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Palatalization in Ukrainian, Polish and Russian. A pilot 3D Ultrasound Study

1. Introduction

The phonetic descriptions of palatalization refer characteristically to tongue body fronting and raising (e.g., Crystal 2008:347, Sagey 1986, Hume 1992, Clements/Hume 1995 etc.). Some recent studies also identified the consistent effect of the tongue root fronting in Polish (e.g., Lulich/Ćavar 2019), Russian (Matsui/Kochetov 2018, Ćavar/Rudman, in preparation, cf. also Proctor 2011) or Irish (Bennett et al. 2018). Acoustically, palatalization is characterized by higher F2 and a big difference between formants F2 and F1 in the transitions (e.g., Kochetov 2017) or frequent appearance of the friction noise in stops (cf. Guion 1998). These characteristics are, however, gradient, that is, one can observe differences in the degree of palatalization between speakers, between dialects or between languages. Sawicka (1999:19) observes that older publications referred often to 'stronger' or 'weaker' palatalization but this aspect is usually omitted in newer works, as suggested by Sawicka, due to the lack of clear articulatory or acoustic criteria for the gradation of palatalization. The current project is an attempt to quantify and compare articulatorily different realizations of palatalization.

In this paper we present results of the pilot study of the articulation in Ukrainian and comparing to the data for Polish and Russian collected using the same methodology, 3D/4D ultrasound imaging. Unlike in earlier studies of Slavic palatalization, apart from the position of the tongue body we evaluate also the position of the tongue root which has traditionally

been overlooked in the analysis of Slavic languages. Additionally, instead of offering impressionistic descriptions, we measure the relative differences in the position of the different points of the tongue which differentiate the palatalized – i.e. phonetically 'soft' – consonants from their non-palatalized counterparts.

We focus on coronal sounds because the sounds articulated with the front of the tongue as their active articulator display a broader array of palatalization processes. In particular, in Polish posterior obstruents can be both inherently palatalized (prepalatals) but also contextually allophonically palatalized (the [šʲ] series). In contrast, Russian palatalization is distinctive and Ukrainian is phonemic in anterior sounds and allophonic – in posterior. This allows us to look at another factor in palatalization, i.e. its phonological status.

2. Method

The data presented in this paper have been collected in years 2016-2020 at the Speech Lab of the Speech and Hearing Department of Indiana University in Bloomington, Indiana. To date, ten native speakers of Polish, nine native speakers of Russian, and six native speakers of Ukrainian were recorded. We present the Ukrainian data from two out of six recorded speakers. The selected speakers come from Western Ukraine and have a salient allophony of posterior sibilants triggered by the high front vowels. Other speakers, primarily from Kyiv and the area around, either did not realize the allophony or did not realize it systematically in the investigated subset of consonants. The Ukrainian data are shown in the context of the data of two speakers of Russian and two speakers of Polish, from whom we could obtain particularly good quality recordings.

Speakers read individual words presented in an orthographic form. The word lists included real and nonce words.[1] In this paper we compare data of corresponding palatalized (soft) and non-palatalized (hard) consonants – anterior stops and posterior fricatives and affricates, as summarized in Table 1. We have compared always pairs of two sounds which differed in softness only but had the same manner, voicing and place of articulation – anterior or posterior. Consequently, we compared the two posterior voiceless fricatives [š] - [ɕ] in Russian and Polish, though they do not alternate

[1] Post-hoc statistical analysis in a similar study of Polish in Lulich/Ćavar (2019) showed no significant difference between real and nonce words.

in synchronic morphophonological process of the given language – as [t] - [tʲ] do in Russian.

Analyzed consonants, both soft and hard, were followed by high non-back vowels. For the analysis of the phonemic palatalization in Polish we exceptionally used words containing the consonants in the bilateral /e/ context.

Table 1: Data overview

Language	Correspondent sound pairs	Phonological status
(Western) Ukrainian	[t] – [tʲ]	phonemic
(Western) Ukrainian	[š] –[šʲ]	allophonic
Polish	[t] – [tʲ]	allophonic
Polish	[š] – [šʲ]	allophonic
Polish	[š] – [ɕ]	phonemic
Russian	[t] – [tʲ]	phonemic
Russian	[š] – [ɕ]	phonemic

The ultrasound data were recorded with a Philips EPIQ 7G system using an xMatrix x6-1 digital 3D/4D transducer (Lulich et al. 2018). The transducer was secured under the chin using an Articulate Instruments ultrasound stabilization headset (Scobbie/Wrench 2008) to keep it in a stable position relative to external points of reference such as the palate, which allows for the direct comparison of the tongue position in reference to the passive articulator within a speaker during one recording session (Charles/ Lulich 2018). Ultrasound files were analyzed using a custom MATLAB toolbox, called 'WASL', developed in the Speech Production Laboratory at Indiana University. Together with the ultrasound data, audio was synchronously recorded with a SHURE KSM32 microphone (sampling rate of 48kHz) and used later to identify the ultrasound frames for analysis.

The traditional x-ray imaging methods could inform us about the changes in the general position and shape of the tongue but could not provide information about the changes in the position of concrete points on the tongue surface because the tongue surface does not have clear landmarks which would be visible in x-ray images. This is only partly true about ultrasound imaging, because the ultrasound recordings we work with usually show some internal structure of the tongue, such as, the borders between tissue layers, sometimes some muscle fibers and systematically the tendon of the genioglossus muscle. The position and the direction of the tendon allows us to identify the corresponding point on the surface of the tongue root opposite of the tendon and evaluate the differences in its position.

The evaluation of the position of the tongue dorsum was impressionistic.[2] We identified and compared the points of the highest raising of the tongue body in the articulation of the corresponding palatalized and non-palatalized consonants. The coordinates of the points were taken and the amount of the relative fronting, raising or advancement (which was calculated as a Euclidean distance between the two corresponding points) was calculated, cf. Fig. 1.

