AN ARTICULATORY STUDY OF ESTONIAN PALATALIZATION

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ABSTRACT

This paper analyzes the effect of palatalization on the articulation and duration of Estonian /s/, /t/, /n/, /l/, and the vowels preceding them in phonologically contrastive word pairs. The experiment with 21 native Estonian participants was carried out using an electromagnetic articulograph (EMA). The results show that in the case of palatalization, the back of the tongue was already raised, and the tongue blade was more fronted during the preceding vowel. The position was maintained through the palatalized consonants. The height of the tongue blade was not affected by palatalization. There was a positive correlation between higher tongue position and longer vowel duration. With consonants, the duration was shorter with higher tongue position, but this effect was inconsistent.

Keywords: articulation, articulography, Estonian, palatalization, Carstens AG501, EMA

1. INTRODUCTION

This paper aims to study the effect of palatalization on the articulatory and temporal properties of Estonian consonants /s/, /t/, /n/, /l/, and the vowels that precede them. Palatalization is a process wherein consonants' place of articulation is altered by a high front vowel or glide /j/ [1]. Estonian has developed many phonologically contrastive pairs in which palatalization is the only distinctive feature, e.g., *pats* [pɑtːs] 'pat' – *pats* [pɑtʲːs] 'braid.' These pairs give a comparable study material to assess the effect of palatalization on articulation.

Studies of different languages have shown that the most persistent descriptive acoustic feature of palatalization is the rise of the F2 value of the vowels preceding consonants [2–9]. This rise in F2 is due to the gesture in which the tongue body rises towards the palate. Studies that have looked at vowel-to-consonant coarticulation [10–13] have found that the following segments are anticipated earlier. The effect of coarticulation might even reach further beyond the syllable boundaries [14, 15].

The rising of the tongue in the vowels have also been observed in the acoustic studies of Estonian consonants. /l/ has higher F2 values with palatalization [3]. The mean spectral energy or the center of gravity of the spectrum (COG) has been measured for plosives and fricatives. COG value can be associated with the frontness (higher frequencies) or backness (lower frequencies) of the tongue [20]. COG is lower for /s/ [16, 17], /t/, and /n/ and higher for /l/ with palatalization in Estonian and in Ocotepec Mixe [17].

Palatographic studies have shown that the ridge in the middle of the tongue was narrower when articulating Estonian palatalized /s/ [18, 19]. This might also explain why the COG values are lower. The place of articulation of /t/ is retracted in Estonian, Russian, and Polish, and the tongue blade and the sides have a wider contact on the alveolar ridge, and the teeth [18–21]. Estonian /n/ has a wider contact area on the post-alveolar region and the teeth [18,19,22]. Estonian /l/ is fronted with palatalization and has a wider contact area on the alveolar ridge and teeth [19, 22, 23].

The raising of the tongue before palatalized consonants has also been shown to lengthen the duration of the vowel in Estonian [3, 9, 24]. This lengthening is used to enhance the perception of palatalization [25]. The duration of Russian /t/ is longer with palatalization [21, 26], as there is a higher degree of aspiration in the release. With /s/, the results vary: [26] found that the duration was shorter with palatalization, and [27] found that it was longer. We could not find any data on the duration of /l/ or /n/. Previous studies have analyzed the duration as a byproduct of the rising of the tongue but have not tried to link it to an articulatory movement.

The present study is a follow-up to [17], where we offer a new perspective on analyzing the dynamic movement trajectories of palatalization. We investigate whether the rising of the tongue can be observed to occur earlier in the vowels and reach further in the consonants than has been previously described. We also supplement the findings in [17] and look at how the rising of the tongue is correlated with the duration of the segments. We will address the following questions:

- How does palatalization affect the position of the tongue of consonants and their preceding vowels? Based on previous research, it will be hypothesized that the position of the tongue will be higher, at least up until the midpoint with palatalization while articulating /s/, /t/, /n/ and retracted while articulating /l/. The tongue is expected to be also higher while producing the preceding vowels. We expect to find a constant movement throughout the vowel instead of a distinguishable rising movement at the end of the vowel.
- If we observe the raising of the tongue with palatalization, we want to know whether this raising can be related to the lengthening or shortening of the segmental durations. As previous studies have pointed out, we expect that the raising of the tongue is causing a longer duration of back vowels and /t/ and possibly /s/.

