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Variation in the realization of Ukrainian back fricatives as onset lenition and non-markedness reducing coda neutralization: a 3D/4D ultrasound study

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A 3D/4D ultrasound analysis of Ukrainian back fricatives provides evidence for onset lenition (debuccalization) and non-markedness reducing place neutralization in the coda (neutralization to the uvular place of articulation). These findings impinge on the role of markedness in predicting synchronic alternations and the direction of sound change. Analyses that rely on markedness as a motivating factor for synchronic patterns of alternations allow for the possibility of coda lenition, but not of onset lenition. However, the analyzed data instantiate debuccalization, a type of lenition, in the onset. Moreover, the observed retraction of place in the coda, resulting in uvular fricatives, is similarly difficult to derive from markedness principles. These findings are not compatible with the view that synchronic alternations must be driven by markedness reduction and suggest that (i) models of synchronic phonology must be designed in such a way as to accommodate segmental alternations that are arbitrary from the point of view of markedness principles, and (ii) reduction of representational complexity cannot be reliably viewed as the driver of neutralization processes.

1 Introduction

Traditional descriptions of Ukrainian identify two contrastive back fricatives, the voiceless one and the voiced one. The voiceless one is uncontroversially velar. There is disagreement in the descriptions of Ukrainian about the place of articulation of the voiced fricative. It is described as either laryngeal /ɦ/, pharyngeal /ʕ/ or velar /ɣ/. We aim to fill the gap in the knowledge by providing the results of an instrumental study of the two back fricatives using 3D/4D ultrasound imaging.

In addition to providing instrumental phonetic evidence, this study has a bearing on the purported role of universals in phonological analyses. The findings of this study have important theoretical implications for the role of markedness in synchronic alternations and diachronic change. Markedness refers to a set of universal principles that govern linguistic systems and which “guide language toward the unmarked” (Hume 2011: 80). Markedness is related to articulatory complexity. Marked sounds involve more articulatory complexity than unmarked sounds, which means that marked sounds require more effort than unmarked sounds (Kirchner 1998). Articulatory complexity is in turn related to representational complexity in the sense that marked sounds show more complex representations than unmarked sounds (Cho 1990). The theory of markedness has two very specific predictions for synchronic alternation patterns and directionality of diachronic changes. First, weak prosodic positions are predicted to be the subject of lenition, conversely, strong prosodic positions should be immune to lenition (Beckman 1998; Lombardi 1999). Second, the output of neutralization should be less marked than the input(s) (or at least it should not be more marked than the input) (Kiparsky 2006). Yet, the results of the current study are inconsistent with these predictions.

First, we confirm that the voiced fricative /ɣ/ is changed into a laryngeal fricative [ɦ] in the onset. This is an instance of debuccalization (the loss of oral place of articulation), which is a type of lenition. According to the theory of markedness, lenitions are driven by the demands to conserve articulatory effort and in this sense are motivated by markedness reduction (Kirchner 1998). Lenitions are expected in weak prosodic positions such as the coda. Insofar as the onset is a strong prosodic position, lenition is not predicted to occur there (unless it occurs in all positions). In fact, strong positions are protected against lenitions and neutralizations with dedicated constraints (Beckman 1998; Lombardi 1999), while weak positions are not similarly protected. However, evidence from the direct articulatory study of Ukrainian shows that debuccalization occurs in the onset, contrary to what markedness predicts. This indicates that sound change and the resulting synchronic patterns are not always required to reduce markedness, contra e.g. Kiparsky (2006) and de Lacy (2006).

In the second part of the ultrasound study, it is found that the front/back position of the tongue reveals a pattern of neutralization in the place of articulation, in which the voiced /ɣ/ and the voiceless /x/ are neutralized to the uvular fricatives [ʁ] and [χ], respectively, in the coda. This pattern is problematic for markedness-based approaches, as [ʁ] and [χ] are not less marked than [ɣ] and [x] and are thus not expected as outputs of neutralization. It follows that the theory of markedness is too restrictive to be useful in explaining the Ukrainian patterns. It is proposed that markedness should not be invoked to predict and explain synchronic alternations and diachronic change. A corollary is that representational complexity, reflecting articulatory complexity, cannot be viewed as the driver of neutralization processes.

The paper is structured as follows. The next section offers some background information about Ukrainian back fricatives. Section 3 lays out the experimental design and presents the results of the articulatory study. In section 4, a formal analysis is provided. Section 5 focuses on the implications of the findings for the theory of markedness. In section 6, additional counterexamples to markedness universals are discussed. Section 7 recapitulates the main conclusions.

2 Background

Ukrainian descriptive sources mention two back fricatives: voiceless and voiced. The voiceless one is velar, /x/. The sources differ on the place of articulation of the voiced fricative. It is classified as either laryngeal /ɦ/ or pharyngeal /ʕ/ with a possible positional velar variant [ɣ]. Both Ziłyński (1932: 101–102) and Shevelov (1977) argue that it is laryngeal. Rusanovskij et al. (1986: 23) describe it as a pharyngeal fricative, with a possible positional velar variant /x/ before /k/ and /t/, e.g. /lɛɣkɔ/ 'light' realized as [lɛxkɔ]. Toc'ka (1981: 83) also classifies it as a pharyngeal fricative and provides a more detailed description. During its articulation the tongue root is moved backwards and as a result the back wall of the pharynx is close to the tongue root (Toc'ka 1981: 83). The articulation of the voiced fricative according to Toc'ka (1981) is shown in **Figure 1**.[1] Zhovtobryux & Kulyk (1972: 127) refer to it as a voiced laryngeal or pharyngeal fricative, with the positional variant /x/ appearing before voiceless consonants. Danylenko & Vakulenko (1995: 12) classify it as a voiced pharyngeal consonant, with voiceless variants /h/ or /x/ before voiceless consonants. Danylenko & Vakulenko (1995: 3) mention that there are 3 main groups of dialects of Ukrainian corresponding to the territories where they are spoken: South-Eastern, South-Western and Northern. None of the sources mention dialectal variation in the realization of the two back fricatives. However, we cannot rule out such a possibility.

[1] It is not clear whether the schematization in **Figure 1** is based on instrumental evidence.

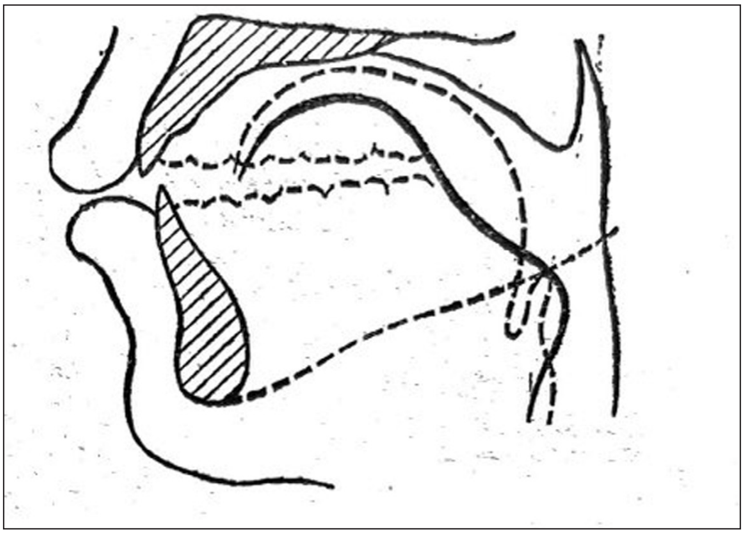

Figure 1: The shape of the tongue during the articulation of the voiced fricative, shown as the solid line (Toc'ka 1981: 83).