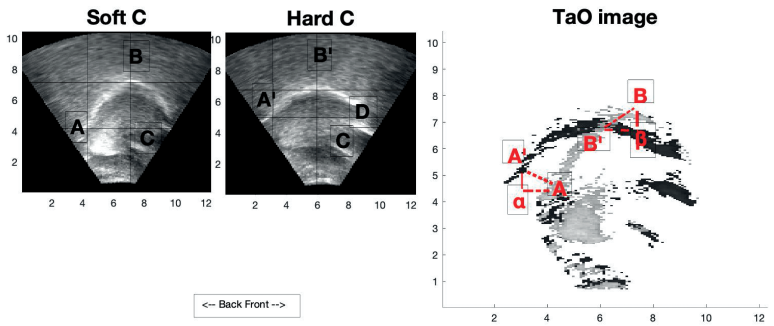

Figure 1: Left: a soft consonant. Center: a hard consonant. Right: overlaid contours of soft and hard consonants. A - point on the surface of the tongue opposite of the tendon of the genioglossus. B - highest point of the dorsum. C- tendon of the genioglossus. D- supralingual cavity. Lines on the TaO image: A-A' advancement of the tongue root, B-β raising of the tongue dorsum, B'-β fronting of the dorsum, B-B' advancement of the tongue dorsum.

3. Results

3.1. Polish

Obstruents in Polish are allophonically palatalized when followed by a high front vowel [i] or the palatal glide [j]. Fig. 2. compares the allophonically palatalized voiceless stop [t] (word-initial, followed by [i]) with a non-palatalized word-initial [t] followed by the high front centralized vowel [ɨ].[3] When looking at the overlaid contours of the tongue in the sagittal view for Speaker P1 (female) represented in Fig. 2A, we observe fronting and minimal raising of the tongue body (0.8 cm and 0.2 cm, re-

[2] Lulich/Ćavar (2019) conducted the measurements twice on 10% of their data. The differences between the two measurements were always below 0.2 cm and in a post-hoc test did not turn statistically relevant.

[3] Phonetic descriptions of Polish agree that [ɨ] in Polish is articulated with fronting of the tongue body (cf. Koneczna/Zawadowski 1951, Wierzchowska 1980).

spectively). The very tip of the tongue is outside of the vision field. The point on the surface of the tongue root in the soft consonant is advanced by approximately 0.7 cm in comparison to the hard consonant. In the coronal view we can see a deep grooving along the center of the tongue at the tongue root in the soft [tʲ], a much smaller grooving in the hard consonant and barely visible grooving marking the center of the tongue at point of maximal dorsum raising. In the mid-sagittal view, we see a contour of the supralingual cavity in the hard consonant but not in the soft consonant.

Speaker P5 (male) has a more conspicuous fronting and raising of the tongue dorsum (in the range of 0.8 cm) in the soft consonant. The tongue root is advanced by approx. 0.9 cm in the soft consonant. Again, a more conspicuous grooving along the center of the tongue is visible in the soft consonant in the area of the tongue root – as compared to the hard consonant and as compared to the coronal view of the dorsum.

Fig. 3 shows the allophonic palatalization of the hard posterior fricative [š] as articulated by the same two speakers. Speaker 1 shows some fronting (approx. 0.5 cm) and minimal raising of the tongue dorsum (less than 0.2 cm, that is, below the margin of error), cf. Fig. 3A. The tongue root is also advanced (approx. 0.5 cm), presumably expanding the pharyngeal cavity. No particular grooving along the center of the tongue can be observed at either tongue root or dorsum for this speaker. Speaker 5, in contrast, shows virtually no difference in the position of the dorsum but the tongue root advancement is visible opposite of the tendon of the genioglossus. No conspicuous grooving along the center of the tongue can be observed in the coronal planes.

Finally, Fig. 4 represents the inherently palatalized phoneme [ɕ] as compared with the other posterior voiceless fricative [š]. For both speakers, the dorsum in [ɕ] is clearly advanced (close to 1 cm). Dorsum is also relatively raised in the range of 0.3-0.4 cm. Both speakers show also a substantial advancement of the tongue root, over 0.6 cm for speaker 1, and over 1 cm in speaker 5. Both speakers produce also a very conspicuous grooving along the center of the tongue in the tongue root area but not in the dorsal area.

