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Research Article

Posterior lingual gestures and tongue shape in Mangetti Dune !Xung clicks

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ABSTRACT

Clicks differ from pulmonic stops in that, in addition to containing lingual gestures that shape the filtering mechanism of the vocal tract, they also contain lingual "rarefaction gestures" that form the source of the lingual ingressive airstream. The current study uses mid-sagittal lingual ultrasound imaging to investigate (1) overall tongue shape, (2) tongue dorsum and root positions, and (3) dynamic rarefaction gestures involving the tongue dorsum and root, in the four coronal click types recognized by the IPA. The study provides quantitative evidence that the four click types differ in overall tongue shape. Additionally, results show that the palatal click has a farther back dorsal constriction than the three pre-palatal clicks, and the tongue root is raised and bunched in the upper pharynx in one variant of the palatal click, but involves retraction of the tongue root proper in the lower pharynx in the alveolar click. A second variant of the palatal click involves posterior gestures more similar to those found in the alveolar click. Results provide evidence that the kinematics of the posterior part of the tongue are important in describing click production, and shed light on synchronic and diachronic sound patterns involving the palatal click in Kx'a languages.

1. Introduction

There are Consonant–Vowel co-occurrence restrictions found between clicks and front vowels in most southern African non-Bantu click languages. Traill (1985) called this constraint The Back Vowel Constraint. Miller-Ockhuizen (2003) and Miller (2010) have suggested that differences in the posterior constrictions of clicks are the phonetic bases of these restrictions, but articulatory differences among the posterior gestures in the four click types have not previously been investigated quantitatively. This study intends to fill this gap by providing a description of overall tongue shape, tongue dorsum and root positions just prior to the anterior release, and posterior gestures during the closure (rarefaction) phase of clicks.

The IPA (2006) recognizes four coronal click types: dental [ǀ], alveolar [ǃ], lateral [ǁ], and palatal [ǂ], which all contrast in Mangetti Dune !Xung. These four click types are known to differ in the location and shape of the anterior constrictions. While clicks are produced similarly to pulmonic stops in that they have a shutting phase, a closure phase, and a release phase (Abercrombie, 1967); their production is unique in that it also involves "rarefaction gestures" occurring during the closure phase, which decrease the pressure in the lingual cavity formed between the two constrictions (Thomas-Vilakati, 2010). These gestures occur prior to the release of the anterior constriction of the click, which allows air to rush into the lingual cavity. The rarefaction gestures are responsible for the decrease in pressure that results in the loud acoustic noise-bursts that are characteristic of clicks. In the current study, ultrasound imaging is used to investigate posterior lingual kinematics that contribute to rarefaction in clicks.

1.1. Previous studies of click production

Previous articulatory descriptions of clicks have mainly been undertaken outside of the laboratory in remote areas of southern and East Africa. These studies have relied on static palatography and linguography. Such techniques, which utilize photographing tongue–palate contact using a dental mirror, are superior to ultrasound for studying anterior constrictions in consonants, given the difficulty of imaging the tongue tip with ultrasound (Stone, 2005). However, static palatography provides incomplete data on posterior constrictions of clicks given the difficulty of covering the soft palate with a charcoal mixture.

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Preliminary descriptions of tongue shapes in the four coronal click types in Mangetti Dune !Xung are provided in Miller, Scott, Sands, and Shah (2009) and Miller (2013).

1.1.1. Posterior constriction locations

Posterior constriction locations of clicks have long been described as velar, where velar refers to the contact point being at the velum (Beach, 1938; Doke, 1923; Ladefoged & Traill, 1994; Ladefoged & Maddieson, 1996; Traill, 1985). The use of the term velar has been carried into phonological representations, where clicks have been described using the feature [+back], grouping together clicks and [k] into a single natural class. Miller, Namaseb, and Iskarous (2007) and Miller, Brugman et al. (2009) have provided lingual ultrasound studies of the posterior constriction locations of clicks in Khoekhoe and N|uu. Due to the 30 fps frame rate that was used in these earlier studies, there was a great degree of variability in the constriction location results. Miller et al. (2007) provide quantitative measurements of the tongue root positions of the alveolar and palatal click types in Khoekhoe, and the data show that the posterior constriction of the palatal click type is behind that of the alveolar click type, and that the different click types involve different overall tongue shapes, including differences in tongue front, body, dorsum, and root postures. They have shown that the posterior constriction location of the alveolar click type is uvular, and the posterior constriction location of the palatal click type is uvulo-pharyngeal. Miller, Brugman et al. (2009) have provided qualitative evidence that a similar difference exists among these two click types in N|uu. They note that there are two distinct posterior constrictions produced by the tongue dorsum and the tongue root in the alveolar click type in N|uu. Investigation of posterior lingual kinematics was not possible in these earlier 30 fps ultrasound studies.

