CLICK ARTICULATIONS IN XHOSA: NEW PERSPECTIVES THROUGH WIGNER DISTRIBUTION ANALYSIS

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ABSTRACT

Three phenomena involving click articulations are investigated using a technique which reveals time-frequency detail not normally achieved with traditional methods. The results suggest an alternative description for affricated and murmured clicks and point to idiosyncratic features in nasal clicks.

INTRODUCTION

This paper focuses on click articulations and their accompaniments in Xhosa employing a technique, which to the best of our knowledge has never been used for the acoustic analysis of these sounds. This technique, referred to as Smoothed Pseudo-Wigner Distribution (SPWD)-analysis combines both the good frequency resolution of narrow band spectrograms and the good time resolution of wide band spectrograms [1]. The acoustic description of clicks in general has received a good degree of attention over the last few decades, culminating in the work of Ladefoged & Traill [2] (henceforth L&T), presenting the most detailed phonetic description of clicks to date. Despite all the attention, there are still a number of issues related to Bantu languages such as Zulu and Xhosa that remain unresolved. We are of the opinion that SPWD-analysis may shed more light on these unresolved issues, specifically due to the fact that it yields a time-frequency resolution in which the finegrained signal structures are considerably more evident than in spectrograms and waveform representations, such as those presented by L&T. Only three **unresolved issues** regarding clicks in Xhosa will be dealt with here, i.e. those relating to, respectively, so-called affricated clicks, nasal clicks, and voiced "murmured" clicks. A comprehensive discussion of all the relevant issues appear in [3].

ACOUSTIC ANALYSIS

Material

The speech of two male native speakers of Xhosa were recorded in a sound studio with high quality equipment. The test data consisted of nonsense /VCV/ utterances where the three click types and their accompaniments (cf. Table 1) occupied the C-slot. The five basic vowels of Xhosa (/a, e, i, o, u/) varied systematically in the V-slots and the tokens were read in a carrier phrase *Ndithi.... (I say....)*

Analysis

The data were edited and analyzed with the S-Tools™ system focusing on the burst of the click and extending the window to at least the first three detectable periods of the following vowel. The theoretical foundations and implementation of SPWD is presented in [4]; suffice to say, however, that the **release transient** of a stop is shown in SPWD as a combination of a vertical line followed by horizontal lines. The vertical line represents an impulse like signal component caused by a sudden release of air behind a constriction. The horizontal lines are interpreted as damped oscillations (formant frequencies) forming the response of the vocal tract to the exciting plosion-pulse. Noise bursts are represented in SPWD as an irregular grid filling a specific area of the time-frequency plane.

Table 1. Xhosa click consonants and accompaniments (orthographic representation). The use of phonetic symbols will be minimalized in this paper in view of some controversies. (Cf. [3]).

Accompaniment	Click type		
	Dental	Alveo-palatal	Lateral
Voiceless	c	q	x
Aspirated	ch	qh	xh
Nasal	nc	nq	nx
Murmured voiced	gc	gq	gx
Murmured nasal	ngc	ngq	ngx

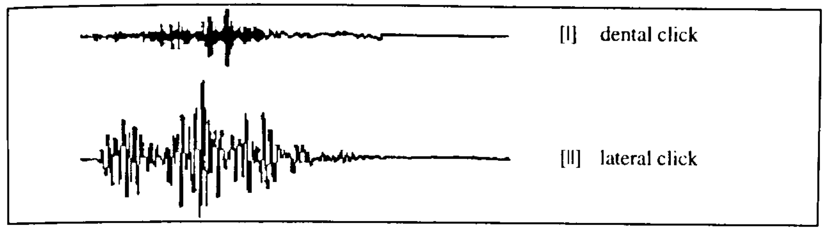

Figure 1. Waveforms of noise bursts for dental and lateral clicks indicating "considerable turbulent noise after the release" presented by Ladefoged & Traill [2:40]