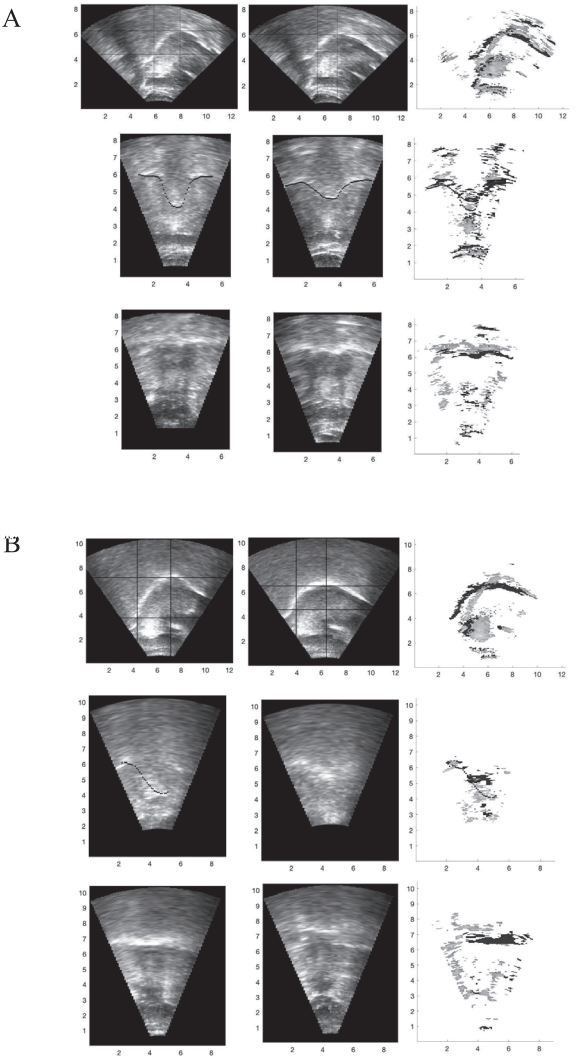

Figure 2: Allophonic palatalization in Polish [t] versus [tʲ]. A: Speaker P1 ([t] in *tylko*, [tʲ] in *tilapia*). B: Speaker P5 (([t] in nonce *tytyt*, [tʲ] in nonce *titit*). Left column: palatalized consonant, center: non-palatalized consonant, right: overlaid and thresholded images of the palatalized (light) and non-palatalized (dark) consonants. The top row (for each speaker) – midsagittal view, the front of the oral cavity to the right. Middle row – coronal view at the tongue root. The bottom row - coronal view at the point of the maximal raising of the tongue body. The location of the coronal slices is marked by the vertical lines in the sagittal view.

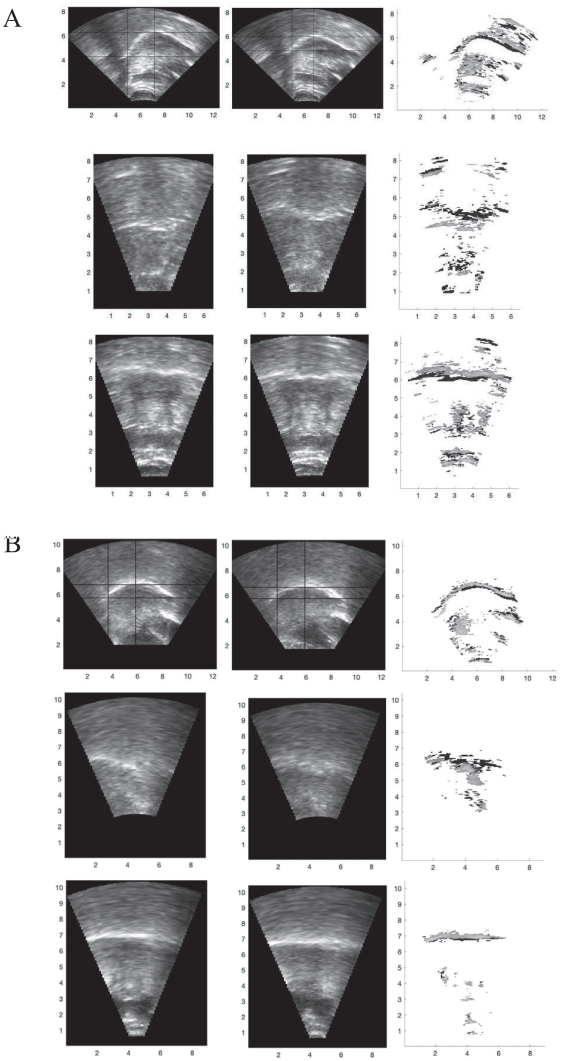

Figure 3: Allophonic palatalization. Polish [š] in *szynka* versus [šʲ] in *Ho Szi Min*. A: Speaker P1. B: Speaker P5. Left column: palatalized consonant, center: non-palatalized consonant, right: overlaid and thresholded images of the palatalized (light) and non-palatalized (dark) consonants. The top row (for each speaker) - midsagittal view, the front of the oral cavity to the right. Middle row - coronal view at the tongue root. The bottom row - coronal view at the point of the maximal raising of the tongue body. The location of the coronal slices is marked by the vertical lines in the sagittal view.

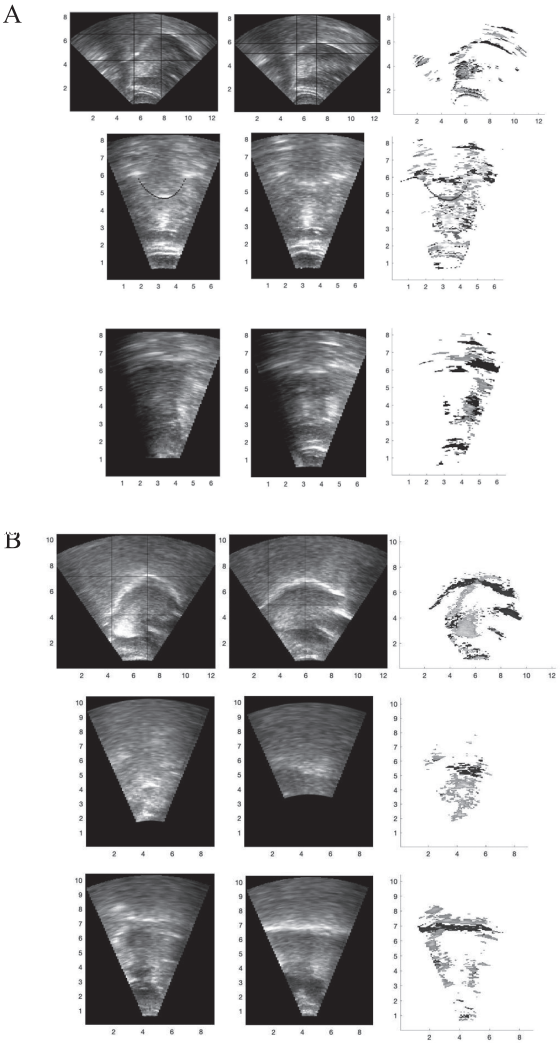

Figure 4: Phonemic palatalization. [š] vs [ɕ]. A: Speaker P1 ([š] in *meszek* vs [ɕ] in *Grzesiek*). B: Speaker P5 ([š] in *szynka* vs [ɕ] in *sito*). Left column: palatalized consonant, center: non-palatalized consonant, right: overlaid and thresholded images of the palatalized (light) and non-palatalized (dark) consonants. The top row (for each speaker) - midsagittal view, the front of the oral cavity to the right. Middle row - coronal view at the tongue root. The bottom row - coronal view at the point of the maximal raising of the tongue body. The location of the coronal slices is marked by the vertical lines in the sagittal view.