Based on acoustic evidence, Pompino-Marschall et al. (2016: 355) report that the laryngeal variant of the fricative appears before vowels, while the voiced velar variant is likely to occur before voiced consonants. The study involved one speaker. In another acoustic study, Vakulenko (2019: 42–43) found that the voiced fricative appears in three partially positional variants: laryngeal, pharyngeal and velar. The laryngeal and pharyngeal variants appear in free variation before vowels, while the velar variant appears before consonants and in the coda. The study also involved one speaker. The results of both acoustic studies reported here should be approached with caution, as they involved just one speaker each. More instrumental evidence is needed to draw reliable conclusions.

Traditional descriptions do not identify contextually conditioned realizations. Both /x/ and /ɦ/ may occur in either onset or coda, word-initially, word-internally or word-finally.

(1) /x/ voiceless velar: /xata/ 'hut', /pux/ 'down', /muxa/ 'fly'
/ɦ/ voiced laryngeal: /ɦarnɔ/ 'well', /bɔɦ/ 'god', /vaɦa/ 'weight'

In contrast, Czaplicki (2006) argues that the voiced fricative has two syllable-conditioned allophones, as shown in (2). Czaplicki's (2006) description is largely consistent with the results of the acoustic study reported in Vakulenko (2019). Insofar as Czaplicki's (2006) description relies on auditory perception and Vakulenko's (2019) acoustic study is based on limited data, a complementary articulatory study is necessary to verify these claims. This study aims to fill this gap in the knowledge by providing instrumental measurements using 3D/4D ultrasound imaging. The current study will help determine the exact place of articulation of the two fricatives.

(2) Syllable-conditioned allophones of back fricatives (Czaplicki 2006)
/x/ voiceless velar
◦ [xata] ‘hut’, [pux] ‘down’
/ɦ/ voiced
◦ onset: laryngeal [ɦ]
[ɦarnɔ] ‘well’
◦ coda: velar [ɣ]
[bɔɣ] ‘god’

Most of the sources concur that the two fricatives have palatalized variants before the vowel /i/ (Toc’ka 1981; Rusanovskij et al. 1986; Danylenko & Vakulenko 1995; Czaplicki 2006; Pompino-Marschall et al. 2016; Vakulenko 2019). In sum, the cited sources describe the voiceless fricative as velar. The articulation of the voiced fricative is less certain. The fricative is laryngeal or pharyngeal and is likely to have a positional velar variant. According to some sources, the laryngeal and pharyngeal variants appear before vowels and the velar variant appears before consonants and in the coda.

In order to better understand the status of back fricatives in modern Ukrainian, it is useful to examine their historical provenance and their phonological behavior in modern Ukrainian. Let us first consider the two fricatives from the historical perspective. The articulation of the voiceless fricative /x/ has been relatively stable in Ukrainian. Cognates in other modern Slavic languages also show /x/.[2] The synchronic voiced fricative /ɦ/, on the other hand, is a result of a series of changes in the history of Ukrainian. Based on historical evidence, Shevelov (1977) argues that the voiced fricative /ɦ/ developed from the voiced velar fricative /ɣ/, which in turn can be traced to the voiced plosive /g/. The latter shows up in cognates in other modern Slavic languages.[3] The intermediate stage, spirantization to the velar /ɣ/, was completed by the early 13th century. As a result, /ɣ/ appeared throughout the Ukrainian territory (this development is shared by Belarussian). Trubetzkoy (1924) argues that the basic motivation for the change of /g/ to /ɣ/ was morphophonological. Shevelov (1977: 147–148) places the subsequent change into the laryngeal/glottal /ɦ/ around the 16th century, though he notes that it was “phonemically and morphophonemically inconsequential”. The historical development of the Ukrainian voiced spirant is summarized in (3). Shevelov (1977) does not discuss the synchronic variation of the spirant in modern Ukrainian.

(3) Development of the modern voiced fricative /ɦ/

		Late 12th c./early 13th c.		16th c. (tentative)
/g/	→	/ɣ/	→	/ɦ/

[2] For example, Polish [dux], Russian [dux], Bosnian-Croatian-Serbian [dux] ‘soul, spirit’.
[3] For example, Polish [bog-a], Russian [bog-a], Bosnian-Croatian-Serbian [bog-a] ‘god’ gen. sg.

Czaplicki (2006) argues based on system-internal and structural evidence that the basic variant of the voiced fricative in the synchronic phonology of modern Ukrainian is the velar /ɣ/. The first argument comes from inventory symmetry. If it is assumed that /ɦ/ is the basic variant, the phonemic inventory shows gaps, as in (4a). Both /x/ and /ɦ/ lack their voiced/voiceless counterparts. On the assumption of /ɣ/ as the basic variant, on the other hand, the system is symmetrical, as depicted in (4b). Symmetrical systems are generally favored over non-symmetrical systems in the languages of the world, as they tend to use more efficiently the various dimensions on which sounds vary in the inventory (Martinet 1939; Clements 2003).

(4) a. k x –
g – ɦ
b. k x
g ɣ

The second argument supporting the underlying /ɣ/ is based on alternations exemplifying the process of palatalization shown in (5) (Czaplicki 2006). The process in (5) gets a uniform formulation as long as the three segments it applies to are represented as velar: /k x ɣ/. The velars correspond to the postalveolars [tʃ ʃ ʒ] before the /-ɛ/ of the vocative singular. In contrast, on the assumption of the non-symmetrical system, i.e. /k x ɦ/, the process cannot be stated equally efficiently, as the input segments are comprised of the velars /k x/ and the laryngeal /ɦ/.

(5) a. [k] : [tʃ]: [junak] ‘young man’ – [junatʃ-ɛ] (voc.)
b. [x] : [ʃ]: [jawtux] ‘a first name’ – [jawtuʃ-ɛ] (voc.)
c. [ɣ/ɦ] : [ʒ]: [druɣ] ‘friend’ – [druʒ-ɛ] (voc.)

The third argument refers to the architecture of Autosegmental Phonology, as implemented by, for example, Cho (1990). Assuming that [ɣ] is Dorsal and [ɦ] is a Place-less laryngeal sound, the change of /ɣ/ → [ɦ] involves the delinking of the Place node (debuccalization). The reverse change, i.e. /ɦ/ → [ɣ], requires a rule inserting the Place node (buccalization). Delinking rules are generally preferred over insertion rules because they are simpler to formulate in terms of autosegments. This preference follows from the fact that debuccalization (a type of lenition) is more typologically common than buccalization (see section 5 for examples). Additionally, an insertion of a Dorsal node cannot be explained as a default process because it is Coronal that is usually regarded as the default place of articulation (Paradis & Prunet 1991). Consequently, some other account would have to be proposed for the choice of Dorsal place over Coronal place.

In sum, historical, theoretical, typological and system-internal considerations point to the velar /ɣ/ as the basic or underlying variant of the voiced fricative in modern Ukrainian. For these reasons and to avoid confusion, the voiced fricative will be denoted as /ɣ/ in the remainder of this paper. This is a departure from the traditional descriptions cited above, which classify it as laryngeal /ɦ/ or pharyngeal /ʕ/. The voiceless fricative is uncontroversial and will be marked as /x/.

3 Experiment

In this section, we present the results of a 3D/4D ultrasound study of the Ukrainian back fricatives. In terms of articulation, the two back fricatives should differ in the position of the tongue dorsum. For velar fricatives, the back of the tongue should be relatively raised but not retracted (Ladefoged & Johnson 2011: 170). No raising is expected for laryngeal fricatives (Ladefoged & Maddieson 1996: 326). In fact, tongue body position for laryngeal fricatives should anticipate the position of the tongue used for the articulation of the following vowel (Keating 1988). In contrast, raising and retracting the tongue dorsum would be indicative of a uvular articulation (Delattre 1972; Lawson et al. 2018; Alwabari 2020).

Assuming that the voiced fricative is underlyingly a velar /ɣ/, debuccalized in the onset, we expect that it would be realized with raising of the tongue dorsum (TD) in the coda and no raising in the onset, as in (6). Onset debuccalization is referred to as Hypothesis I (H1).

(6) H1 for the articulatory study: Onset debuccalization
There is raising of TD in the coda.
There is no raising of TD in the onset.