2. MATERIALS AND METHODS

The data for this study was collected in the Phonetics Laboratory at the University of Tartu, Estonia, from 21 native Estonian speakers (10 male, 11 female). The data consisted of 11 minimal pairs of meaningful words with a CVC: structure, where the target consonant was in the post-vocalic position. The test words were embedded in a medial position of carrier sentences, followed by a comma and a word starting with [mi], e.g. *Külmal hommikul oli maas hall* [hɑlː], *mida oli ilus vaadata.* 'On a cold morning, the land was covered with frost, that was beautiful to look at.' *Minu auto oli hall* [hɑlʲː], *mitte valge.* 'My car was gray, not white.'

The articulatory data were recorded with a Carstens AG501 electromagnetic articulograph, with a 200 Hz sampling rate. We analyzed the data from 3 sensors from the midsagittal plane of the tongue. The sensor on the anteo-dorsum and the sensor on the tongue blade were used to estimate the height of the tongue, and the sensor on the medio-dorsum was used to estimate the frontness or backness of the tongue. Statistical analysis was carried out with the R software [28]. The generalized Additive Mixed Model was used from mgcv package [29] to estimate the effect of palatalization on the height and the frontness or backness of vowels and consonants. The effect of tongue height, vowel, and consonant on the segmental duration values were tested with Linear Mixed Model from lme4 package [30]. In all models, a random intercept for the speaker was included. In the case of trajectory comparisons, post-hoc testing was done with multcomp [31] package using Bonferroni-Holm correction.

3. RESULTS

3.1. The position of the tongue

Figure 1 panels a and b show the data of the words with /l/. During the vowels preceding /l/, the anteo-dorsum was higher ($p < 0.001$) with palatalization. In the case of /ɑ/, also the tongue blade was higher ($p < 0.001$). The tongue was more anterior for both vowels with palatalization ($p < 0.001$).

During the palatalized /l/, the anteo-dorsum was higher in the context of both vowels ($p < 0.001$), the tongue blade was higher in the context of /ɑ/, and the tongue was more anterior ($p < 0.001$) compared to the non-palatalized /l/. The panels c and d of Figure 1 present the results of the words with /n/. The vowels preceding palatalized /n/ were produced with higher anteo-dorsum ($p < 0.001$), and the tongue was more anterior ($p < 0.001$) compared to the non-palatalized context. The tongue blade during /ɑ/ was lower in the palatalized context ($p < 0.001$), but no significant palatalization effect on tongue blade height occurred for /o/.

During palatalized /n/, the anteo-dorsum was higher ($p < 0.001$), and the tongue was more anterior ($p < 0.001$) compared to non-palatalized /n/. Palatalization had no significant effect on the height of the tongue blade. In the case of the vowels preceding palatalized /s/ (Figure 1 panels e and f), the anteo-dorsum was higher ($p < 0.001$), and the tongue was more anterior ($p < 0.001$) compared to the non-palatalized /s/ context. In the palatalized context, the tongue blade was lower for /u/ ($p < 0.001$) but not significantly different for /ɑ/.

The palatalized /s/ was produced with a higher anteo-dorsum and more anterior tongue position ($p < 0.001$). The tongue blade was lower in the context of /u/ ($p < 0.001$), but in the /ɑ/ context, palatalization did not affect the tongue blade during /s/. The words with /t/ are presented in Figure 1 panels g and h. During the vowels preceding palatalized /t/, the anteo-dorsum was higher ($p < 0.001$), and the tongue was more anterior ($p < 0.001$) compared to the non-palatalized context. The tongue blade was lower with palatalization in the case of /o/ ($p = 0.005$), but no palatalization effect occurred in the case of /u/. During palatalized /t/, the anteo-dorsum was higher ($p < 0.001$), the tongue blade was lower in the context of both vowels ($p < 0.001$), and the tongue was more anterior ($p < 0.001$) compared to non-palatalized /t/. In the case of /t/, palatalization did not affect the height of the tongue blade.