3.2. Russian

Palatalization in the Russian data below is phonemic, both in the anterior and posterior area. That is, the pairs of non-palatalized and palatalized consonants articulated in the same manner with the same voicing value and at a roughly the same place of articulation are contrastive. It is 'roughly the same place of articulation' because, as observed in Bondarko (2005), the exact place of articulation is slightly modified though the change in place is not prominent enough to be noted in **phonological** descriptions. Thus, the dental [t] and the alveolar [tʲ] are both anterior.

Fig. 5 represents the anterior stops of Russian. Speaker 9 (female) is a teacher of Russian as L2. She spoke at a slightly slower pace than other speakers and articulated very carefully, which resulted in high temporal resolution and high quality and easily interpretable ultrasound images. The tongue dorsum in the soft [tʲ] is relatively fronted by more than 0.5 cm, cf. Fig. 5A. There is a minimal difference in the raising of the dorsum. The measured advancement of the tongue root is in the range of 0.7 cm. Both soft and hard consonants have a well-defined tongue groove along the center of the tongue in the tongue root area but the groove in the palatalized consonant is much deeper. The coronal cross-sectional view at the dorsal point shows no grooving for either sound.

The position of the tongue dorsum in speaker 7 (female) for the palatalized and non-palatalized dental stops is similar, cf. Fig. 5B. The point opposite the tendon of the genioglossus is relatively more advanced in the soft consonant by approx. 0.8 cm. Both soft and hard anterior consonants have a central grooving in the tongue root area though the grooving is considerably bigger in the soft consonant. No grooving along the center of the tongue is visible in the dorsum area.

Moving on to posterior fricatives, Speaker 9 shows a strong effect of dorsum fronting (in the range of approx. 1.4 cm) and raising (approx. 0.4 cm), cf. Fig. 6A. The tongue blade in the soft consonant is oriented steeply down, while in the hard consonant it is still oriented downwards but not under such a steep angle. The tongue tip is not visible. Both consonants display a pronounced grooving in the tongue root though the grooving in the soft consonant is considerably deeper. No grooving can be observed in the area of the maximal raising of the tongue body. Speaker 7 demonstrates also a huge relative advancement of the whole body of the tongue (approx. 1.8 cm for the dorsum and above 1.5 cm for the tongue root area). While the tongue tip is not visible, the tongue blade in both cases points down, and the tongue blade in the soft consonant is oriented steeply down. As for the other consonants, the soft consonant is characterized by a distinct grooving along the

center of the tongue in the tongue root area. Some grooving can be observed also in the tongue root area in the hard consonant, while no grooving is visible in the dorsal area for either segment.

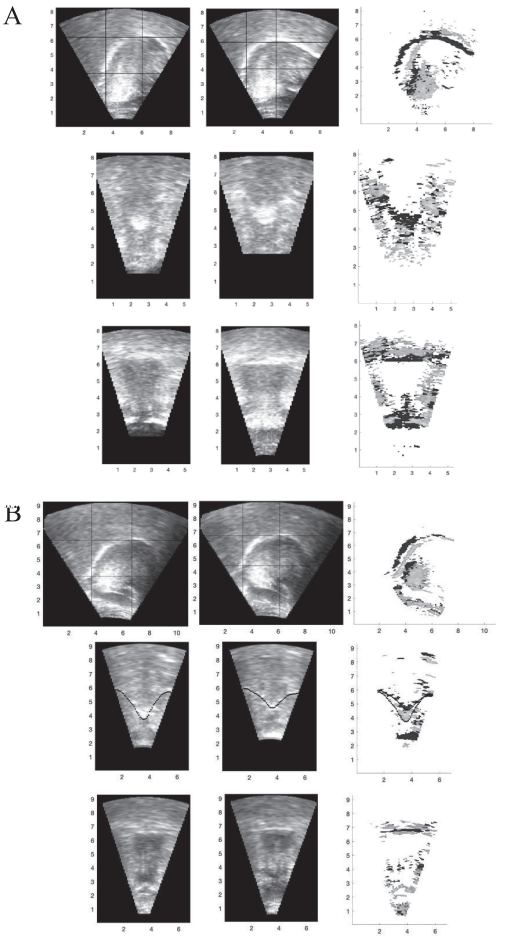

Figure 5: Phonemic palatalization. [tʲ] in nonce тити (left), [t] in nonce тыты (center). A: Speaker R9. B: Speaker R7. Left column: palatalized consonant, center: non-palatalized consonant, right: overlaid and thresholded images of the palatalized (light) and non-palatalized (dark) consonants. The top row (for each speaker) – midsagittal view, the front of the oral cavity to the right. Middle row - coronal view at the tongue root. The bottom row - coronal view at the point of the maximal raising of the tongue body. The location of the coronal slices is marked by the vertical lines in the sagittal view.