The second hypothesis that we test is that the voiced fricative /ɣ/ and the voiceless fricative /x/ are articulated farther back in the coda than in the onset. It is stated as H2 in (7). Although this pattern has not been instrumentally verified thus far for Ukrainian fricatives to our knowledge, it is worth exploring, as neutralization in the coda is cross-linguistically common (see section 5). If confirmed, the hypothesis will mean that there is coda neutralization of the two fricatives to a uvular place of articulation. The resulting sounds are represented as [ʁ] for /ɣ/ and [χ] for /x/.

(7) H2 for the articulatory study: Coda place of articulation neutralization
The TD for the fricatives /x/ and /ɣ/ in the coda is farther back than in the onset.

The third hypothesis (H3) is based on the descriptive studies cited in section 2 and proposes that the two fricatives have palatalized variants before the high front vowel /i/.

(8) H3 for the articulatory study: Palatalized variants of the fricatives before /i/.
The TD is raised and moved forward for /x/ and /ɣ/ before /i/.

3.1 Design

For the purposes of this ultrasound study, we evaluate the place of articulation of a consonant by measuring the relative height and front/back position of the tongue dorsum at the point of the maximal elevation as visible in the ultrasound image. The results are then compared across the two fricatives, /x/ and /ɣ/, across the two syllable positions: the onset and the coda, and in the context of different vowels.

Stimuli are words that contain the voiceless and voiced fricatives in either onset or coda. The stimuli are real words of 1–3 syllables. The investigated fricatives are always in stressed syllables in line with the evidence that articulatory gestures in stressed syllables, compared to those in unstressed ones, show greater movement range, increased duration, and greater resistance to coarticulation (Beckman & Edwards 1994; de Jong 1995; Cho & McQueen 2005).[4] The word-medial context was not studied.[5] The onset fricatives are also word-initial, while the coda fricatives are also word-final. Several of the words are morphologically complex (e.g. /ˈɣutʃ-n-ɔ/ 'loudly' ~ /ˈɣuk/ 'noise, sound'), but this should not impact the results, as the relevant fricatives are word peripheral (the fricatives are not adjacent to internal morphological boundaries). The fricatives are investigated in the context of six vowels: /a/, /ɛ/, /i/, /ɔ/, /u/, and /ɨ/. The list of stimuli is provided in Appendix A.

The data were collected in the Speech Lab at Indiana University, Bloomington, from 9 native speakers of Ukrainian, aged 23–60. All the participants declared that they speak standard Ukrainian. We made sure that the participants had no articulatory problems and did not use prosthetics. All the participants knew Russian, but they all declared Ukrainian as their first language. 4 of the participants had spent 10–20 years in the USA, 2 participants had been there for 1–2 years and 3 were there on a short-term visit (less than 6 months). We did not analyze data from one participant, as they used a mixture of Ukrainian and Russian.[6] 5 of the accepted participants took part in previous experiments conducted by the second author.[7]

[4] The words are of different length (1–3 syllables). While we cannot rule out that word length could have some effect on the results, we believe that there is more compelling evidence for the influence of stress on articulatory gestures. Stress was controlled for in the data.

[5] It is possible that the word-medial context (VɣV) is different from the word-initial context for the onset position. Similarly, the word-medial position for the coda consonant (VɣCV) might be different from the word-final context. Relatedly, recall from section 2 that in words like /lɛɣkɔ/ 'light' the voiced fricative can be devoiced to /x/ before a voiceless consonant: [lɛxkɔ] (Rusanovskij et al. 1986: 23). Thus, articulation in the word-medial context depends on the quality of the following consonant. In addition, an investigation of the word-medial context would need to take into consideration morphological structure. We leave the word-medial context for future research.

[6] The excluded speaker in place of the expected voiced fricative used the voiced plosive [g]. This usage is indicative of "surzhyk", a speech variety showing a mixture of Ukrainian and Russian phonological, morphological, syntactic and lexical characteristics.

[7] As mentioned in section 2, we cannot rule out the possibility that there is (unidentified thus far) dialectal variation in the realization of the two fricatives. However, due to the limited access to Ukrainian speakers in Bloomington, USA, we could not address this issue properly. We must leave it for future studies.

The test items were presented in the Ukrainian orthography on the screen. The task was to read the presented words in isolation at a normal pace. The data were recorded with the Philips EpiQ7G system using an xMatrix x6-1 digital 3D transducer secured under the chin using an Articulate Instruments ultrasound stabilization headset. The acoustic signal was recorded with a microphone placed 1 meter in front of the participant. In the evaluation of the ultrasound images, we measure the relative height of the tongue dorsum at the point of the maximal elevation. The established point of maximal elevation on the y-axis was then used to obtain the position of tongue dorsum on the x-axis to determine the degree of tongue dorsum fronting/backing. For the analysis of images, we use a custom Matlab toolbox WASL, which is an open-source MATLAB-based software, originally developed by Steven Lulich to handle 3D/4D ultrasound data (Lulich et al. 2018; Lulich 2020). **Figure 2** is an example of an ultrasound image that was used for further analysis. We use for the analysis the frames closest to the mid-point of the fricative. The shape of the tongue was traced using the WASL toolbox in Matlab. 24 tokens for each speaker were analyzed, 192 tokens in total.

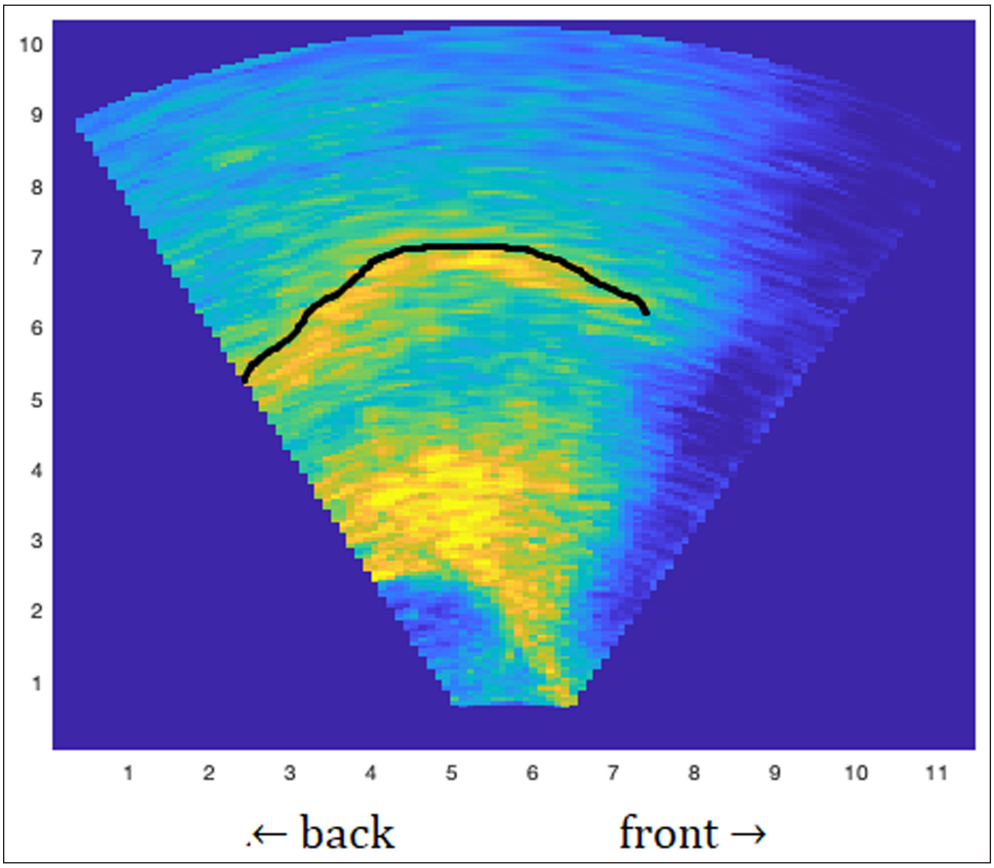

Figure 2: Mid-sagittal view of the tongue dorsum during the production of /x/ for one speaker.

