

PHONETIC REDUCTION OF CLICKS – EVIDENCE FROM N|UU

Carina Marquard^a, Oliver Niebuhr^b & Alena Witzlack-Makarevich^a

^aISFAS, Kiel University, Germany; ^bIDK/IRCA, University of Southern Denmark, Denmark
carina.marquard@web.de; olni@sdu.dk; awitzlack@isfas.uni-kiel.de

ABSTRACT

Based on spontaneous speech data of the Tuu language N|uu, we used the cross-linguistically established domain-initial strengthening concept in order to examine, if and in which way clicks are subject to speech reduction (lenition) in relation to a reference sample of plosives. Results of combined acoustic and auditory analyses suggest that clicks can be reduced in a gradual fashion and show more reduction phrase-finally than phrase-initially, just like plosives. However, unlike plosives, it seems that the reduction of clicks does not primarily affect the complex articulatory process itself, but rather its effort and coordination with phonation.

Keywords: click, plosive, reduction, lenition, N|uu.

1. INTRODUCTION

Clicks represent an active and developing field of research in phonetic science, particularly since there is growing evidence that they are not restricted to “exotic” African languages like !Xóǀ, Khoekhoegowab, and Zulu. As has recently been stressed in a special issue on non-pulmonic sounds in JIPA [1], clicks are also anything but rare in European languages, although they occur here only non-phonemically and with different speaker-specific frequencies. However, in studying clicks the focus is often on phonemic and other functional analyses, in which researchers identify the non-pulmonic sounds and describe their key features on an auditory basis.

Our study aims at supporting a complementary line of research on the instrumental phonetic measurement of clicks, as in [2,3,4]. With a stronger focus on comparative, context-related analyses of acoustic details, we are interested in determining (1) the characteristics of clicks at different places of articulation and (2) the variation of clicks in different segmental and prosodic contexts. These are largely open questions, at least relative to what we know about pulmonic sound classes.

We recently started dealing with question (1) and investigated on the basis of N|uu, if and how bilabial, dental, alveolar, lateral, and palatal clicks are distinguished acoustically. N|uu is an ideal research subject, as clicks are the largest consonant group in this language. N|uu has 45 click phonemes. They

cover all five places of articulation and can additionally involve a number of secondary distinctive features like nasalization, glottalization, or voicing [5].

Focusing on plain voiceless clicks, our acoustic analysis showed for question (1) that bilabial and lateral clicks differ from dental, alveolar, and palatal clicks in total duration and voice onset time (VOT), as well as in the spectral energy maximum and mean energy level of their aperiodic sections after closure release. The aperiodic sections after closure release are, in addition, most relevant for distinguishing dental, alveolar, and palatal clicks, for example, in terms of their lower spectral energy boundary and spectral center of gravity (CoG) [6]. These findings fit in well with the empirical picture outlined in [7].

Based on this initial work on question (1), the present study addresses question (2). We investigate, if clicks can also become subject to speech reduction processes in general, and lenition in particular. Unlike plosives, clicks involve two closures. The first one is formed in the back of the oral cavity, and the second one follows shortly afterwards somewhere in the front of the oral cavity. The two oral closures are released in reverse temporal order while reducing the air pressure between them, cf. [8]. Thus, the articulation of clicks is much more complex in terms of movements and coordination than that of plosives and requires more effort. It would be reasonable to assume on this basis that clicks are also more robust against speech reduction than simple plosives.

We test this assumption by means of a concept whose cross-linguistic relevance is well established: domain-initial articulatory strengthening, see [9,10,11]. That is, using promising reduction parameters based on [6], we compared the acoustic and auditory characteristics of clicks in words that are located at the onset, in the middle, and at the offset of intonation phrases; and as in our previous study [6], we focused on the simplest type of clicks: plain, voiceless clicks. The results are analyzed and interpreted relative to a reference condition of voiceless, un-aspirated plosives in N|uu.