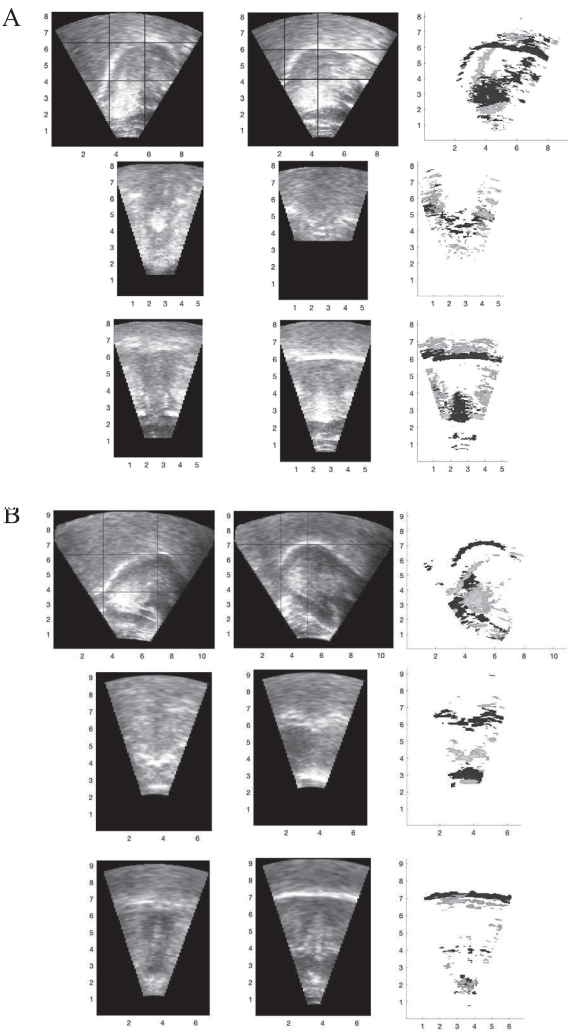

Figure 6: Phonemic distinction in Russian. [š] in nonce *ашаша* versus [ɕ] in nonce *ацаца*. A: Speaker R9. B: Speaker R7. Left column: palatalized consonant, center: non-palatalized consonant, right: overlaid and thresholded images of the palatalized (light) and non-palatalized (dark) consonants. The top row (for each speaker) – midsagittal view, the front of the oral cavity to the right. Middle row – coronal view at the tongue root. The bottom row - coronal view at the point of the maximal raising of the tongue body. The location of the coronal slices is marked by the vertical lines in the sagittal view.

3.3. Ukrainian

In Ukrainian the phonemic softness contrast is present in anterior sounds (Shevelov 1979, Danylenko/Vakulenko 1995, Buk/Mačutek/Rovenchak 2008). The speakers from Western Ukraine show an allophonic variation in the realization of posterior obstruents, with palatalization before the high front tense vowel [i] (but not in the context of the high front lax vowel [ɪ] (cf. Zilyns'kyj 1979, Pompino-Marschall et al. 2017).[4]

Fig. 7 presents the articulation of the phonemic palatalization in anterior stops. Danyenko/Vakulenko (1995:8, 10) describe the non-palatalized stops as dental and the palatalized stops as alveolar. While the position of the tip of the tongue is not visible in the ultrasound recordings, one can notice a substantial difference in the position of the tongue dorsum and blade. In speaker 1 (female), the point of the maximum raising of the tongue body is relatively fronted by approx. 1.5 cm, cf. Fig 7A. The dorsum and blade are also relatively raised in the soft anterior consonant (with the size effect of approx. 0.4 cm), presumably forming a longer constriction extending further backwards than for the non-palatalized counterpart. One can also observe the advancement of the tongue root in the range of 0.4 cm. The central groove in the tongue root area is visible in both the palatalized and non-palatalized anterior stops.

In Speaker 6 also, the biggest effect is that of the dorsum fronting (approx. at 0.9 cm) with some relative dorsum raising and some advancement of the tongue root (both at approx. 0.4 cm), cf. Fig. 7B. Both consonants are characterized by the grooving along the center of the tongue root with no such grooving visible in the tongue dorsum area.

Finally, the contextual palatalization of posterior sounds shows a surprisingly sizable effect, cf. Fig. 8. Both speakers have a comparable effect of the tongue dorsum fronting and tongue root advancement in the palatalized segments. Speaker 1, cf. Fig. 8A, has the dorsum shifted in the palatalized posterior forward – in comparison – to the non-palatalized sound – by approx. 1.8 cm, and the tongue root advanced by approx. 1.5 cm. For speaker 6, the two values are in the range of 0.5-0.6 cm, cf. Fig. 8B. No

[4] The other speakers recorded in the study showed characteristic features of the Eastern Ukrainian dialects and had 'semi-palatalized' posteriors in all contexts, cf. Pompino-Marschall et al. (2017) and references therein. Such realizations are not analyzed in this paper. Also, we do not analyze here the sibilants in words like піддашя and подорожі. In the realization of the Western Ukrainian speakers, whose data we analyze here, they were impressionistically different from (softer than) both non-palatalized posteriors and allophonically palatalized posteriors before vowel [i].

conspicuous relative raising of the tongue body can be noticed for either speaker. All posteriors, regardless of palatalization, in both speakers show the tongue blade oriented downwards (the tip of the tongue is not visible).

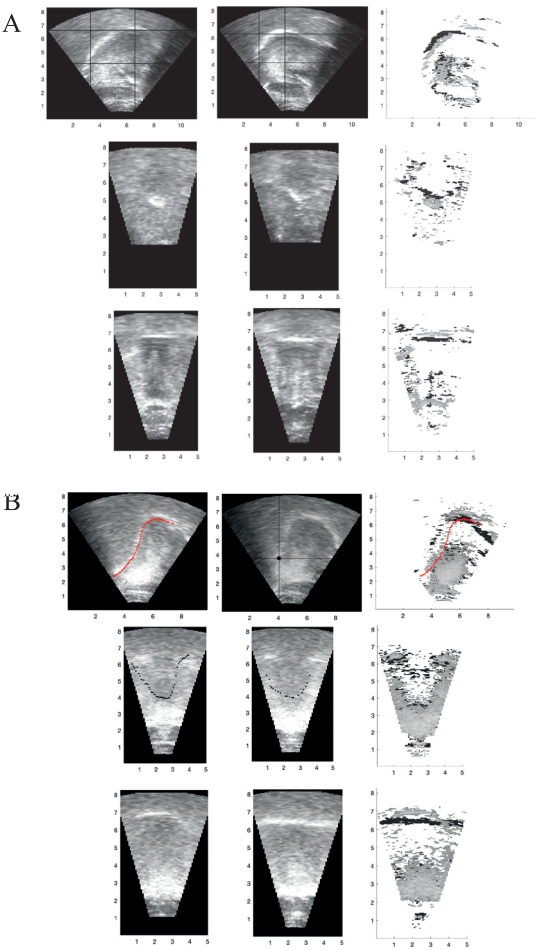

Figure 7: Phonemic distinction in Ukrainian [t] in nonce word тити versus [tʲ] in nonce тіті. A: Speaker U1. B: U6. Left column: palatalized consonant, center: non-palatalized consonant, right: overlaid and thresholded images of the palatalized (light) and non-palatalized (dark) consonants. The top row (for each speaker) - midsagittal view, the front of the oral cavity to the right. Middle row - coronal view at the tongue root. The bottom row - coronal view at the point of the maximal raising of the tongue body. The location of the coronal slices is marked by the vertical lines in the sagittal view.