RESULTS AND DISCUSSION

Affricated clicks

The earliest descriptions of click sounds mention that some clicks, notably the dental/alveolar "c" [|] and the lateral "x" [||] clicks are pronounced with friction or as "affricative" segments. This view is also supported by L&T. In everyday phonetic terms an affricate is considered to be a stop with affricated (fricative) release [5,6]. In an acoustic study of Xhosa clicks Sands concludes: "It seems that the lateral and the dental clicks are made with a long constriction release, which is more gradually, causing the release to be affricated." [7:3]. Referring to the respective waveforms of the dental and lateral clicks (Figure 1) L&T [2:40] state that these clicks have "... considerable turbulent noise after the release." They note a crescendo and decrescendo effect and continue: "For the noisy clicks, after the anterior closure is released, the noise increases in intensity until it reaches a maximum, after which the noise decreases in intensity." [2:41]. Their position seems to be quite clear: the silence of the closure phase of the click is broken by the anterior release after which the frication builds up to a maximum and then decreases before the transition to the following vowel is made, hence an **affricated click** is constituted.

Now consider the following SPWD-analysis of such an alleged affricated dental click in Xhosa:

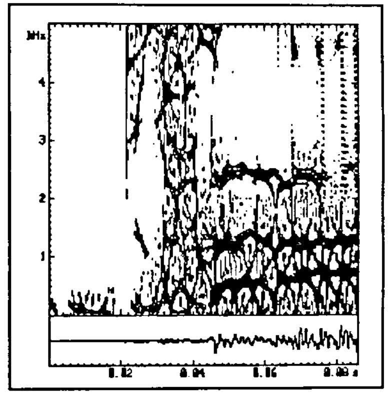

Figure 1. SPWD analysis of the noise burst of a voiceless dental click "c" in Xhosa

Following the silence of the closure phase (0-0.02s) frication excitation extending over the whole spectrum is clearly attested up to a point (0.046s) where impulse excitation is attested (a vertical line extending into a horizontal island at 1200 Hz). This impulse then extends towards the first and second formant frequencies of the following low vowel /a/ without excessive high frequency turbulence. The acoustic pattern of this articulation is unambiguously clear: frication followed by an impulse. This order of acoustic events is not reconcilable with the notion of affrication traditionally assigned to it; as a matter of fact the opposite, **pre-affrication** actually takes place. Translated into articulatory terms this is to be expected with sounds utilizing ingresssive air stream mechanisms; a backward (and downward) movement of the anterior closure (due to lower pressure within the points of closure) creates friction up to the point where the seal is finally broken with enough energy to result in a pulse-like excitation.

L&T's interpretation of the waveforms (Fig 1), namely that the turbulent noise occurs **after the release** cannot be supported. The first deviations from the zero-line does not necessarily imply a "release"; these deviations are indeed representative of frication prior to the (full) release attested in the following pulse. An exact definition of the notion "release" would clarify L&T's position considerably. In the case of the other "noisy" click, i.e. lateral [ǁ], there is likewise no evidence of an impulse excitation followed by turbulence to justify affrication in the classical sense of the word. What is present is high intensity frication over the whole spectrum with some suggestion of a weak impulse-like excitation indicating the final breaking of the seal. Pre-affrication is not clearly attested in these forms, however, they are characterized by high intensity frication throughout the articulation.

The frication and, or preaffrication of the "noisy" clicks are clearly distinguishable from the transient impulse-like click "q" [!]:

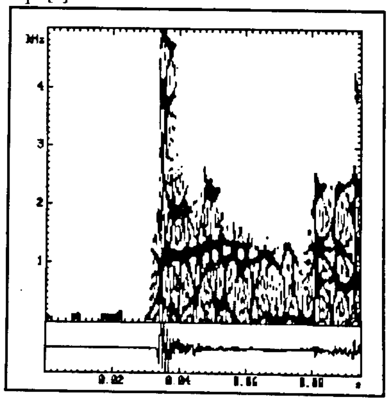

Figure 2. SPWD analysis of the noise burst of a voiceless alveo-palatal click "q" in Xhosa

Nasal Clicks: L&T [2:46] correctly refer to these clicks as "nasal clicks" and not as "nasalized clicks" (cf. [7]). These clicks contrast lexically with other click forms and are not the product of a specific phonological process. In viewing the structure of the particular waveform, L&T [2:47] conclude "The clicks (...) occur almost at the end of an accompanying nasal." A detailed SPWD-analysis of the articulation of these sounds, however, reveal rather interesting features not normally detectable in a waveform presentation alone.