Figure 3 shows an example of the manual tracing of the shape of the tongue surface for Speaker 1. The figure shows overlaid shapes of the tongue for the voiceless and voiced fricatives in the onset and coda in the context of the vowel /a/. To represent the voiceless fricative, we use the symbol /x/, and for the voiced fricative – the symbol /ɣ/. The vowel symbol encodes the syllable position of the represented fricative. Thus, /xa/ and /ax/ stand for the voiceless fricative in the onset and coda, respectively, and similarly, /ɣa/ and /aɣ/ stand for the voiced fricative in, respectively, the onset and coda. The dotted curve labeled /a/ represents the tongue surface during the production of the vowel /a/. The lowest position of the tongue dorsum is found for the voiced fricative in the onset (/ɣa/). The voiceless fricative in both syllable positions (/xa/ and /ax/) and the voiced fricative in the coda (/aɣ/) show similar elevations of the tongue. The vowel /a/ shows an intermediate elevation of the tongue, between the elevation typical for the voiced fricative in the onset /ɣa/ and the voiced fricative in the coda /aɣ/. The results from Speaker 1 in **Figure 3** are consistent with the hypothesis that the voiced fricative is laryngeal in the onset, with no raising of the tongue dorsum. In contrast, the tongue dorsum in the voiced fricative in the coda is raised, which is consistent with the velar articulation.

The raising of the tongue root and retraction of the tongue dorsum in the voiced and voiceless fricatives in the coda position, visible in **Figure 3**, is also consistent with uvular articulation. Notice that for the speaker in **Figure 3** both the voiceless fricative /ax/ and the voiced fricative /aɣ/

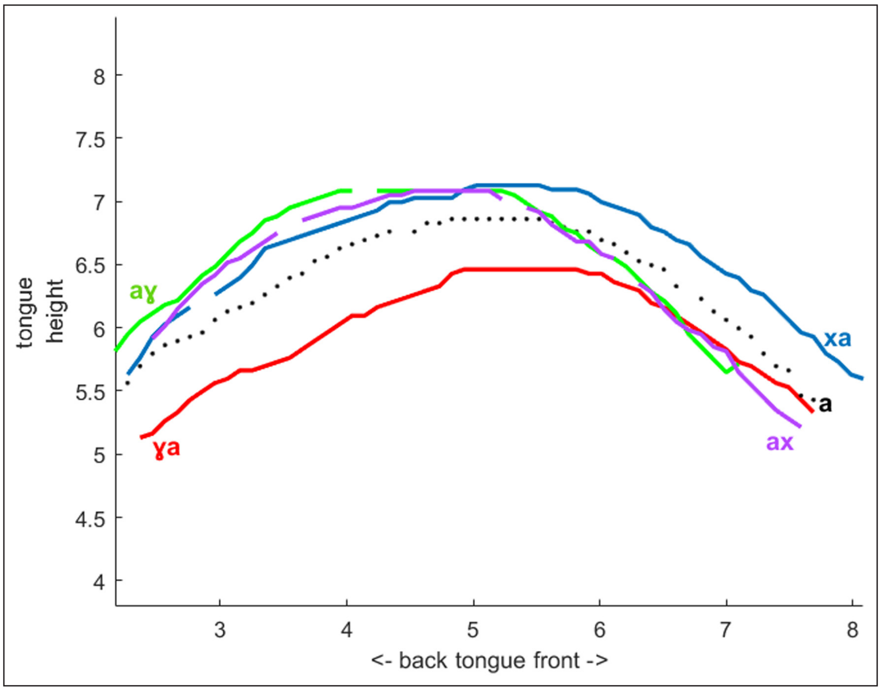

Figure 3: Tongue surface for /x/ and /ɣ/ in the onset and coda in the context of the vowel /a/ for Speaker 1.

in the coda show overall high similarity. In particular, both fricatives in the coda are more retracted than the voiceless velar one in the onset /xa/. The next section aims to determine whether these results can be generalized.

3.2 Statistics

In the following sections, we attempt to verify H1, H2 and H3. We test the impact of various predictors on the height (sections 3.2.1 and 3.2.2) and front/back position of the tongue (sections 3.2.3 and 3.2.4) during the articulation of the two fricatives.

3.2.1 Tongue height

Statistical analyses were conducted in the R environment (R Development Core Team 2010). We used linear mixed effects models to analyze the influence of the fixed effects FRICATIVE (x, ɣ), VOWEL (a, ɛ, i, ɔ, u, ɨ), POSITION (coda, onset) on the dependent variable TONGUE HEIGHT. In addition, all interactions of the predictor variables were included into the initial model.

To account for variability among speakers and to minimize Type I error (Barr et al. 2013), random intercepts for participants and words as well as by-speaker slopes for FRICATIVE, VOWEL and POSITION were included as well.[8] By means of ANOVAs, the maximized model was tested against less complex models and the best-fit model was taken as a final model. All p-values were based on Satterthwaite approximation available in the package “lmerTest” (Kuznetsova et al. 2015), providing different kinds of tests for linear mixed-effects models implemented in the “lme4” package (Bates et al. 2015). The factor predictors were coded with treatment contrasts: FRICATIVE was coded as x (reference) > ɣ, POSITION was coded as coda (reference) > onset and VOWEL was coded as a (reference) > ɛ > i > ɔ > u > ɨ. The results of the linear mixed effects regression are provided in Appendix B. In section 3.4, an analogous analysis will be used to determine the influence of FRICATIVE, VOWEL and POSITION on the front/back position of the tongue (FRONT/BACK POSITION OF TONGUE) for the two fricatives.

3.2.2 Results

The best-fit model included the following predictors: FRICATIVE, POSITION, and VOWEL as well as two interactions FRICATIVE by POSITION and POSITION by VOWEL. The interactions FRICATIVE by VOWEL and FRICATIVE by POSITION by VOWEL were not included in the final model, as they worsened the fit of the model (based on ANOVA). **Figure 4** shows the results for the tongue height in the two syllable positions: coda versus onset (predictor: POSITION). The tongue is higher for coda fricatives than for onset fricatives. The difference is statistically significant (coda 6.859 cm vs. onset: 6.743 cm, $t = –2.547$, $p = .01$).

[8] The tongue height was measured from the surface of the probe to the surface of the tongue. Between-speaker anatomical differences were controlled for by including by-speaker slopes into the model.

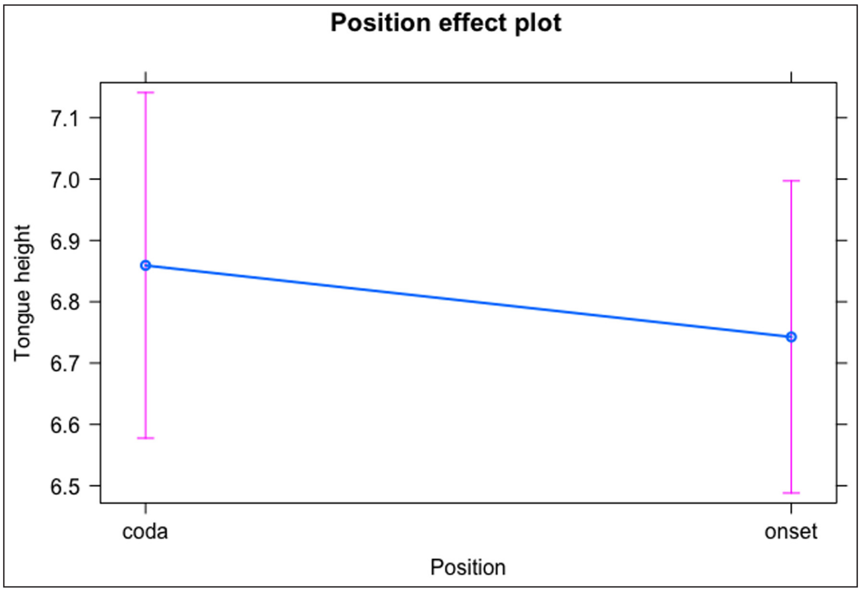

Figure 4: The effect of POSITION on TONGUE HEIGHT.