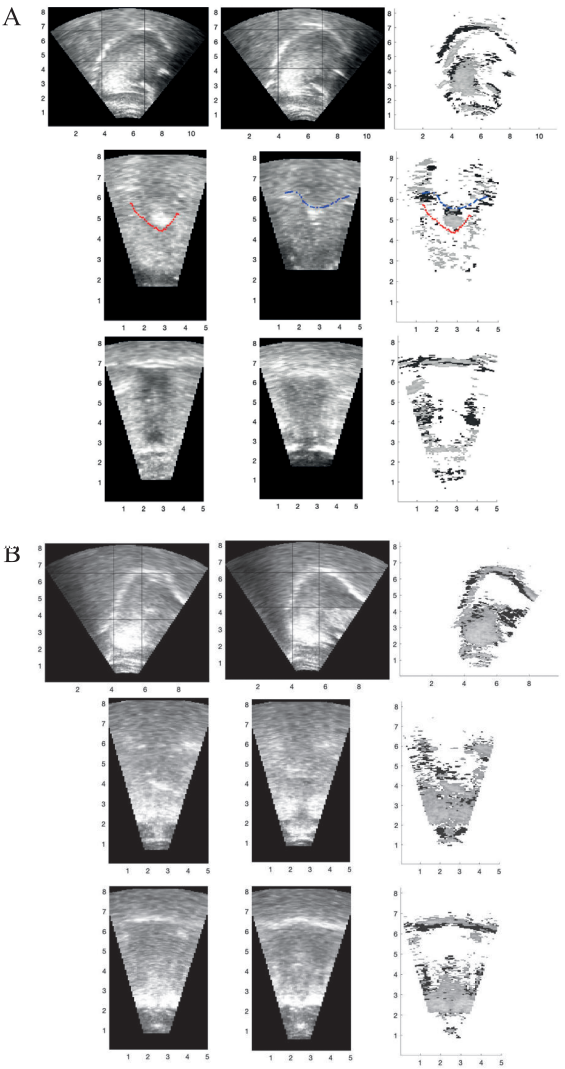

Figure 8: Allophonic effect in Ukrainian [š] in nonce шиши versus [є] in nonce шіші. A: Speaker R9, bottom: SR7) Left column: palatalized consonant, center: non-palatalized consonant, right: overlaid and thresholded images of the palatalized (light) and non-palatalized (dark) consonants. The top row (for each speaker) - midsagittal view, the front of the oral cavity to the right. Middle row - coronal view at the tongue root. The bottom row - coronal view at the point of the maximal raising of the tongue body. The location of the coronal slices is marked by the vertical lines in the sagittal view.

3.4. Descriptive statistics

The amount of the fronting of the tongue dorsum ranged from negative values (which, however, did not exceed 0.2 cm i.e. the margin of error established in earlier studies, e.g., Lulich/Cavar 2019) to 1.96 cm - with an average of 0.94 cm. The combined effect of fronting and raising was bigger, with values ranging between 0.17-2.08 cm (average = 1.04 cm, st.dve. = 0.5 cm). The rising of the tongue dorsum was relatively small and inconsistent. The effect of the advancement of the tongue root was slightly smaller than that of the tongue dorsum (0.31-1.63 cm) with the average of 0.90 cm and the smallest st.dev. of 0.41 cm. This is summarized in Fig. 9.

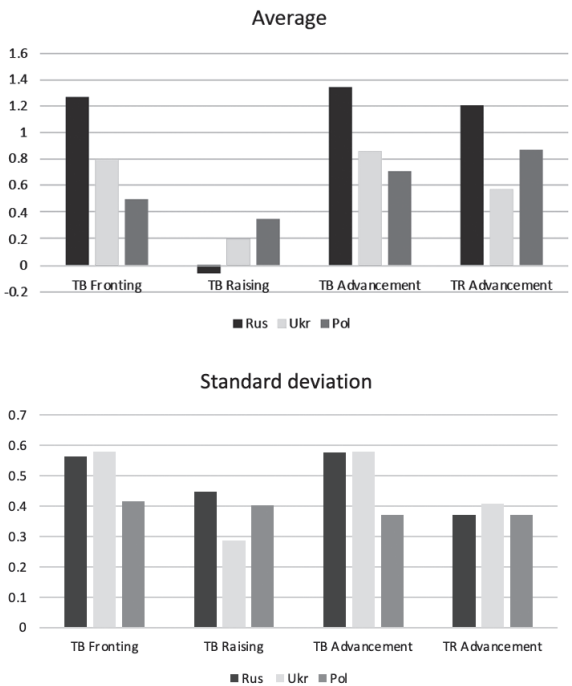

Figure 9: Average values for all speakers and palatalization types across languages (top) and the standard deviation values (bottom).

Unsurprisingly, the effects are bigger for phonemic processes than allophonic within language but also across languages, as shown in Fig. 10. The tongue root behavior, however, goes against the trend with a slightly bigger effect size for the aggregated allophonic data, Ukrainian data and probably Polish.

