AN ACOUSTIC STUDY OF XHOSA CLICKS

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ABSTRACT

Clicks in Xhosa, a Bantu language spoken in South Africa, are made with one of three front closures, and with one of five accompaniments. The dental and lateral click types are characterized by an affricated release, while the alveolopalatal click type is not. Coarticulatory relations between clicks and vowels are less extensive than those between other consonants and their following vowels. Neither the front nor the back click closure varies much according to vowel context. The only coarticulatory effects seen are due to lip rounding, which uses an articulator which is not involved in the production of clicks in Xhosa.

1. INTRODUCTION

There is much that is unknown about how clicks pattern with respect to other consonants. First, it is not clear whether clicks involve the same features as other consonants. And it is not clear whether the phonetic properties of these features are the same for clicks as they are for pulmonic consonants. An invariant acoustic property which is argued to exist for some feature or place of articulation should also exist for clicks sharing that feature or place of articulation. A feature such as [coronal] should have the same definition for pulmonic stops and fricatives and clicks. Unfortunately, the work on acoustic invariance [4] has largely ignored clicks in the determination of acoustic properties of features. Second, the way clicks interact with neighboring segments may be different from the way pulmonic consonants behave. Do clicks coarticulate with neighboring vowels?

2. CHARACTERISTICS OF THE FRONT CLICK CLOSURE

The data analyzed in this study were taken from a recording, kindly supplied by Professors Louw and Finlayson, of four male and four female Xhosa speakers saying words containing each of the 15 phonemic clicks before each of the vowels /i/, /e/, /a/, /o/ and /u/. Temporal characteristics of the clicks were also analyzed and are reported in [5]. The spectra in this study were made using a 25 ms window starting at the release of the consonant. Spectra were made on the DSP Sonagraph using speech sampled at 40,960 Hz. Frequencies range up to 16,000 Hz. The power spectra of the click bursts of eight speakers for the voiceless aspirated, voiceless unaspirated and breathy voiced clicks before each of the five vowels were analyzed, giving 120 tokens of each click type. As the back click closure is released shortly after the release of the front closure, some noise from the back release may be included in the 25 ms window used.

The degree of coarticulation between a stop consonant and a following vowel can be examined by comparing the spectral pattern of the consonant burst before different vowels. If vowel position is anticipated in the consonant, the burst will show modifications that echo some characteristics of the vowels.

2.1 SPECTRAL ANALYSIS

As seen in Figures 1 and 2, the dental clicks have a diffuse spectrum, and a great deal of energy above 6000 Hz. Dental clicks typically have energy present from 0 to 9000 Hz, and energy of

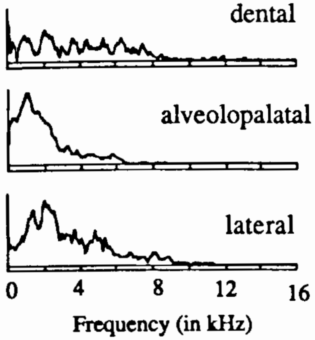

Figure 1: Mean spectra of the dental, alveolopalatal and lateral clicks before the vowels /i,e,a/ for two male Xhosa speakers. Each curve is the mean of six spectra.

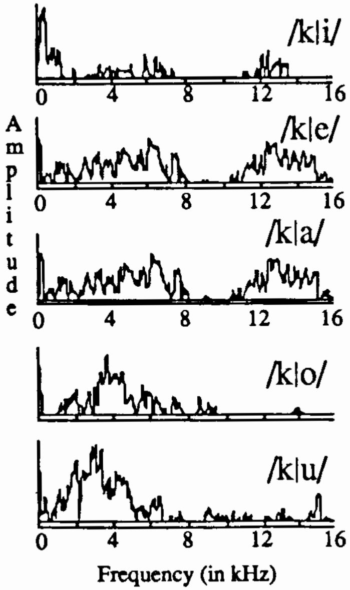

Figure 2: Spectra of voiceless unaspirated dental clicks of one female speaker of Xhosa, before each of the five vowels.

lesser amplitude present up to 16,000 Hz. The amplitude level of the dental clicks is lower than that of the lateral or the alveolopalatal clicks. While all of the dental clicks can be characterized as having a diffuse spectrum, as would be predicted by [1,6].

As Figure 2 shows, tokens preceding the rounded vowels show a concentration of energy in the lower spectral region resulting from attenuation of amplitudes in the higher frequency range. The energy in the lower frequency band is greater in amplitude relative to the energy above 10,000 Hz for the clicks before rounded vowels. In particular, they show a peak of energy around 3000-4000 Hz.

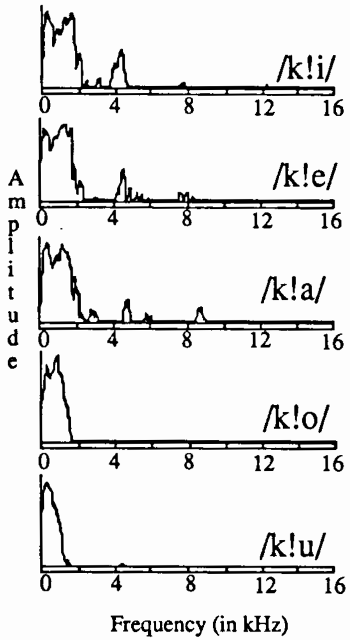

Figure 3: Spectra of voiceless unaspirated alveolopalatal clicks of one female speaker of Xhosa, before each of the five vowels.

For the alveolopalatal clicks, as seen in Figures 1 and 3, there is typically one main band of energy in the low frequency range, between 1000 and 1700 Hz. The frequency range of this band tends to be higher for the female speakers than for the males. Alveolopalatal clicks are non-anterior and have a compact spectral shape. This is similar to pulmonic coronal consonants which are not anterior, which are usually characterized as having a compact spectral shape [1].