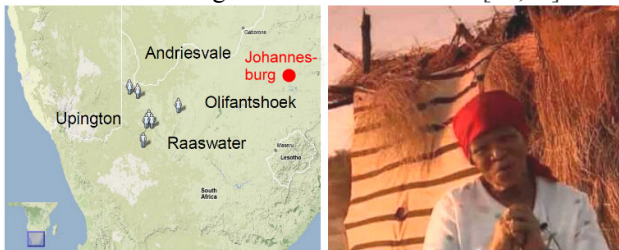
2. METHOD

N|uu (or N|ng) is the last living member of the !Ui branch of the Tuu language family. It is a moribund language currently spoken in South Africa by a handful of individuals. About 150 years ago, there

were still several hundred N|uu speakers. However, in the 1930s, the N|uu territory became the Kalahari Gemsbok National Park. In consequence, N|uu speakers moved into other speech communities, and their children mainly grew up speaking a different mother tongue. After the fieldwork of [12], N|uu was for a long time considered extinct, until it was re-discovered in the late 1990s [13]. Several other publications followed [7,14,15,16,17,18,25].

The speech corpus [19] used in this study was created in 2007–2014 and includes recordings of 7 speakers. These 7 speakers were the last confirmed speakers of N|uu when the corpus was compiled. The speakers were between 65 and 75 years old. Their geographical distribution is shown in Figure 2.

Figure 2: Left: The remaining N|uu speakers in South Africa. Right: Ouma Aenki Kassie [26,27].



The corpus section used for our analysis consists of about 6 hours of spontaneous speech, which includes interviews as well as narratives. The 6 hours are not equally distributed across the 7 remaining N|uu speakers, but every speaker contributed at least 30 minutes to the corpus. The corpus is grammatically and lexically annotated based on [20]. We made use of this annotation in order to find suitable target words and locate potential intonation phrase boundaries, which were, however, ultimately determined on an auditory basis by the first author. As the first author does not speak N|uu, we took care to select only clear phrase boundaries, i.e. boundaries that involve a pause, breathing, and/or strong final lengthening in combination with a terminal F0 fall and a subsequent reset of the F0 level. Phrase boundaries that resulted from obvious disfluencies were disregarded for our speech sample.

Our target words showed one of the five click phonemes /ǀ, ǁ, ǃ, ǂ, Ǆ/ in word-initial position (N|uu does not allow clicks in other positions, [7]). We focused on plain, voiceless clicks without phonological post-aspiration or other secondary articulatory or phonatory features. Moreover, all clicks occurred at the beginning of high-frequency nouns or verbs like /ǀooe/ (meat), /ǁaeki/ (woman), /ǃ!uu/ (person), /ǂlaaxe/ (sibling), and /Ǆoo/ (man). Each of the five clicks was represented by 60 target words. The target words were equally distributed across 3 positions in the intonation phrase: phrase-initial, phrase-medi*al, phrase-final. The positions are assumed to

differ in the degree of initial strengthening. Twenty target words occurred in phrase-initial position, except for the bilabial click, for which we were only able to find 16 phrase-initial target words. Twenty target words were produced phrase-medially, which means that there were at least two words before and after the target word. Another 20 target words were located at the end of an intonation phrase. In total, the click sample included 296 items.

The click sample was complemented by a reference sample of simple, voiceless, unaspirated stops. We used the two phonemes /p/ and /k/ for that purpose, as they occur particularly frequently at the onset of high-frequency nouns and verbs in N|uu. Like in the click sample, the corresponding target words starting with /p/ and /k/ were located in equal numbers at the beginning, in the middle, and at the end of intonation phrases. We included 10 target words per plosive at each phrasal position so that the reference sample includes a total of 60 items.

The two types of target-word initial stops – clicks and plosives – were always surrounded by vowels and came from stretches of speech without overlapping environmental noise. Both stop samples, i.e. the click sample and the plosive sample, included tokens of all 7 remaining N|uu speakers.

