# Phonetic Analysis of Clicks, Plosives and Implosives of IsiXhosa: A Preliminary Report

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**Abstract**: This pilot study examined the effectiveness of locus equations in differentiating places of articulation among stop consonants (clicks, plosives and implosives) in IsiXhosa in the context of the vowel /a/. The results obtained showed that the slope values for the dental and the postalveolar clicks are similar and shallower than that of the lateral click. Velar stops (plosives, implosives and ejectives) exhibited a steeper slope than either the bilabial or the dental stops. These results suggest that locus equations may be effective at distinguishing places of articulation for a variety of stop consonants.

## 1. Introduction

IsiXhosa is a language spoken in South Africa that uses 18 clicks (three places and six manners of articulation). This paper is a pilot study of the acoustic properties differentiating place or articulation of clicks and plosives in isiXhosa in the context of the following low vowel: /a/.

## 2. Literature Review

### 2.1. Background of isiXhosa

IsiXhosa is a member of the Nguni languages, which belong to a large family of languages called Bantu, named by the German linguist, Wilhelm Bleek, from the word for ‘people’ (Niesler et al. 2005: 460, Pinnock 1998: 5). The language is one of the few Bantu languages that use clicks, and clicks are viewed as the features of earlier languages (Herbert 1990). According to the 2011 census (Statistics South Africa, 2012), it is a statutory national language of South Africa, and there are over 8.15 million native speakers. IsiXhosa is related to Zulu and shares approximately 80% of its vocabulary, and isiXhosa is said to have acquired clicks through contact with the Khoisan language (Pinnock 1998:5-8, Ager 1998). Contemporary isiXhosa is influenced by Dutch, English and Afrikaans, and most of the loan words are names for artifacts, clops and animals. (Pinnock 1998: 10)

### 2.2. Clicks and Plosives in IsiXhosa

IsiXhosa is said to have clicks that are unaspirated, aspirated, voiced, and nasalized ("Xhosa” *About World Languages; http://phonetics.ucla.edu/course/chapter6/xhosa/xhosa.html*) produced at three places of articulation: dental, alveopalatal and alveolar lateral. According to Jessen & Roux (2002), the so called “voiced” clicks exhibit a weak and short voicing duration during the closure similar to what is found in their voiceless counterparts. The most reliable acoustic feature associated with the voiced click is the lowering of the fundamental frequency (F0), or pitch, in the following vowel. In addition, it has been claimed that vowels following voiced stops and voiced clicks are also breathy. However, based on acoustic measurements of $H^*_1$-$H_2$ (H1-H2 amplitude) and $H^*_1$-$H^*_3$ (H1amplisude-amplitude of the most prominent harmonic in the third formant region), Jessen & Roux (2002) concluded that the breathiness in the vowels following voiced clicks in isiXhosa is not as strong as the breathy voice in Hindi or Marathi but as weak as "slack voice" in Shanghai Chinese[1] and Wu dialect of Chinese. In this paper, the term "slack voice" will be adopted.

IsiXhosa also has labial, dental/alveolar, palatal and velar stops produced with four different manners of articulation: ejectives, aspirated, slack voice and implosives. Palatal stops will not be included in this study. The inventory of clicks and stops investigated in this paper is presented in Table 1 below.

Table 1: IsiXhosa consonants studied in this study (IPA and orthography)

| | | Labial | Dental / Alveolar | | Postalveolar | Velar |
|---|---|---|---|---|---|---|
| | | | Central | Lateral | | |
| Click | Plain | | [k\|] c | [k\|\|] x | [k!] q | |
| | Aspirated | | [k\|ʰ] ch | [k\|\|ʰ] xh | [k!ʰ] qh | |
| | Slack voice | | [g̊\|ʱ] gc | [g̊\|\|ʱ] gx | [g̊!ʱ] gq | |
| Plosive | Tenuis/Ejective | [p'] p | [t'] t | | | [k'] k |
| | Aspirated | [pʰ] ph | [tʰ] th | | | [kʰ] kh |
| | Slack voice | [b̥ʱ] bh | [d̥ʱ] d | | | [g̊ʱ] g |
| | Implosive | [ɓ] b | | | | |