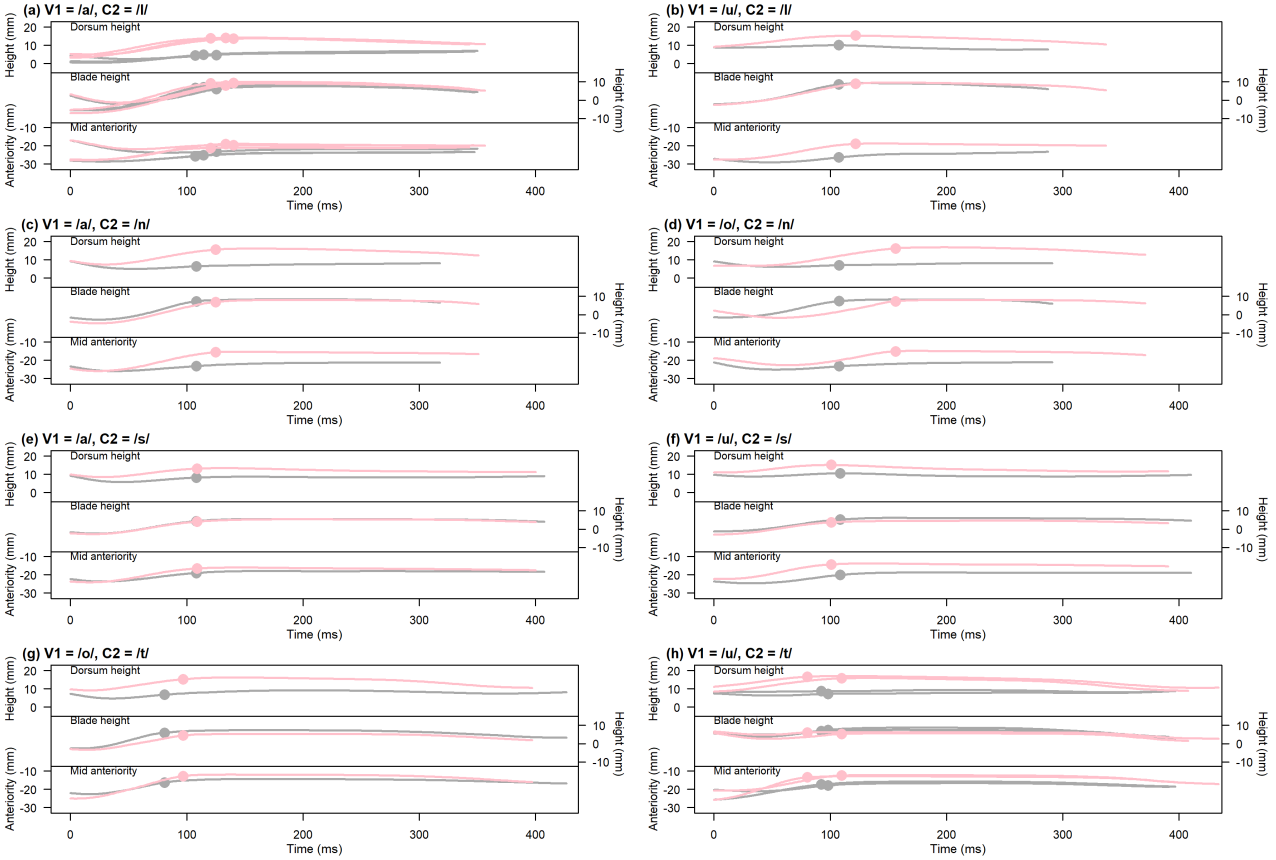

Figure 1: The height of the anteo-dorsum and the tongue blade, and the anteriority of the tongue in millimeters when producing the VC sequence of the words with palatalized (pink) and non-palatalized (gray) consonants. The dot marks the acoustic boundary between the vowel and the consonant. The panels are grouped by V1 and C2. The contours are averaged over the speakers.

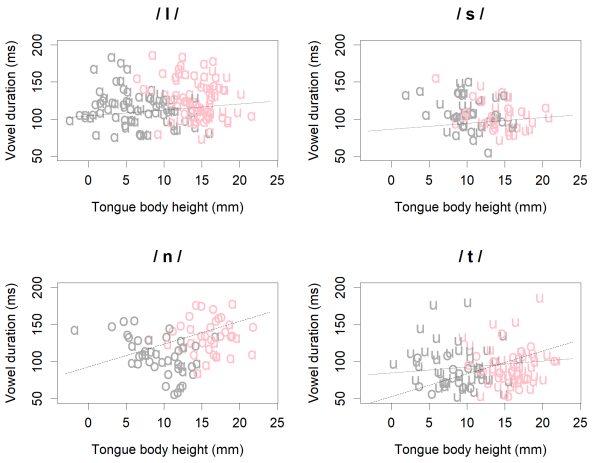

Figure 2: The duration of the vowels preceding non-palatalized (black) and palatalized (pink) consonants (in milliseconds) depending on the height of the tongue (in millimeters).