Figure 5 shows the crucial predictor of the tongue height: the interaction of POSITION in the syllable and FRICATIVE. The results reveal that the largest differences between the two fricatives are found in the onset (the second panel). The tongue dorsum is placed higher for /x/ than for /ɣ/. In the coda the two fricatives show similar tongue height (the first panel). The interaction of FRICATIVE and POSITION is significant (/x/ coda: 6.888 cm, /ɣ/ coda: 6.830 cm, /x/ onset: 6.874 cm, /ɣ/ onset: 6.62 cm, $t = -4.027$, $p < .001$).

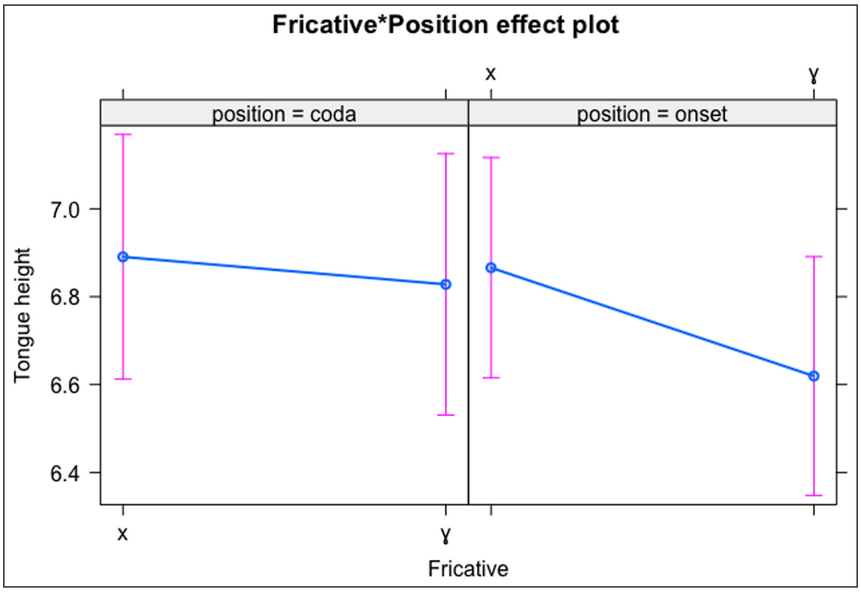

Figure 5: The effect of FRICATIVE by POSITION on TONGUE HEIGHT.

The effects of the predictor VOWEL did not reach statistical significance. However, the *interaction* of VOWEL and POSITION was statistically significant for vowels /i/ ($t = 2.903$, $p < .01$), /ɨ/ ($t = 3.509$, $p < .001$), and /ɔ/ ($t = 2.385$, $p < .05$) in comparison against the vowel /a/. Further, vowel /i/ was different from vowel /a/ ($t = –2.906$, $p < .01$). Vowel /ɔ/ was different from vowel /a/ ($t = –2.384$, $p < .05$). Vowel /u/ was different from vowel /ɨ/ ($t = 2.132$, $p < .05$). Vowel /ɨ/ was different from vowels /a/ ($t = –3.507$, $p < .001$) and /u/ ($t = –2.131$, $p < .05$). As shown in **Figure 6**, these results mean that when the fricative is in the onset and when the adjacent vowel is /i/, /ɨ/ or /ɔ/, the tongue during the production of the two fricatives is significantly higher than when the adjacent vowel is /a/. Given that /i/, /ɨ/ are high vowels[9] and /a/ is a low vowel, these results constitute evidence for a degree of coarticulation between the fricatives and adjacent vowels.[10] In other words, the tongue height during the production of the onset fricatives is influenced to a significant extent by the tongue height used for the following vowel.[11] This finding is elaborated below.

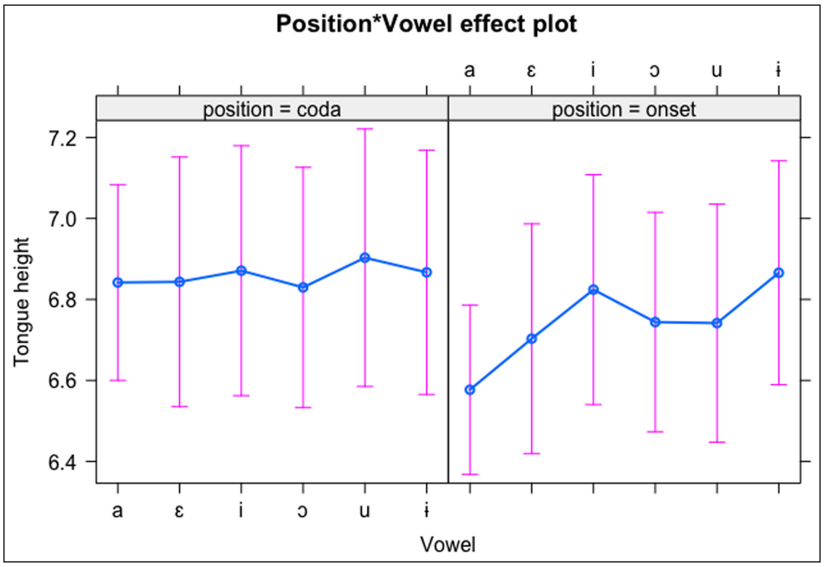

Figure 6: The effect of VOWEL by POSITION on TONGUE HEIGHT.

[9] According to Pompino-Marschall et al. (2016), the vowel labeled here as /ɨ/ phonetically is a front vowel close to [ɪ].

[10] For the back vowels /u/ and /ɔ/, the results are less straightforward. The vowel /ɔ/ appears to be more different from the vowel /a/ than the vowel /u/. This might have to do with the fact that the articulatory space in the back of the oral cavity is smaller than the space in the front.

[11] Following a reviewer's suggestion, a post-hoc correction was applied, as the predictor VOWEL has six levels. We ran pairwise comparisons of the different levels of VOWEL by POSITION using the *emmeans* () function in the *emmeans* package (Piepho 2004). The Tukey method was used. Here none of the pairwise comparisons turned out significant. This result, however, is not unexpected, as the variability between the participants in this type of data is very high.

The interaction plot in **Figure 7** shows the three-way interaction of FRICATIVE by POSITION by VOWEL from the maximized model and is used to complement the results shown in **Figure 6**. Although the three-way interaction was not included in the final model (a non-significant effect), it is shown in **Figure 7** to get a better grasp of the results. The *emmip* () function in the *emmeans* package (Piepho 2004) was used. As evident from **Figure 7**, the tongue height is relatively stable in the coda across all the vowels for the two fricatives (the left panel). In the onset (the right panel), on the other hand, the tongue height for /ɣ/ stands out. The values for the tongue height of /ɣ/ in the onset are noticeably lower than the values for the tongue height of /x/ in the same position and for the tongue height of /ɣ/ in the coda. In addition, Figures 6 and 7 demonstrate that the degree of coarticulation between adjacent consonants and vowels is greater for onset consonants than for coda consonants. Finally, it is important to observe that the context of the high vowels /i/ and /ɨ/ shows up in the results as the most different from the /a/-context for the voiced fricative in the onset. Recall from section 3 that laryngeal fricatives, to a larger extent than velar fricatives, tend to anticipate the position of the tongue of the following vowels. /i/ and /ɨ/, being high vowels, require the maximum raising of the tongue from the position required for /a/.