## 2.3. Measurements of clicks in previous studies -- Locus Equation

A locus equation is "a straight-line regression fit to coordinates formed by plotting onsets of second formant (F2) transitions in relation to their coarticulated F2 mid vowel 'target frequencies'" (Sussman et al. 1993: 1256). In the study of Sussman et al. (1993) Thai, Cairene Arabic, and Urdu were investigated using the locus equation, and the results indicated that the locus equation is a useful tool to identify the places of articulation (Sussman et al., 1993). However, the psychological validity of locus equations as perceptual cues to place of articulation has been questioned by others (e.g., Fowler, 1994; Brancazio & Fowler, 1998). According to Fowler (1994), due to their different degrees of coarticulatory resistance, alveolar stops and fricatives have significantly different slope values suggesting, therefore, that locus equations cannot accurately cue alveolar place of articulation.

Locus equations can indicate degrees of coarticulation between a plosive and a following vowel, with the strongest degree of coarticulation for bilabials, with the steepest slope, an intermediate degree for velars and the smallest degree of coarticulation for alveolars with the

[1] In Shanghai Chinese, a moderate degree of breathiness after stop release has been identified as "slack voice" (Gao, et al. 2011).

shallowest slope (Reetz & Jongman, 2009). However, by correlating electropalatographic (EPG) and locus equation data, Tabain (2000) found that locus equations accurately reflect degrees of coarticulation for stops and nasals, but not for fricatives. In this study, locus equations as a cue to place of articulation to clicks and plosives in IsiXhosa are explored.

## 3. Methodology

### 3.1. The Consultant and Word List

The consultant is a female native isiXhosa speaker in her 20s from Port Elizabeth, South Africa. Words used in the current study are selected using an online dictionary called Xhosa Live Dictionary and are listed in Appendix A. To control for the effects of vowel quality on click production, only the low central vowel /a/ was used. To control for the effects of nasalization, target consonants appear in either word-initial position or are preceded by a vowel or an oral plosive (See Appendix A for the wordlist containing clicks and Appendix B for the wordlist containing plosives).

Three words were chosen for each consonant from an online dictionary by the researcher and were double-checked by the consultant. Each word was written on a separate index card with English translation to make sure there is no confusion. In order to avoid the listing effect, target words were randomly read in the carrier phrase, “Say ____again,” and repeated twice.

### 3.2. The Recording

The data is collected in a soundproof room of the Linguistics laboratory at the University of Florida, using Praat (http;//www.praat.org/) software on a MacBook Air. Recordings were done with a Blue Microphone’s Snowball which frequency response ranges between 40Hz and 18KHz. It was used on the third position setting with the sampling rate of 44.1kHz. It was placed approximately six inches from the speaker’s mouth at a 45-degree angle.

### 3.3. Measurements

The target words were excised from the carrier sentence, resampled to 11025 Hz, and saved as separate files. F2 values were obtained from the first 50-ms from the vowel onset and the middle of the vowel /a/ of each target word using the function To LPC (autocorrelation) in Praat (Prediction order =12, and window length = 0.025 sec). The duration of the vowel is determined by the onset of F1 to the offset of F2. The onset was determined as the beginning of the first full cycle of the sound wave after the first glottal pulse.

## 4. Results

### 4.1. Clicks

Table 2 below shows the F2 values at the onset and the midpoint of /a/ following the clicks. Figures 1-3 show locus equations separately for bilabial plosives, dental plosives, and velar plosives. Table 3 show the slope, y-intercept and $R^2$ values drawn from Figures 1-3.