The analysis was done in two different ways. First, we conducted an acoustic analysis with Praat [21], based on those prosodic parameters whose relevance was attested in [6] and that were most likely to be affected by phonetic reduction: duration, intensity, and with reference to [24] also spectral CoG.

As regards duration, we measured the total duration of the sound segment from the creation of the closure in the vocal tract through the release burst(s) and the subsequent aperiodic section to the onset of the following vowel. Additionally, we determined the positive VOT from the release burst to the first periodic vocal-fold vibration. Duration measurements were generally made with reference to the segmentation guidelines provided by [22].

Intensity was also represented by two parameters: the mean acoustic energy levels *before* and *after* the release burst.

CoG was automatically measured in a frequency range of 1-16 kHz. CoG measurements were taken at intervals of 10 ms across the aperiodic section after the release burst. The resulting values were averaged in order to get the mean CoG of the entire aperiodic section. When clicks had two clearly separate release bursts, all duration and intensity measurements of the aperiodic section started at the first burst.

The second way of analysis was conducted on an auditory basis. The second author determined the perceptual prominence of each stop in its respective syllable (i.e. vowel) context, based on the 4-level

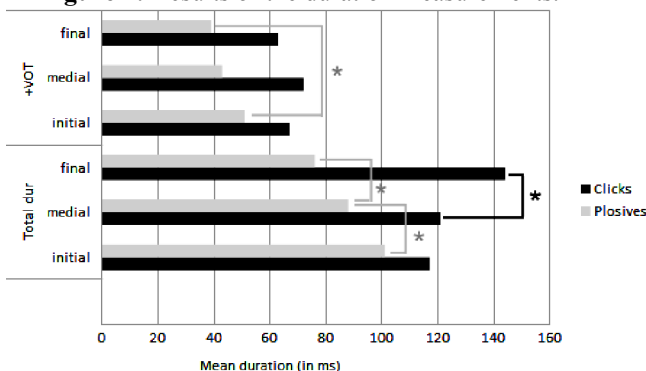
scale of PROLAB [23]: 'no prominence' (=0), 'weak prominence' (=1), 'regular prominence' (=2), 'emphatic prominence' (=3). The second author is trained to apply this scale to speech material. Based on these scalar prominence judgments, it was counted across the clicks and plosives, how often the four prominence labels occurred for the target words in each initial-strengthening condition.

The acoustic measurements were statistically analyzed in a two-way MANOVA, based in the fixed factors Stop Type (clicks vs plosive) and Stop Position (phrase-initial vs phrase-medial vs phrase-final). Post-hoc t-tests with Bonferroni corrections were conducted to determine the relevant (i.e. significant) measurement differences within each factor. The frequency distributions resulting from of the auditory prominence analysis were processed in two separate 4 x 3 and 4 x 2 Chi-squared tests.

3. RESULTS

The results for the two duration parameters – total segment duration and +VOT – are statistically very similar. Both parameters yielded a significant main effect of Stop Type in the MANOVA (total duration: $F[1,352] = 5.198, p < .05$; +VOT: $F[1,352] = 8.614, p < .001$). As can be seen in Figure 2, this main effect reflects that clicks have longer segment durations, including longer +VOT durations, than plosives. This is true at all three positions in the intonation phrase. The fixed factor Stop Position has no separate main effect on the two duration measurements.

Figure 2: Results of the duration measurements.