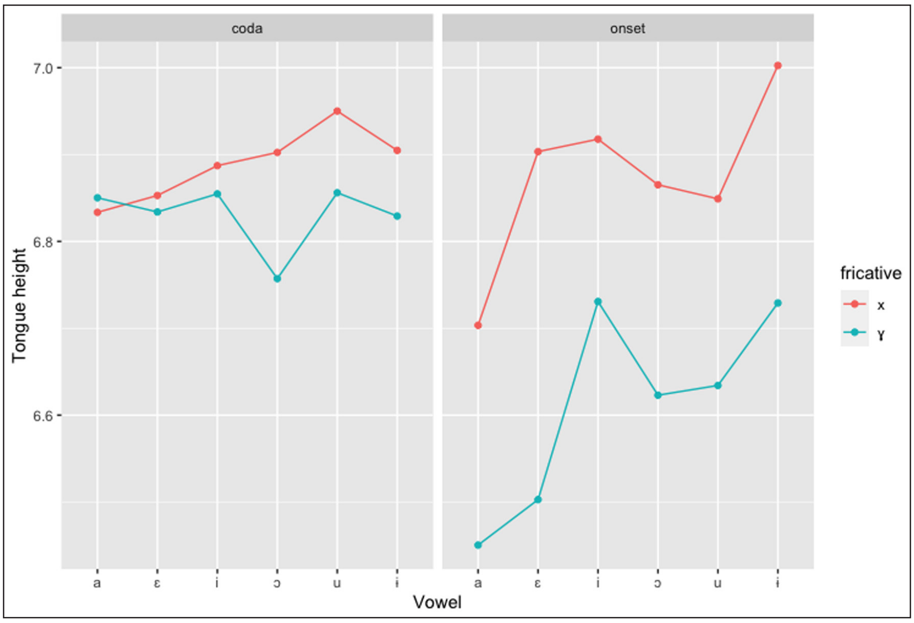

Figure 7: The effect of FRICATIVE by POSITION by VOWEL on TONGUE HEIGHT.

The different influence of adjacent vowels on the two fricatives in different positions, shown in Figures 6 and 7, makes sense if (i) the voiceless fricative is dorsal, and (ii) the voiced fricative is dorsal in the coda, but laryngeal in the onset. Dorsal consonants use the tongue as the active articulator, which means that in the CV context the tongue is already raised before the vowel is initiated. In contrast, in the articulation of laryngeal consonants the tongue is not the active articulator, which means that it will anticipate the position of the tongue of the following vowel (Keating 1988) (analogously in the VC context). In other words, we expect tongue raising during the production of dorsal fricatives, but no raising for laryngeal consonants. This is what we find in the results shown in **Figure 7**. The voiceless fricative is dorsal (raising). The voiced fricative is dorsal in the coda (raising), but laryngeal in the onset (no raising).[12]

In summary, these results are fully consistent with H1, which states that /ɣ/ is laryngeal in the onset, but velar or uvular in the coda.[13] In other words, /ɣ/ is debuccalized in the onset. In addition, the analysis provides evidence suggesting a significant degree of coarticulation of the fricatives with adjacent vowels. We return to this issue in section 3.2.4.

(9) Underlying /ɣ/ is laryngeal (no tongue dorsum raising) in the onset; it is velar or uvular in the coda (tongue dorsum raising).

Figure 8 shows a 3D representation of the overlaid tongue shapes of the tongue for the two realizations of /ɣ/: in the onset (visible as the lower shape) and in the coda (visible as the higher shape).[14]

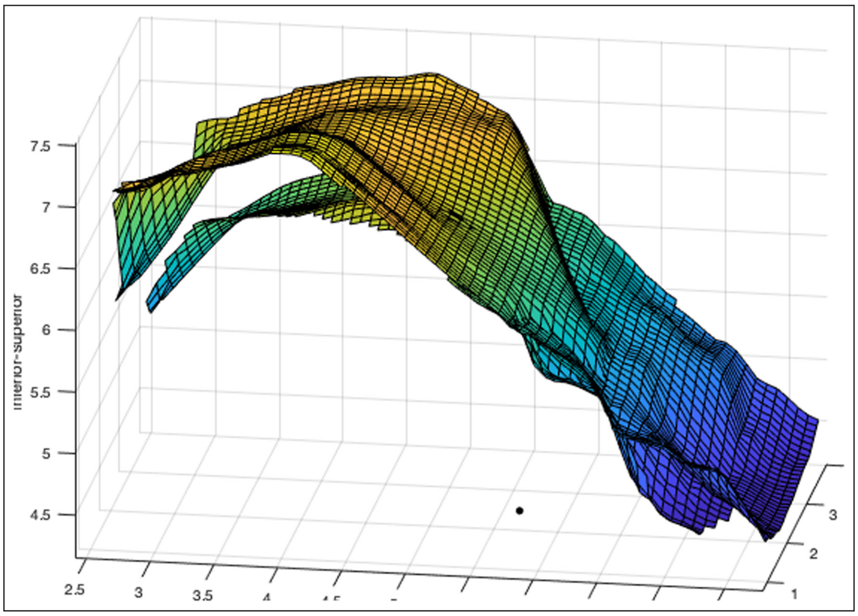

Figure 8: Overlaid shapes of the tongue for the two contextual variants of /ɣ/: lower – laryngeal [ɦ], higher – velar or uvular [ɣ]/[ʁ].

[12] The fact that the effect of the three-way interaction FRICATIVE by POSITION by VOWEL (**Figure 7**) did not reach significance in our analysis probably means that we need a larger sample of participants.

[13] The exact place of articulation of the coda variants of the two fricatives will be determined in the next sections.

[14] The data used to create the image were extracted using SLURP in WASL (Naga Karthik et al. 2020; Lulich et al. 2020).

Finally, taking into consideration the fact that the voiced fricative was originally velar (as discussed in section 2), these findings provide evidence that the velar fricative underwent debuccalization in the onset (/ɣ/ → /ɦ/ in the onset).

3.2.3 Coda neutralization: front/back position of the tongue

In this section we discuss the results of an analysis of the relative fronting or retraction of the tongue dorsum. We hypothesize that the coda realizations of the voiceless and voiced fricatives are relatively retracted as compared to their onset realizations. If the coda realizations turn out to be different (more back) from the onset realizations this will constitute evidence that the coda realizations of the two fricatives are in fact uvular.

Similarly to the analysis of tongue height, for this analysis we established the point of the maximal elevation of the tongue and used the values on the horizontal plane to obtain the front/back position of the tongue dorsum. The front/back position of the tongue dorsum is encoded by the variable FRONT/BACK POSITION OF TONGUE. A linear mixed effects model has been run on the data with FRONT/BACK POSITION OF TONGUE as the dependent variable and FRICATIVE, POSITION and VOWEL as predictors. In addition, interactions of the predictor variables were included into the initial model.

Similarly to the analysis presented in the previous sections, to account for variability among speakers and minimize Type I error (Barr et al. 2013), random intercepts for participants and words as well as by-speaker slopes for FRICATIVE, VOWEL and POSITION were included. By means of ANOVAs, the maximized model was tested against less complex models and the best-fit model was taken as a final model. The coding of factor predictors with treatment contrasts was the same as in the analysis in the previous sections. The results of the linear mixed effects model analysis are presented in Appendix B.

3.2.4 Results

The best-fit model included the predictors FRICATIVE, POSITION and VOWEL. None of the interactions were included in the final model, as they did not improve the fit of the model. **Figure 9** shows the effect of syllable position (POSITION) on the front/back position of the tongue dorsum for the fricatives (FRONT/BACK POSITION OF TONGUE). Higher values of FRONT/BACK POSITION OF TONGUE indicate a more front position of the tongue dorsum. In the coda, the two fricatives are articulated farther back than they are in the onset. The difference is statistically significant (coda: 5.32 cm, onset: 5.66 cm, $t = 4.428$, $p < .001$). There was no significant effect of FRICATIVE. The interaction of FRICATIVE and POSITION was not included in the final model, as its effect was not significant and its inclusion worsened the fit of the model (based on ANOVA).