Table 2: F2 values of /a/ following the clicks

| | **Dental Click** | F2 Mid-Point | F2 Onset | **Lateral Click** | F2 Mid-Point | F2 Onset | **Post-Alveolar Click** | F2 Mid-Point | F2 Onset |
|---|---|---|---|---|---|---|---|---|---|
| **Plain** | c (cacisa) | 943.42 | 1003.26 | x (xaba) | 1518.00 | 1598.48 | q (qaphela) | 1201.57 | 1173.72 |
| | c (ucango) | 1122.39 | 1091.97 | x (xabana) | 1152.54 | 1165.98 | | | |
| **Aspirated** | ch (chama) | 1175.69 | 1220.82 | xh (xhathisa) | 1211.23 | 1327.00 | qh (qha) | 1300.32 | 1324.67 |
| | ch (chapaza) | 1135.28 | 1138.40 | | | | qh (qhawula) | 1430.55 | 1434.15 |
| **Slack Voice** | gc (isigcawu) | 1084.28 | 1091.05 | gx (gxadazela) | 1094.76 | 1143.71 | gq (igqala) | 1661.18 | 1584.61 |
| | gc (imigca) | 1117.74 | 1225.23 | gx (iligxa) | 1036.54 | 1048.32 | gq (igqabi) | 1114.07 | 1092.40 |

Figure 1: Dental Click

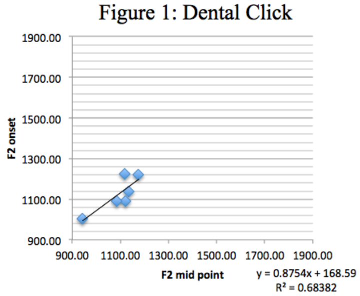


Figure 2: Lateral Click

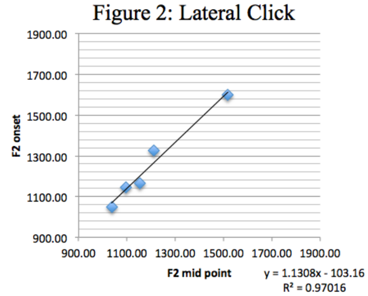


Figure 3: Postalveolar Click

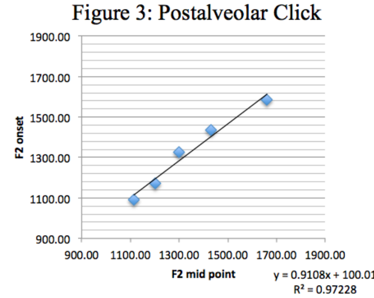


Table 3: Slopes and intercepts of clicks

| | Slopes | Intercepts | $R^2$ |
|---|---|---|---|
| Dental click | 0.8754 | 168.59 | 0.68382 |
| Lateral click | 1.1308 | -103.16 | 0.97016 |
| Postalveolar click | 0.9108 | 100.01 | 0.97228 |

From Table 3, we see that the slope values for the lateral click is quite different from those of dental and postalveolar clicks, whereas the slope values for the last two are comparable. These results show that locus equations can be used to identify the place of articulation of clicks.

### 4.2 Plosives/implosives/ejectives

Table 4 contains the values of F2 of /a/ at onset and midpoint, Figures 4-6 show locus equations separately for bilabial, dental, and velar stops, and Table 5 contains slope, intercept and $R^2$ values drawn from Figures 4-6.

Table 4: F2 values of /a/ following stops

| | **Bilabial Plosive** | F2 Mid-Point | F2 Onset | **Dental Plosive** | F2 Mid-Point | F2 Onset | **Velar Plosive** | F2 Mid-Point | F2 Onset |
|---|---|---|---|---|---|---|---|---|---|
| **Tenuis/ Ejective** | p (ipali) | 1295.82 | 1078.68 | t (itayi) | 1336.40 | 1039.47 | k (kama) | 1183.82 | 1075.30 |
| | p (ipapa) | 1228.23 | 1136.34 | t (tarhuzisa) | 1260.36 | 1239.45 | k (kakubi) | 1655.28 | 1566.18 |
| **Aspirated** | ph (phaka) | 1216.12 | 1320.80 | th (thatha) | 1183.00 | 1183.55 | kh (khala) | 1249.81 | 1344.06 |
| | ph (phakama) | 1028.01 | 1120.65 | th (thambeka) | 1180.57 | 1115.31 | kh (khazimla) | 1183.24 | 1247.07 |
| **Slack Voice** | bh (ibhaso) | 1803.09 | 1086.52 | d (dala) | 1658.12 | 1056.91 | g (gabha) | 1869.83 | 1793.54 |
| | bh (ibhayi) | 1513.21 | 1181.13 | d (idama) | 1564.29 | 996.71 | g (igazi) | 1604.63 | 1679.16 |
| **Implosive** | b (baleka) | 1235.19 | 1154.74 | | | | | | |
| | b (bandakanya) | 1128.65 | 1173.13 | | | | | | |