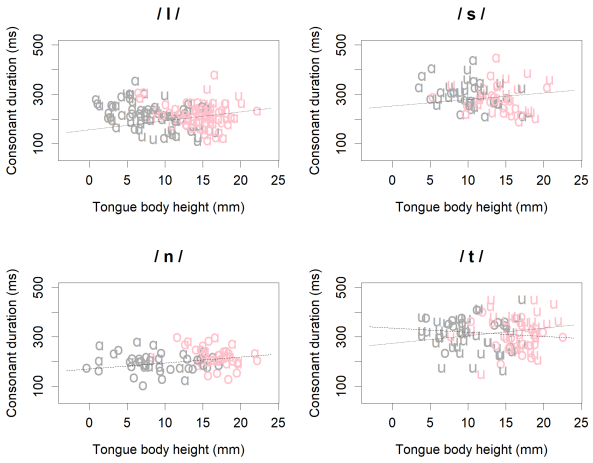

Figure 3: The duration of non-palatalized (black) and palatalized (red) consonants (in milliseconds) in the context of different vowels depending on the height of the tongue (in millimeters).

3.2. Effect of the tongue height on segmental durations

The effect of the tongue height on segmental durations was tested with vowel category and the following consonant using a linear mixed model. As there was a strong correlation between palatalization and tongue height, only the latter was chosen as an independent factor in the model. The data for the vowels are plotted in Figure 2.

The average duration of the vowel was 112 ms. The model showed that with the tongue rising, the vowel duration is longer (β = 1.3 ms/mm, p < 0.001). Compared to (the base value) /ɑ/, the duration of /u/ was not significantly different, but /o/ was shorter (β = -40 ms, p < 0.001). Compared to the (base value) /l/ context, the vowel duration was shorter before /n/ (β = -12 ms, p = 0.003), /s/ (β = -18 ms, p < 0.001) and /t/ (β = -20 ms, p < 0.001). An interaction in the model between the vowel and tongue body movement showed that (compared to /ɑ/) the duration of /o/ was even longer when the tongue was raised (β = 1.8 ms/mm, p = 0.007). Another significant interaction, however, showed that before /n/, the duration of /o/ was longer (β = 32 ms, p < 0.001), neutralizing the strong negative main effect of /o/.

Figure 3 presents the effect of the tongue height on the duration of consonants. The model showed no significant main effect of tongue height. In the case of (base values) /l/ following /ɑ/, the duration was 230 ms, but it was significantly shorter following an /u/ (β = -74 ms, p <0.001). Consonant /n/ was shorter than /l/ (β = -48 ms, p <0.012). Consonants /s/ (β = 96 ms, p < 0.001) and /t/ (β = 117 ms, p <0.001), on the other hand, were longer. Additionally, the model showed two interactions with the tongue height: when following an /u/ and the tongue, the consonant was longer (β = 4.6 ms/mm, p < 0.001), and if the consonant was /n/, and the tongue was higher the duration was also longer (β = 1.4 ms/mm, p = 0.012).

4. DISCUSSION

Based on [18–21], we hypothesized that the place of articulation of consonants would be higher for /s/, /t/, /n/, /l/ and retracted for /t/. The results showed that the tongue was always higher and more fronted while articulating palatalized consonants. Our study did not confirm that the place of articulation of /t/ is retracted with palatalization. Due to the sensors, the tongue may not have enough freedom to move, and thus we did not capture the movements that would occur in more natural circumstances. The results also show that contrary to the claim by [32], the tongue was raised throughout the production of consonants with palatalization, not only in the beginning.

We confirmed the hypothesis based on studies [2, 3, 5–9, 24] that the place of articulation of the vowel preceding palatalized consonants is also higher. Our results showed a constant movement throughout the vowel where the tongue was higher than in the non-palatalized counterpart. In the speech, the following segments are anticipated and adjusted for [10–13]. As palatalized consonant demands a higher secondary place of articulation, the tongue is already raised anticipatorily from the beginning of the vowel.

Based on previous research [3, 9, 24], we expected that the durations of the vowels and consonants /t/ and /s/ are longer. We found that with the tongue raising, the duration of the vowels that preceded palatalized consonants was lengthened. This lengthening of the vowel is used to enhance the perception of palatalization and to give the listener time to process upcoming information [25]. For consonants, we could not find that the tongue raising affected the duration of /s/ or /t/. The duration of /l/ and /n/ were shorter with palatalization. Fricatives and plosives might be harder to produce with sensors on the tongue, and a temporal compromise is made in the vowels.

5. CONCLUSIONS

This paper studied the effect of palatalization on the articulation and duration of the Estonian /s/, /t/, /n/, /l/, and the preceding vowels using an electromagnetic articulograph (EMA). The results showed that the back of the tongue was always higher, and the tongue was more fronted when articulating palatalized consonants. This position was reached already during the preceding vowels. The height of the tongue blade was not affected by palatalization. With the raising of the tongue, the duration of the vowels that preceded palatalized consonants were longer. The duration of /s/ and /t/ were not affected by the tongue raising, but /l/ and /n/ were shorter.

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7. REFERENCES

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