The effect of a rounded vowel on a preceding click can be seen for the alveolopalatal clicks in Figure 3. As for the dental clicks, those preceding the rounded vowels show a concentration of energy in the lower spectral region, that is, below 2000 Hz. Energy occurs in a narrower band for the clicks preceding rounded vowels. The majority of tokens before the unrounded vowels have fairly prominent energy between 3800 and 4800 Hz, but the majority before rounded vowels do not. It may be that all alveolopalatal clicks have audible energy in this range which does not appear in spectra designed to show the prominent peaks, as it is of such low amplitude relative to the low frequency band of energy.

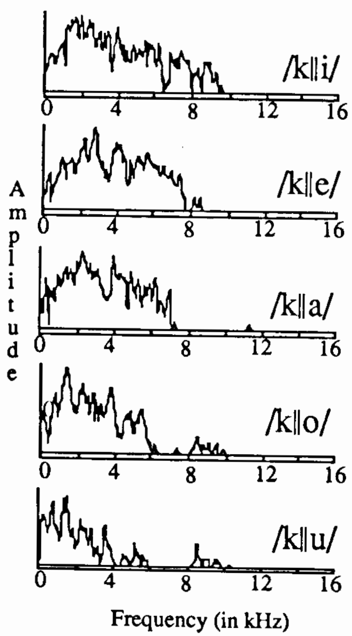

Figure 4: Spectra of voiceless unaspirated lateral clicks of one female speaker of Xhosa, before each of the five vowels.

The lateral click bursts, as seen in Figures 1 and 4, have a diffuse spectrum in the frequency range of 0 to 5000 Hz. They often have energy up to 8000 Hz or beyond, but it is typically of lower amplitude relative to energy below 5000 Hz. The energy in the spectrum is greatest in three broad frequency ranges, which are lower for male speakers than for female speakers. The spectrum can be delineated into regions presumably because of zeros caused by side cavities to the lateral channel of airflow. The majority of tokens before the unrounded vowels have energy present in the first range, between 1000 and 2000 Hz. The second region ranges from 2100-4000 Hz for female speakers, and from 2000-2900 Hz for male speakers. The third region ranges from 4000-4800 Hz for female and from 3000-4500 Hz for male speakers. As seen in Figure 4, the peak of energy which occurs below 2000 Hz tends to be at a lower frequency for clicks preceding a rounded vowel. The lateral click bursts share certain acoustic characteristics with other laterals. Lateral clicks and lateral approximants typically have energy at 3000 Hz and above. While lateral approximants typically have energy around 1200 Hz, the lateral clicks typically have a prominence between 1000 and 2000 Hz.

There were no consistent differences between the power spectra of any of the three click types before the vowels /i, e, a/. In particular, no consistent effect of the high front vowel /i/ is seen. This is the vowel which commonly causes extensive coarticulation effects with other consonants. There are however notable differences between the power spectra of the clicks preceding /i, e, and a/ and those preceding the rounded vowels /o/ and /u/, which is an expected result of anticipation of the rounding of these vowels. Before rounded vowels, clicks show a shift in energy to the lower frequency region.

3. CHARACTERISTICS OF THE BACK CLICK CLOSURE

It may be that transitions into a following vowel are affected by click type. We might expect some information about click type to be contained in the vowel onset transitions, as this is often considered to be the primary cue for place of articulation of pulmonic stops. Alternatively, vowels following clicks might be expected to all have onset transitions which are indicative of a dorsal consonant since the release of the back click closure follows the release of the front one.

Measurements were made of formant transitions and vowel formants for the first three formants of the vowels /i, e, a, o, u/ occuring after dental, lateral and alveolopalatal voiceless unaspirated clicks. The vowels of 7 Xhosa speakers were analyzed. Formants were measured using LPC analysis on the Macintosh using UCLA/Uppsala Soundwave. A 256 point analysis window was used, and speech was sampled at 11 KHz. Formants were measured in the middle of the vowel and at the onset of voicing, and averaged.

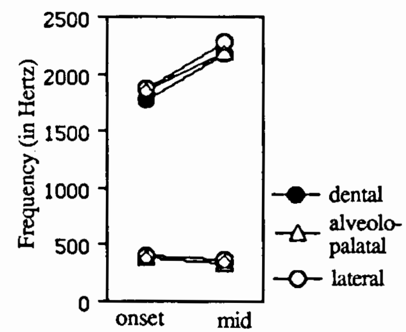

Figure 5: F1 and F2 at onset and middle of /i/, averaged over 7 speakers.

No significant differences in the vowel formant onsets, were found for vowel by front click closure, using a 2-factor ANOVA. There is no significant acoustic evidence indicating that the vowel formant onset transitions vary due to type of front click closure. As seen in Figure 5, the difference between the onset for /i/ following each of the click types was very similar. The dentals show marginally lower F2 and F3 than the laterals, but these differences are not significant.

4. SUMMARY

Clicks have similar spectral characteristics to non-click consonants. Coarticulatory relations between clicks and vowels are less extensive than those between other consonants and their following vowels. However, this is not surprising, considering that the tongue body cannot freely vary its position in clicks because both the front and the back of the tongue have to be in particular positions to produce the consonant. Coarticulation involving the tongue position of vowels must be limited. This is similar to the constraints observed in vowel to vowel coarticulations across a consonant with a secondary palatal or velar articulation. The only coarticulation effect seen is that due to the anticipation of vowel rounding, since this does not involve a gesture used in the click prodution. These facts seem more compatible with a phonological theory in which the articulators are primary nodes [2] rather than features for place of articulation [3].

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5. REFERENCES

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