Figure 4: Bilabial Plosive

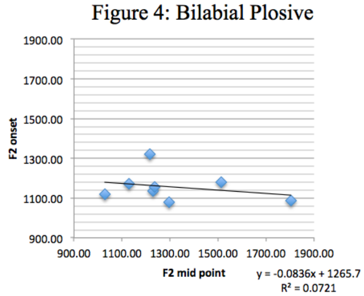


Figure 5: Dental Plosive

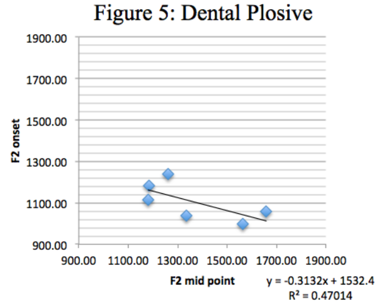


Figure 6: Velar Plosive

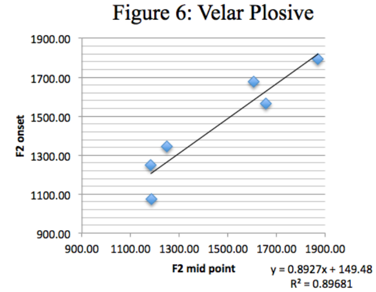


Table 5: Slopes and Intercepts of plosives

| | Slopes | Intercepts | $R^2$ |
|---|---|---|---|
| Bilabial plosive | -0.0836 | 1265.7 | 0.0721 |
| Dental plosive | -0.3132 | 1532.4 | 0.47014 |
| Velar plosive | 0.8927 | 149.48 | 0.89681 |

At a glance, we can see that the slope values for bilabial and dental plosives are quite different from that of velar plosives. The slope values of the bilabial and dental stops are slightly different and are relatively flat in comparison to that of velars. Note that unlike previous studies where only voiced stops are included, our study included voiced implosives and voiceless stops. These results suggest that locus equations may not be as effective in differentiating bilabial stops from dental stops when a variety of stops (ejective, aspirated, slack voice, and implosives) are involved.

## 5. Conclusion

Clicks are unique to a limited number of African languages, yet their places of articulation may be differentiated by locus equations. Our results show that, in the context of the vowel /a/, the slope of the dental click is shallowest and that of the alveolar lateral click is the steepest. In addition, the difference in slope values between the lateral click and both the dental and the postalveolar clicks is greater than between the dental and the postalveolar click. This suggests that locus equations may be less effective at differentiating a dental click from a postalveolar click.

Locus equations seem to also be able to differentiate places of articulation of other stop consonants in IsiXhosa even when voiceless plosives, ejectives and voiced implosives are included. Specifically, we found that the slopes for the bilabial and dental stops are shallower than that of velar stops. The slope values of the bilabial and dental stops are relatively flat in comparison to that of velar.

However, this pilot study only focused on clicks and stops preceding the low vowel /a/ produced by a female native speaker in her mid-20s. For more definite results, it is important to collect and analyze more data of multiple speakers of both genders in the same age group, who speak the same dialect of isiXhosa. Because isiXhosa has words with pre-nasalized consonants, further studies should also include investigation of nasal variants of clicks as well.

## References

Ager, S. (1998). Xhosa (isiXhosa). Retrieved from http://www.omniglot.com/writing/xhosa.htm

Brancazio, L. and Fowler, C. A. (1998). On the relevance of locus equations for production and perception of stop consonants. *Perception and Psychophysics* 60: 24–50.

Fowler, C. A. (1994). Invariants, specifiers, cues: An investigation of locus equations as information for place of articulation. *Perception and Psychophysics* 55: 597–610.

Gao, J.Y., P. Hallé, K. Honda, S. Maeda, and M. Toda (2011) 'Shanghai slack voice: acoustic and EPGG data', *Proceedings of the International Congress of Phonetic Sciences XVII*, Hong Kong, 17-21 August 2011, 719-722,

Herbert, R. K. (1990). The sociohistory of clicks in Southern Bantu. *Anthropological linguistics*, 295-315.