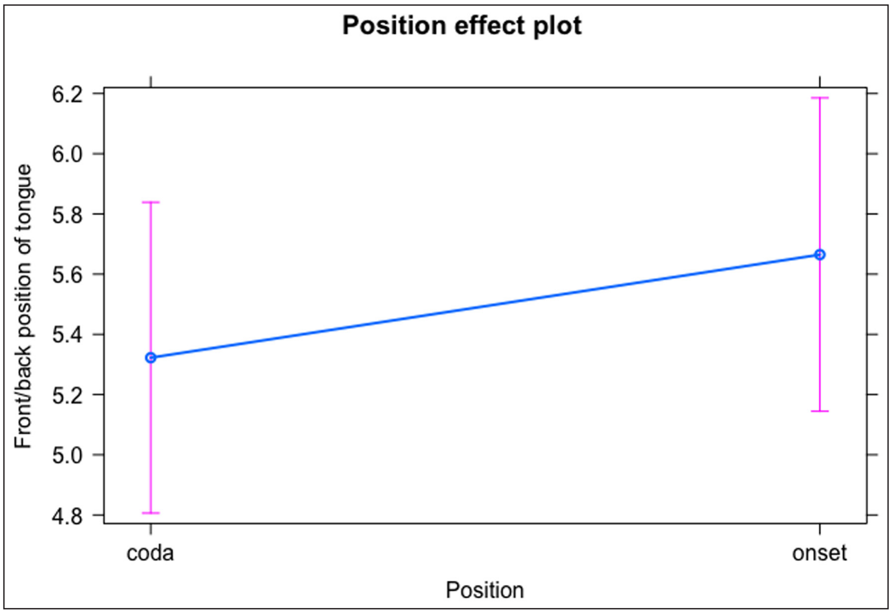

Figure 9: The effect of POSITION on FRONT/BACK POSITION OF TONGUE.

Figure 10 shows the effect of vowel quality (VOWEL) on tongue fronting of the fricative (FRONT/BACK POSITION OF TONGUE). In comparison to vowel /a/, vowel /i/ causes a significant effect of tongue fronting for adjacent fricatives (t = 3.047, p = .016). Vowels /ɨ/ and /ɛ/ also cause tongue fronting, but this effect reaches only the level of a statistical trend: t = 2.002, p = .08 for /ɨ/ and t = 1.853, p = .094 for /ɛ/. There is no tongue fronting for vowels /u/ and /ɔ/. Further, vowel /ɛ/ was different from vowels /ɔ/ (t = –2.661, p < .05) and /i/ (t = 2.363, p < .05). Vowel /i/ was different from all the other vowels: /a/ (t = –3.047, p < .05), /ɔ/ (t = –3.360, p < .01), /u/ (t = –2.870, p < .05), /ɛ/ (t = –2.363, p < .05) and /ɨ/ (statistical trend, t = –2.164, p = .066). Vowel /ɔ/ was different from vowels /i/ (t = 3.361, p < .01), /ɛ/ (t = 2.662, p < .05) and /ɨ/ (t = 2.589, p < .05). Vowel /u/ was different from vowel /i/ (t = 2.869, p < .05). Vowel /ɨ/ was different from vowel /ɔ/ (t = –2.590, p < .05).[15] These results can be explained once we take into consideration the quality of the vowels: for front vowels the tongue dorsum is fronted unlike for back vowels. Among the front vowels, vowel /i/ shows the largest degree of tongue fronting. Thus, the results represented in **Figure 10** show that tongue dorsum during the production of the fricatives reflects the front/back position of the tongue used for adjacent vowels, with the strongest effect found for /i/.

[15] Similarly to the analysis of TONGUE HEIGHT, a post-hoc correction using the *emmeans* () function (Tukey method) was used for the predictor VOWEL. None of the pairwise comparisons came out as significant here.

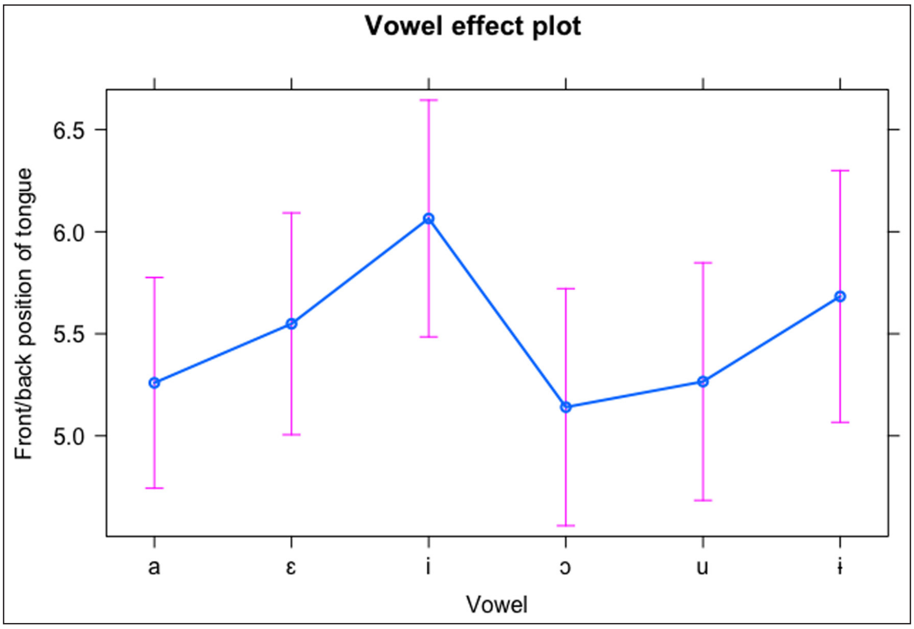

Figure 10: The effect of VOWEL on FRONT/BACK POSITION OF TONGUE.

In sum, the results are consistent with the hypothesis that both the voiced and the voiceless fricative are uvular in the coda (H2). The voiceless fricative is velar in the onset. The fact that the interaction of FRICATIVE and POSITION did not turn out to have a significant effect means that syllable position fully determines the front/back position of the tongue for both fricatives. That is, the two fricatives /x/ and /ɣ/ are articulated as the uvular [χ] and [ʁ], respectively, in the coda. This is an instance of positional neutralization with respect to the place of articulation.

Finally, we have identified effects of coarticulation of the fricatives with adjacent vowels, especially with /i/ (tongue raising and fronting). The results are consistent with hypothesis H3 suggesting that the two fricatives show palatalized variants, [xʲ] and [ɣʲ], in the context of the vowel /i/.[16]

4 Analysis

The results of the articulatory study presented in the previous sections together with the arguments given in section 2 strongly support an account in which the two phonemic back fricatives (voiceless and voiced) do not differ in terms of the place specification in the lexical representation, as represented in (10) (Lar stands for the Laryngeal node).

[16] In fact, tongue raising (significant effect) and fronting (statistical trend) is also observed in the context of the other high front vowel, /ɨ/, but the effects are not as consistent as for the vowel /i/ (significant effects).

(10) Underlying representation of Ukrainian back velars

```
           /x/                  /ɣ/
          /   \                /   \
      Lar   Place          Lar   Place
       /          \          /         \
  [–vd]           Dorsal  [+vd]         Dorsal
```

We propose that the voiced back fricative undergoes debuccalization in the onset, which can be represented as delinking of the Place node.

(11) Debuccalization of /ɣ/

```
          ɣ                           →      ɦ
       /    ǂ                                 |
     Lar  Place  / in the onset              Lar
      /        \                              |
  [+vd]       Dorsal                        [+vd]
```

A representation with a placeless voiced consonant as in (11) yields then a surface laryngeal [ɦ]. The problem with this analysis for markedness-based approaches is that leniting changes of this type are not supposed to happen exclusively in an onset, the latter being a prosodically strong position. The problem challenges the current markedness theory regardless of whether we assume the underlying /ɣ/ or /ɦ/. Looking at the surface distribution of the allophones, having a segment with a specified Place (uvular) in a coda and a Place-less (unspecified for Place) segment in an onset is not expected. The current approaches to markedness theory operate with general constraints against marked representations and universally higher-ranked constraints against marked representations in codas. Current models do not normally assume constraints against the marked representations in onsets only (Beckman 1998). It is expected that lenition may occur in a strong position but only as a part of the general process including a weak position. This is not the case in Ukrainian.

