always identical across listeners.

The place contrast between dentals and alveolars is an uncommon contrast. This study has shown how production of this contrast doesn't result in a categorical distinction of the two categories. Future studies are planned for conducting the perception tasks with listeners of Mapudungun, which also is reported to have this place contrast [1]. Such a study would show us whether Mapudungun and Tshivenda use cues that are comparable when dental nasals are distinguished from alveolar nasals. This perception test would also suggest how this hard-to-hear place contrast is perceived cross-linguistically.

5. APPENDIX: WORD LIST

A list of known words

Tshivenda	Gloss
n̪ánzwa	lick
n̪àmà	meat
n̪ìànì	(place name)
n̪úla	take out
n̪ùruwa	peel off skin
n̪ènga	sneak away
n̪ótshí	bee
n̪ówá	snake
n̪òkà	melt
nánga	choose
nánguludza	select
nà	full rain
nìwa	be wetted by rain
nùkha	stink
nése	nurse
nènga	sneak
nóthé	you all
nòna	become fat

A list of words that are identified as unknown by at least one participant

Tshivenda	Gloss
n̪álèdzí	star
n̪àngá	flute
n̪ínga	punch
n̪úvhedza	immerse
n̪ùwà	believe oneself
n̪ékana	give one another
n̪étshea	accept
n̪ènya	walk stealthily
n̪òn̪ì	gemsbok
nàpudza	flip a switch
nínga	hit sideways
núnúvhè	larva in cocoon
núsa	feed baby
nùngú	porcupine
nékwa	favorite child
nèmbè	dangle

6. ACKNOWLEDGEMENTS

This work was supported by JSPS KAKENHI Grant Number 16K02641 to the second author. We thank Crous Hlungwani, Thomas Davemore and Vicent Maswanganyi for coordinating the data collection at the University of Venda, and Akari Sekiguchi for data processing. We also thank audience members of LSJ156, Linglab members at ICU and three anonymous reviewers.

7. REFERENCES

[1] Fasola, C., Painequeo, H., Lee, S. J., Perkins, J. 2015. Acoustic properties of the dental vs. alveolar contrast in Mapudungun. *Proc. of ICPhS*.

[2] Fitzpatrick, J. and Wheeldon, L. 2000. Phonology and phonetics in psycholinguistic models of speech perception. In: Burton-Roberts, N. et al. (eds.) *Phonological Knowledge: Conceptual and Empirical Issues*. Oxford University Press. Pp. 131-160.

[3] Fruehwald, J. 2013. The phonological influence on phonetic change. PhD Dissertation. University of Pennsylvania.

[4] Guthrie, M. 1967–1971. *Comparative Bantu: an introduction to the comparative linguistics and prehistory of the Bantu languages*. Farnborough: Gregg Press.

[5] Lee, S.J., Tshithuke, S., Suzuki, M. 2018. An acoustic study of dental vs. alveolar contrast in Tshivenḓa nasals. *The 156th Linguistics Society of Japan*.
[6] Lindblom, B. 1963. On vowel reduction. *Technical Report 29 The Royal Institute of Technology, Speech Transmission Laboratory*. Stockholm, Sweden.
[7] Poulos, G. 1989. *A linguistic analysis of Venda. Grammar*, Via Africa.
[8] Radzhadzhi, M. A. 2002. Nasal assimilation and related processes in Tshivenda: a linear and non-linear phonological analysis. MA thesis, University of Stellenbosch.
[9] Tabain, M., Butcher, A., Breen, G., Beare, R., 2016. An acoustic study of nasal consonants in three Central Australian languages. *Journal of Acoustical Society of America* 139(2): 890-903.
[10] van Warmelo, N. J. 1995. *Venda Dictionary*. Hippocrene Books.