Jessen, M. and Roux, J. (2002). Voice quality differences associated with stops and clicks in Xhosa. *Journal of Phonetics* 30, 1-52.

Niesler, T.R., P.H. Louw, and J.C. Roux. Phonetic analysis of Afrikaans, English, Xhosa and Zulu using South African speech databases. *Southern African Linguistics and Applied Language Studies*, 23(4): 459–474, 2005.

Pinnock, P.S. (1998). *Xhosa: A cultural grammar for beginners*. African Sun Press.

Reetz, H. and Jongman, A. (2009). Phonetics: Transcription, Production, Acoustics, and Perception. Chichester, U.K.: Blackwell.

Soli, S. D. (1981). Second formants in fricatives: Acoustic consequences of fricative-vowel coarticulation. *The Journal of the Acoustical Society of America*, *70*(4), 976-984.

Statistics South Africa. *Census 2011*. (2012). Retrieved from http://www.statssa.gov.za

Stevens, K. N., & Blumstein, S. E. (1978). Invariant cues for place of articulation in stop consonants. *The Journal of the Acoustical Society of America*, *64*(5), 1358-1368.

Sussman, H. M., Hoemeke, K. A., & Ahmed, F. S. (1993). A cross-linguistic investigation of locus equations as a phonetic descriptor for place of articulation. *The Journal of the Acoustical Society of America*, *94*(3), 1256-1268.

Tabain, M. (2000). Coarticulation in CV syllables: A comparison of locus equation and EPG data. *Journal of Phonetics* 28, 137–159.

Xhosa Live Dictionary. Retrieved from http://www.gononda.com/xhosa/

## Appendix A – IsiXhosa words with clicks

| IsiXhosa | IPA | English Translation |
|---|---|---|
| cacisa | /k\|’ak\|’iːsa/ | illustrate |
| chama | /k\|ʰaːma/ | to urinate |
| chapaza | /k\|ʰap’aːz̤a/ | drip |
| gxadazela | /g̊ǁʱad’az̤eːla/ | stagger |
| igqabi | /ig̊!ʱaːɓi/ | leaf |
| igqala | /ig̊!ʱaːla/ | expert/old man |
| iligxa | /iliːg̊ǁʱa/ | shoulder |
| imigca | /imiːg̊ǀʱa/ | lines |
| isigcawu | /isig̊ǀʱaːwu/ | spider |
| qaphela | /k!’apʰela/ | take note |
| qha | /k!ʰa/ | only |
| qhawula | /k!ʰawuːla/ | break off |
| ucango | /ukǀ’aːng̊ʱo/ | door |
| xaba | /kǁ’aːɓa/ | to obstruct |
| xabana | /kǁ’aɓaːna/ | argue |
| xhathisa | /kǁʰaːsatʰiːsa/ | resist |

## Appendix B – IsiXhosa words with stops

| IsiXhosa | IPA | English Translation |
|---|---|---|
| baleka | /ɓaleːk’a/ | run |
| bandakenya | /ɓand̥ʱɐkeːɲa/ | join/involve/include |
| dala | /d̥ʱaːla/ | to create |
| gabha | /g̊ʱaːb̥ʱa/ | puke |
| ibhaso | /ib̥ʱaːso/ | prize/reward |
| ibhayi | /ib̥ʱaːji/ | the bay (=Port Elizabeth) |
| idama | /id̥ʱaːmɐ/ | dam |
| igazi | /ig̊ʱaːz̤i/ | blood |
| ipali | /ip’aːli/ | pole |
| ipapa | /ip’aːp’a/ | porridge |
| itayi | /it’aːji/ | tie |
| kakubi | /k’ak’uːɓi/ | badly |
| kama | /k’aːma/ | to comb |
| khala | /kʰaːla/ | suspense/fear |
| khazimla | /kʰaz̤iːmla/ | sparkle |
| phaka | /pʰaːk’a/ | dish up |
| phakama | /pʰak’aːmɐ/ | stand up |
| tarhuzisa | /t’axuz̤iːsa/ | beg for mercy |
| thambeka | /tʰamɓeːk’a/ | lean (over) |
| thatha | /tʰaːtʱa/ | take |