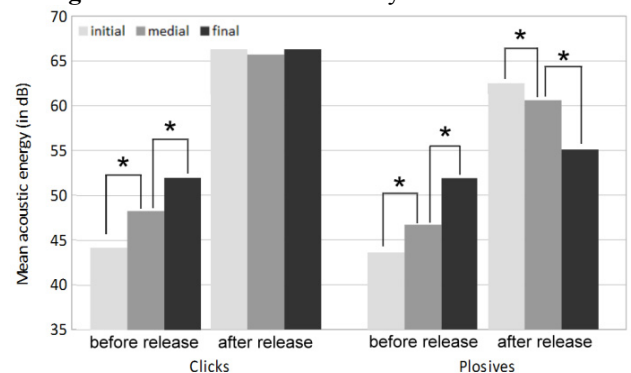


However, there is significant interaction of Stop Position and Stop Type (total duration: $F[2,358]=10.617, p < .001$; +VOT: $F[2,358]=2.194, p < .05$) for both duration measurements. Total durations decrease for plosives from phrase-initial through phrase-medial to phrase-final positions. In contrast, click durations change in the opposite direction and are larger in phrase-final than in phrase-medial and phrase-initial position. The significances of these within-factor differences were determined in post-hoc tests and are asterisked in Figure 2. The post-hoc tests for +VOT show that these durations also

decreased from initial to final position for plosives, whereas they remained constant across all three stop positions for clicks.

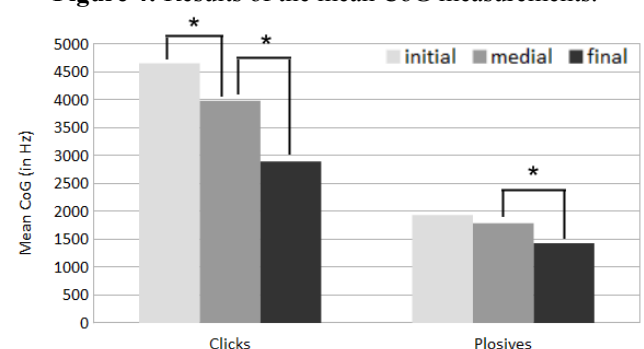
The results of the mean acoustic energy levels clearly differ in the measurements taken before and after the release burst. As is summarized in Figure 3, the energy levels *before* the release burst increase in the same order of magnitude for both clicks and plosives from phrase-initial to phrase-final position, hence yielding no main effect of Stop Type, but a significant main effect of Stop Position ($F[2,352]=4.258, p < .05$). Post-hoc tests show that all stop positions differ significantly from each other. There is no interaction between Stop Type and Stop Position.

Figure 3: Results of the intensity measurements.



The aperiodic section *after* the release burst has a higher acoustic energy level for clicks than for plosives, which results in a main effect of Stop Type ($F[1,352]=14.818, p < .001$). Stop Position has no separate significant main effect. However, Stop Position significantly interacts with Stop Type ($F[2,358]=23.450, p < .001$). The reason for this interaction is that the acoustic energy level after the release burst remained constantly high in the case of clicks, but significantly decreases for later phrasal positions in the case of plosives, see Figure 3.

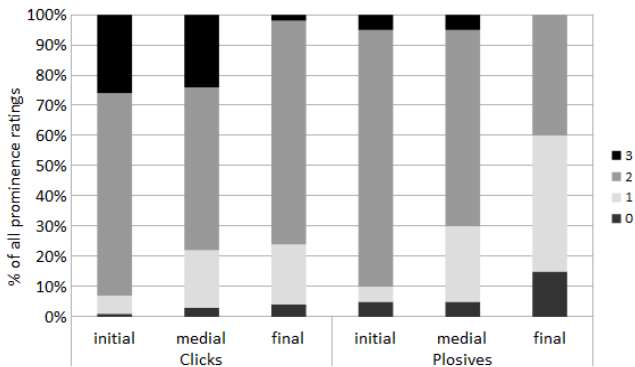
Figure 4: Results of the mean CoG measurements.



The mean CoG measurements resulted in significant main effects of Stop Type ($F[1,352]=127.980, p < .001$) and Stop Position ($F[2,352]=30.664, p < .001$). The interaction between the two factors is also significant ($F[2,358]=35.240, p < .001$). As is depicted in Figure 4, these findings reflect that clicks have a higher mean CoG than plosives across all phrasal

positions; and although mean CoG generally decreases from phrase-initial to phrase-final position, this decrease is much more pronounced for clicks than for plosives. Thus, post-hoc tests show that the mean CoG levels differ significantly between all three stop positions for clicks, whereas for plosives only the phrase-final position differs from the initial and medial positions.