Thomas-Vilakati (2010) provides a quantitative study of the production of the three contrastive click types (Dental, Palato-alveolar and Lateral) in the Bantu language Zulu using static palatography, linguography, electropalatography and airflow. Due to the difficulty of covering the soft palate with a pseudo-palate, electropalatographic data of the palato-alveolar click type in Zulu shows little to no contact between the tongue dorsum and the front edge of the pseudo-palate. Thus, the results provide evidence that the posterior constriction involved in the palato-alveolar click type is farther back than that found in the dental and lateral click types, where the contact of the posterior constrictions are clearly seen on the pseudo-palate. The airflow data also provides indirect evidence of a post-velar constriction in the palato-alveolar click type.

1.1.2. Tongue movement during click closures

Movement of the tongue tip and tongue dorsum have been shown to occur during click closures. Ladefoged and Traill (1994) have shown that the palatal click type in !Xóõ involves retraction of the tongue tip. Thomas-Vilakati's Zulu study shows that the dental click type involves no tongue dorsum retraction, while the palato-alveolar click type involves some degree of tongue dorsum retraction during rarefaction. Her study also surmises movements of the tongue root from airflow data.

The current study differs from earlier studies in that it provides novel data on the dynamics of posterior lingual movements in clicks using high frame rate ultrasound data obtained using the CHAUSA method (Miller ,& Finch, 2011). Ultrasound allows us to directly view the rear part of the tongue dorsum and the tongue root, which cannot be viewed with electropalatography. The current study includes all four contrastive coronal click types and the retracted velar pulmonic stop [k̠] that occurs in the [ɑ] context. High frame rate ultrasound makes it possible to view lingual dynamics that occur over short temporal intervals, by providing images of the majority of the tongue every 8.77 ms with good spatial clarity.

1.2. Qualitative description of tongue shape and rarefaction gestures in Mangetti Dune !Xung clicks

Fig. 1 provides two frames taken from lingual ultrasound videos of the production of a single token of three of the four contrastive coronal click types that occur in Mangetti Dune !Xung. These productions are from a male speaker (JF). The first image of the tongue (labeled Frame 1) is the first identifiable frame in the closure phase (the first frame where both constrictions are in place). The second image (labeled Frame 2) is the last frame prior to the anterior release – that is, the last frame in the closure phase. Fig. 1 provides an illustration of the phenomena under investigation. Overall tongue shapes and indirect evidence of differences in lingual kinematics among the four click types are visible. A video in the supplemental material provides the raw ultrasound videos of all four click types produced by the same speaker (JF) to allow direct viewing of the kinematics.

I will focus first on tongue shape differences found in the back part of the tongue in the frames labeled Frame 2 on the right side of Fig. 1, and then turn to describing the rarefaction gestures, which are visible through comparing differences in the tongue shapes in Frames 1 and 2. Tongue Dorsum Constriction Locations (TDCL) and Tongue Root Constriction Locations (TRCL) are labeled in the images. Lingual cavities are also labeled in the ultrasound images of the second frame, to help the reader interpret the figures, though tongue body lowering involved in rarefaction is not investigated in the current study.

The three click types differ in their overall tongue shapes, and in the angle of the overall tongue from front to back. The height of the coronal and dorsal constrictions is relatively even in the dental and alveolar click types, leading to the visual impression that the tongue slope is relatively flat from front to back in these two clicks. A similar flat tongue shape is seen in the supplemental video of these click types. In the palatal click type, the Tongue Dorsum constriction is much lower in height than the coronal constriction, which suggests that the dorsal constriction is in the uvulo-pharyngeal region, not in the back dorsal region, as in the dental and alveolar click types.

Differences in the Tongue Dorsum Constriction Locations (TDCL) just prior to the anterior release of the clicks are visible among the three click types. Namely, the palatal click type has a farther back posterior constriction than the dental and alveolar click types.