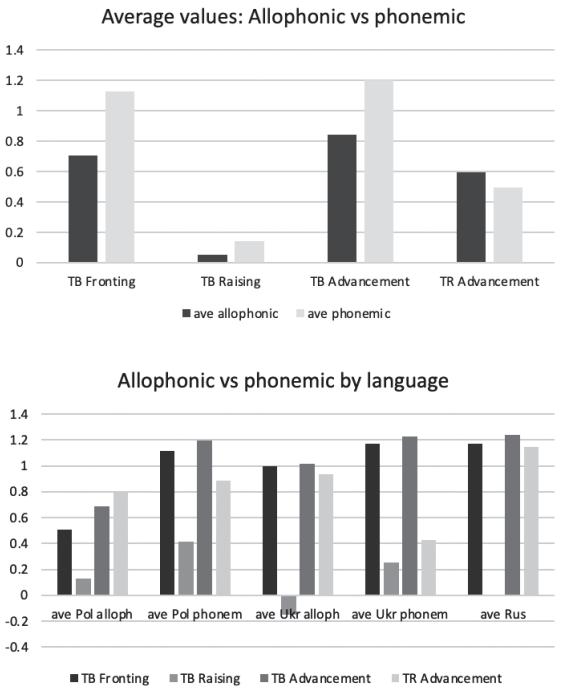

Figure 10: Average values for allophonic versus phonemic processes. All values (top). Values by language (bottom).

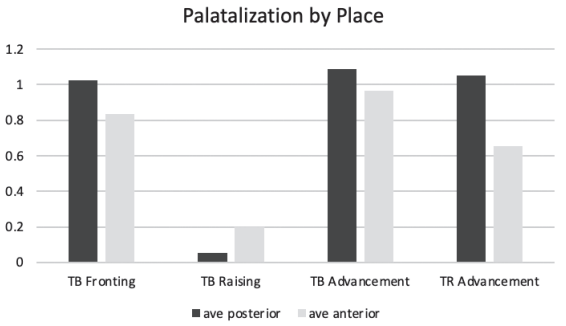

Figure 11: Palatalization in posteriors versus anteriors

Across languages, there is more tongue dorsum fronting or advancement as well as tongue root advancement in posterior sounds than in anterior.

The only dimension where anteriors' 'win' is the tongue dorsum raising, the effect of which is small in general but particularly small in posterior sounds, as shown in Fig. 11.

4. Discussion

The presented data come from a pilot study and a small number of speakers does not allow for a systematic statistical analysis. However, a number of observations can be made.

While the fronting of the dorsum is systematic, dorsum raising effect size is small and less systematic.

Apart from the generally recognized effect of the fronting of the tongue body, we observe a systematic substantial effect of the tongue root advancement in the three languages and in both allophonic and phonemic palatalization. The effect size in cm equals or goes beyond the ranges reported for the tongue root advancement in vowels in languages where [ATR] is a distinctive feature (cf. Hudu 2014, Tiede 1996). The systematic correlation between the tongue body fronting and tongue root advancement across speakers, languages, types of palatalization, places of articulation cannot be a coincidence. As argued in Cavar/Lulich (forthcoming) it is not unexpected since the tongue root and tongue dorsum are parts of the same organ. One can view the advancement of the tongue root as an enhancement of the fronting of the dorsum – or the fronting of the tongue dorsum as a physiological consequence and an enhancement of the effect of the root advancement. Lulich/Ćavar (2019), Ćavar/Lulich (forthcoming), Ćavar/Rudman (in preparation), Ćavar et al. (forthcoming) argue for the latter on the grounds of phonological processes and typology as well as anatomy and physiology.

Physiologically, palatalization has to be originally related to the activity of the muscles responsible for the advancement of the tongue root. Wood (1979) describes [i] as produced by the contraction of genioglossus, especially posterior fibers, which results in the advancement of the tongue root. In support he cites works investigating the electrical activity of muscles during speech production such as Rafael and Bell-Berit (1975) and Miyawaki et al. (1975). Additionally, he states explicitly that "[t]here are no muscles that pull the tongue up towards the hard palate" (Wood 1979:35).

The data presented in the current article further support this approach. One observation is that the grooving along the center of the tongue in the

root area opposite the tendon of the genioglossus should be interpreted as an evidence of the muscle contraction and its active involvement in the production of the palatalization gesture. Another observation is that the tongue root advancement effect size is similar in allophonic and phonemic processes and – the size of the tongue dorsum effect is on average bigger in the phonemic processes. This makes sense if we treat the tongue body effect as an enhancement strategy in phonology and the tongue root advancement in consonants – as a simple articulatory assimilation.

It seems that Polish among the three languages has smallest values for all reported dimensions. However, the small sample size as well as the high number of allophonic data for Polish might be the reason for this result. The differences between the average for particular languages are small, often around 0.2 cm. More data need to be analyzed to draw conclusions.

5. Summary and conclusions

The paper presents to our knowledge first 3D ultrasound data of palatalized sounds in phonemic and allophonic palatalization in Ukrainian. The images of articulation in Ukrainian are compared with the images of palatalized sounds in Polish and Russian obtained using the same method (cf. Lulich/Ćavar 2019, Ćavar et al., forthcoming, Ćavar/Lulich, forthcoming). We have attempted to quantify the degree of palatalization by comparing the position of the two points on the surface of the tongue; specifically, the highest raised point of the tongue dorsum and the point opposite the tendon of the genioglossus muscle in palatalized versus non-palatalized sounds which are otherwise exactly corresponding in terms of other phonological distinctive categories. The study confirms a conspicuous effect of the tongue dorsum fronting. The tongue dorsum raising is substantially smaller on average and not systematic across different conditions. Apart from the fronting and raising of the tongue dorsum, palatalized consonants show a systematic effect of the advancement of the tongue root. The preliminary results indicate that the effect of the position of the dorsum is bigger in phonemic palatalization than in allophonic palatalization, while the effect size of the tongue root remains similar across palatalization types.

Naturally, to be able to conduct a statistical analysis and to eliminate the potential errors due to individual differences between speakers a larger number of speakers and tokens per speaker need to be analyzed.

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References

Bennett Ryan / Ni Chiosain Maire / Padgett Jaye / McGuire Grant, 2018, An ultrasound study of Connemara Irish palatalization and velarization, in: Journal of the International Phonetic Association 48(3), pp. 261-304.