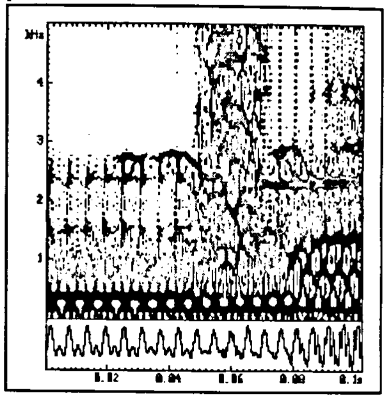

Figure 3. SPWD analysis of the noise burst of a nasal dental click "nc" in Xhosa

The nasal waveform is observable from the beginning of the window up till approximately 0.08s with the click clearly **superimposed** on this wave at a point approximately 0.06s into the signal. This superimposition of a click without significantly changing the structure of the nasal waveform is characteristic with all three click types in our data. In a certain sense it may even be argued that the click is an accompaniment of the nasal and not vice versa. This predominance of the nasal and the superimposition of the click surely shed some light on the process of click acquisition where children initially tend to nasalize all clicks [8] [9], as well as on a phonological process in which a nasal preceding a click surfaces phonetically as a single murmured nasal click [3].

Voiced "murmured" clicks

The clicks represented orthographically as gc, gq, gx are described by L&T [2:46, 47] as "murmured" clicks because they are accompanied by a "murmured velar plosive [g]". This click is tran-

scribed with a voiced velar symbol with a dieresis under it (implicating breathy voice) preceding the click symbol: [g̈!],. However, referring to the waveform they state that "...there is no breathy voice during the closure", and furthermore, that the murmur "... is not accompanied by strong breathy voice during the release of the closure as it is in languages such as Hindi or Marathi." Although they find no breathiness in the signal as such they maintain the use of the dieresis in view of the observation that the murmured nasal belongs to a set of depressor consonants (allegedly exhibiting some degree of breathy voice, cf. [10:477]) that has a lowering effect on the tone of the following vowel. The question then remains what constitutes the perceptual murmur? Catford [11:101] indicates that Bell may have first used this term in 1867 describing it as "whisper and voice heard simultaneously." and that Ladefoged's interpretation assumes "one form of whispery voice." Consider now the following SPWD-analysis which reveals information not visible in the waveform alone:

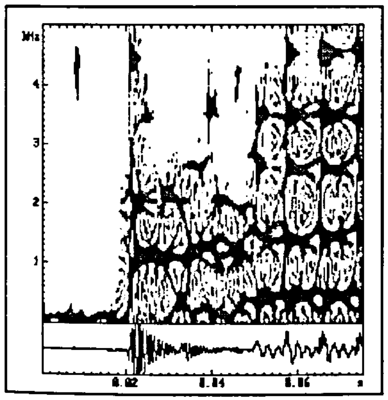

Figure 4. SPWD analysis of the noise burst of a voiced alveo-palatal click "gq" in Xhosa

A distinctive double impulse excitation is attested with the second impulse representing the release of the velar closure. Editing of the signal results in the first impulse clearly being perceived as a click and the second as a clear voiced velar stop. This impulse-like excitation following the click is attested in the other two click types as well. In fast succession, however, a voiced release may be perceived, but certainly no breathy voice. Lowering of pitch in the following vocalic segment need not have anything to do with vocal fold activity simutaneously facilitating breathy voice, but might correlate with the voicing of the short obstruent that follows the click.

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