Figure 5: Results of the auditory prominence ratings.



Finally, Figure 5 shows the frequencies the 4 auditory prominence levels of our clicks and plosives. Overall, the ratings are similar for clicks and plosives in that the 'emphatic prominences' (=3) decrease from phrase-initial to phrase-final position, while at the same time the 'non-prominent' and 'weakly prominent' ratings (=0/1) increase. Accordingly, a χ^2 -test shows that the frequencies of the 4 prominence levels (across the two stop types) differ significantly between the initial, medial, and final stop positions ($\chi^2[6]=77.990$, $p<.001$). Crucially, Figure 5 shows in addition that clicks were far more often judged to be 'emphatically prominent' than plosives; and in phrase-final position clicks still sounded mainly 'normally prominent' (=2), whereas plosives were already predominantly 'weakly prominent' (= 1). Therefore, another χ^2 -test shows that the frequencies of prominence levels (across stop positions) also differed significantly between clicks and plosives ($\chi^2[3]=44.774$, $p<.001$).

4. DISCUSSION AND CONCLUSIONS

Compared with plosives, clicks had in general larger +VOT and total durations, as well as higher mean CoG and acoustic energy levels in the aperiodic section after the release burst. These findings support the fact that clicks are more complex and require more effort than their plosive counterparts. But, does this entail that clicks are more robust against phonetic reduction, which means 'lenition' in our study?

A reduction of stop consonants should manifest itself in the following way: Total segment duration and +VOT duration should both decrease. The acoustic energy level of the aperiodic section *after* the release burst should decrease as well. The acous-

tic energy level *before* the release burst should, in turn, increase, as more voicing of the preceding vowel extends into the stop closure. Finally, the mean CoG of the aperiodic section after the release burst should decrease, as [24] showed that friction sounds produced with less effort have a steeper spectral tilt, particularly at high frequencies.

The changes that /p/ and /k/ underwent from phrase-initial through phrase-medial to phrase-final positions are completely consistent with the expected effects of reduction. It is therefore reasonable to assume that /p/ and /k/ were least reduced in phrase-initial position and most reduced in phrase-final position. That is, plosives in Nluu are subject to gradual phonetic reduction, and domain-initial strengthening is one of the factors that determines the degree of reduction, as in probably every other language.

Unlike the plosives, the clicks show the expected reduction changes from phrase-initial to phrase-final position only in terms of mean CoG and the acoustic energy level before the release burst. This means on the one hand that clicks can basically also be subject of gradual phonetic reduction, just like plosives. On the other hand, our results suggest that clicks are not reduced in the same way and to the same degree as their articulatorily simpler counterparts. It seems that the complex articulation process of clicks as well as its time frame are not affected by reduction, at least not by those reduction demands imposed by phrasal position. Rather, what seems to be subject to reduction in clicks is the effort spent on controlling the airflow during the articulation process. This includes the interruption of voicing after the preceding vowel (see the energy level before the release burst) and the power/velocity with which air is sucked into the mouth (see mean CoG).

Our conclusions that there is initial strengthening in Nluu, and that clicks seem to be more robust against reduction than plosives are also in line with our auditory prominence ratings. Prominence levels decrease for later phrasal positions, but much stronger for plosives than for clicks. Clicks in phrase-medial positions evoked similar auditory prominences as plosives in phrase-initial position.

An obvious task of follow-up studies would be to confirm our conclusions on the basis of direct articulatory measurements. It would also be interesting to test if factors other than phrasal position are more effective in reducing clicks, and whether all clicks are similarly robust against reduction. Our data indicate that bilabial and dental clicks, i.e. the two anterior places of click articulation, are probably more susceptible to reduction than the other clicks /l, ʎ, ʞ/. For example, a few instances of clicks could not be analyzed, as they were reduced to approximants. All of them were all either bilabial and dental clicks [6].

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