Bondarko Liya, 2005, Phonetic and phonological aspects of the opposition of soft and hard consonants in the modern Russian language, in: Speech Communication 47, pp. 7-14.

Buk Solomiya / Mačutek Ján / Rovenchak Andrij, 2008, Some properties of the Ukrainian writing system, in: Glottometrics 16, pp. 63-79.

Ćavar Małgorzata E. / Lulich Steven M., forthcoming, Articulation of the Palatalization Contrast in Russian and the Phonology of Palatalization, submitted to: Phonological Data and Analysis.

Ćavar Małgorzata E. / Rudman Emily / Lulich Steven M., forthcoming, Palatalization in coronal consonants of Polish: a 3D/4D ultrasound study, in: JASA-Express Letters.

Ćavar Małgorzata E. / Rudman Emily, in preparation, The Articulation of the 'Softness' Contrast in Russian Consonants and the Phonology of Palatalization.

Charles Sherman / Lulich Steven M, 2018, Case study of Brazilian Portuguese laterals using a novel articulatory-acoustic methodology with 3D/4D ultrasound, in: Speech Communication 103, pp. 37-48.

Clements George N. / Hume Elizabeth V., 1995, The Internal Organization of Speech Sounds, in: Goldsmith John (ed.), Handbook of Phonological Theory, Oxford, pp. 245-306.

Crystal David, 2008, A Dictionary of Linguistics and Phonetics, Oxford.

Crystal David, 2008, A Dictionary of Linguistics and Phonetics, Malden.

Danyenko Andrii / Vakulenko Serhii, 1995, Ukrainian, Lincom Europa.

Guion Susan G., 1998, The role of perception in the sound change of velar palatalization, in: Phonetica 55, pp. 18-52.

Fusheini Hudu, 2014, [ATR] feature involves a distinct tongue root articulation: Evidence from ultrasound imaging, in: Lingua 143, pp. 36-51.

Hume Elizabeth V., 1992, Front Vowels, Coronal Consonants and their Interaction in Nonlinear Phonology, Ph.D. thesis, Cornell University.

Kochetov Alexei, 2017, Acoustics of Russian voiceless sibilant fricatives, in: Journal of International Phonetic Association 47(3), pp. 321-348.

Koneczna Halina / Zawadowski Witold, 1951, Przekroje rentgenograficzne głosek polskich, Warszawa.

Lulich Steven / Berkson Kelly / Jong Kenneth, 2018, Acquiring and visualizing 3D/4D ultrasound recordings of tongue motion, in: Journal of Phonetics 71, pp. 410-424.

Lulich Steven M. / Ćavar Małgorzata E., 2019, Phonetics of Polish 'soft' – 'hard' vowel allophony. in: Journal of Acoustical Society of America 146(4), pp. 2263-2278.

Matsui Mayuki / Kochetov Alexei, 2018, Tongue Root Positioning for Voicing vs. Contrastive Palatalization: An Ultrasound Study of Russian Word-Initial Coronal Stops, in: Journal of the Phonetic Society of Japan 22(2), pp. 81-94.

Miyawaki Kuniko / Hirose Hajime / Ushijima Tatsujiro / Sawashima Masayuki, 1975, A preliminary report on the electromyographic study of the activity of the lingual muscles, in: Annual Bulletin of the Research Institute of Logopedics and Phonetics 9, pp. 91-106.

Proctor Michael, 2011, Towards a gestural characterization of liquids: Evidence from Spanish and Russian, in: Laboratory Phonology 2(2), pp. 451-485.

Pompino-Marschall Bernd / Steriopolo Elena / Żygis Marzena, 2017, Ukrainian, in: Journal of the International Phonetic Association 47(3), pp. 349-357.

Raphael Lawrence J. / Bell-Berti Frederica, 1975, Tongue musculature and the feature of tension in English vowels, in: Phonetica 32, pp. 61-73.

Sagey Elizabeth C., 1986, The representation of features and relations in non-linear phonology, PhD Diss, Massachusetts Institute of Technology.

Scobbie James / Wrench Alan / van der Linden Marietta, 2008, Head-probe stabilisation in ultrasound tongue imaging using a headset to permit natural head movement, in: Sock R./Fuchs S./Laprie Y. (eds.), Proceedings of the 8th International Seminar on Speech Production, Strasbourg, pp. 373-376.

Sawicka Irena, 1999, Problemy Typologii Fonetycznej Słowiańszczyzny, in: Sawicka I./Grzybowski S., Studia z Palatalności w Językach Słowiańskich, Toruń, pp. 9-102.

Shevelov George Y., 1979, A Historical Phonology of the Ukrainian Language, Heidelberg.

Tiede Mark K., 1996, An MRI-based study of pharyngeal volume contrasts in Akan and English, in: Journal of Phonetics 24, pp. 399-421.

Wierzchowska Bożena, 1980, Fonetyka i fonologia języka polskiego, Wrocław.

Wood Sydney, 1979, A radiographic analysis of constriction locations for vowels, in: Journal of Phonetics 7, pp. 25-43.

Zilyns'kyj Ivan, 1979, A phonetic description of the Ukrainian language, Cambridge, MA.

Palatalization in Ukrainian, Polish and Russian. A pilot 3D Ultrasound Study

The paper reports findings of a pilot 3D/4D ultrasound study on the articulation of palatalized coronal obstruents in Ukrainian, Polish and Russian. The study quantitatively evaluates the degree of palatalization looking at the relative dorsum frontings/dorsum raising/advancement of the tongue root as variables. Apart from the fronting and raising of the tongue dorsum, palatalized consonants show a systematic effect of the advancement of the tongue root. The preliminary results indicate that the effect of the position of the dorsum is bigger in phonemic palatalization than in allophonic palatalization, while the effect size of the tongue root remains similar across palatalization types.

Keywords: palatalization, ultrasound speech research, [Advanced Tongue Root].