The second important finding is that in the coda the two fricatives are articulated farther back than a model velar in an onset position and, therefore, they are better described as uvular. This is an instance of positionally restricted neutralization with respect to the place of articulation.[17] We consider three approaches to the representation of velars and uvulars in terms of distinctive features. The first approach is based on McCarthy (1994) and Vaux (1999), the second one on Hayes (2009), and the third one on Zsiga (2013).

[17] We do not claim that this is a case of a complete neutralization of the two fricatives in the coda. First, the fricatives differ in voicing. Second, we cannot rule out the possibility that the preceding vowels contain some cues to the contrast. For example, the effect of consonant voicing on the duration of the preceding vowel has been identified in many languages, including English, Russian, and Polish (Maddieson & Gandour 1976).

In the first approach to the representation of velar and uvular fricatives, we refer to the feature [ATR], which stands for advanced tongue root (McCarthy 1994). [+ATR] refers to sounds which show advancement of the tongue root, while [–ATR] characterizes sounds with a retracted tongue root. Following Vaux (1999), it is proposed that velars are specified as [dorsal] and uvulars are [dorsal, –ATR], where the feature [dorsal] specifies a primary articulator and the feature [ATR] specifies a secondary articulator.[18] The feature [ATR] belongs under the articulator Radical (related to the root of the tongue, Vaux 1999). The rule in (12) is a schematic representation of the change of a velar into an uvular in the coda in Ukrainian. The change involves the addition of the [–ATR] feature together with the articulator Radical. The outcome is a segment with the [–ATR] specification, a uvular.

(12) x/ɣ / in the coda → χ/ʁ

x/ɣ		χ/ʁ	
Place	→	Place	
Dorsal		Dorsal	Radical
			[–ATR]

In a different approach, Hayes (2009: 87) treats dorsal consonants as analogous to the closest similar vowel. With relevance to the discussion at hand, (central) velars are specified as [+high, –low, –front, –back], like vowels [ɨ] and [ʉ], while uvulars are represented as [–high, –low, –front, +back], like vowels [ɤ] and [o]. Zsiga (2013: 267) proposes that velars differ from uvulars in the feature [±strident]: velars are [-strident], while uvulars are [+strident]. In addition, uvulars are specified as [+low], while velars are underspecified for this feature.

What all the three approaches share is that the change from velars to uvulars does not reduce structure; the representations of uvulars do not show a reduction in complexity in relation to the representations of velars. This finding will be crucial in the next section, where we consider the implications that each of the three representational approaches has for the theory of markedness and for the typology of neutralizations.

[18] Vaux (1999: 3) suggests that velars use the primary articulator [Dorsal] and are underspecified for [ATR] (see underspecification theory, e.g. Steriade 1995), while uvulars have two articulators, the primary one is [Dorsal] and the secondary one is [–ATR]. The issue of underspecification is not central for the current analysis. What is important is that uvulars have a secondary articulation, marked as [–ATR] (retracted tongue root), and in this way systematically differ from velars, which are either [+ATR] or underspecified for [ATR].

5 Implications for the theory of markedness

The articulatory results presented in the previous sections have implications for the theory of markedness. The concept of markedness dates back to Nikolai Trubetzkoy and Roman Jakobson, two influential representatives of the Prague School. Trubetzkoy (1958) used the term markedness to define relations between sounds that stand in opposition in linguistic systems. One member of the opposition bears a given property (mark), while the other member lacks it. In modern phonological research markedness is defined by reference to typological frequency of sound or phonological structures or by reference to complexity of articulation. A less marked member of a specific opposition tends to be more frequent, easier to produce, more natural and more predictable than a more marked member of this opposition (Hume 2011: 80). In terms of phonological representations, markedness translates directly to complexity of structure. Arsenault (2008: 5) claims that typological rarity of marked sounds is caused by the complexity of articulation. It is important to note that markedness is relative, that is, it makes sense to talk about it when comparing two classes of sounds. Markedness has also been used to mean a set of universal principles that govern linguistic systems and which “guide language toward the unmarked” (Hume 2011: 80).

The main diagnostics that were previously used to assess markedness are language acquisition, typological frequency/token frequency, articulatory difficulty/perceptual distinctiveness, cognitive factors, and phonological patterns (Hume 2011: 88). We focus on phonological patterns and articulatory difficulty/perceptual distinctiveness, as these criteria are particularly relevant for the present study. Moreover, after a careful evaluation of all markedness criteria, Rice (1999) concludes that the strongest arguments for markedness come from synchronic phonological patterns (see de Lacy 2006 for a similar view).

5.1 Markedness in synchronic phonological patterns

Markedness plays a role in predicting the inputs and outputs of phonological processes. Some preferences are given in (13) (Rice 1999, 2007).

(13) Examples of markedness reduction
- Assimilation – targets are unmarked, triggers are marked
- Epenthesis – epenthetic consonants are unmarked
- Deletion – targets are unmarked
- Neutralization – outputs of neutralization are unmarked.

More marked features resist assimilation, while less marked features are subject to assimilation (Rice 1999). For example, coronals in Korean assimilate to dorsals or labials. A labial assimilates to a dorsal but fails to assimilate to a coronal. A dorsal does not assimilate to either a labial or coronal. This follows from the universal scale of markedness in (14), where coronals are the least marked and therefore the most susceptible to assimilation across languages.

(14) Universal markedness scale of major places of articulation based on assimilation patterns (Hume 2011).
dorsal > labial > coronal

Unmarked segments are subject to epenthesis, marked segments are not. Glottals are epenthesized in German and coronals in Axininca Campa (Payne 1981). This has been taken to imply that glottals and coronals are unmarked in relation to other consonants with lingual and non-lingual articulations.

(15) Universal markedness scale of places of articulation based on patterns of consonantal epenthesis (de Lacy 2006)
dorsals, labials > glottals, coronals

The output of neutralization is predicted to be unmarked relative to the input. In Polish, Russian, and other languages, final devoicing produces voiceless obstruents, which implies that voiced obstruents are marked in relation to voiceless obstruents.

(16) Markedness scale of voicing features based on neutralization patterns
voiced obstruents > voiceless obstruents

Croatian has no velar nasals. Additionally, the Chakavian dialect of Croatian neutralizes the contrast between labial and coronal place in nasals in the coda, allowing only coronals in this position (e.g. Galović & Jutronić 2021: 46 and references therein).

(17) Markedness scale of place features based on neutralization patterns
Dorsal > Labial > Coronal

5.2 Positional markedness

The relative markedness of segments/structures is often dependent on position. Minimal Sonority Distance and Syllable Contact serve as examples of well-established principles invoking syllable-conditioned positional markedness. Minimal Sonority Distance states that complex onsets with segments that have a greater sonority distance (e.g. obstruent + liquid) are unmarked relative to those with a small sonority distance or sonority plateaus (e.g. obstruent + nasal or obstruent + obstruent) (Vennemann 1972; Hooper 1976). Syllable Contact defines the preferred relations between adjacent syllables. If there is a heterosyllabic sequence of consonants C1.C2, C1 is preferably more sonorous than C2 (Hooper 1972; Murray & Vennemann 1983; Vennemann 1988).

Neutralization typically applies in weak prosodic positions, such as syllable codas or word-final positions, as opposed to strong prosodic positions, for example, syllable onsets (Beckman 1998). Lenition processes (i.e. reduction in the magnitude or duration of articulatory gestures, Kirchner 1998) are common in a syllable coda, as opposed to fortition processes which can create more marked segments in a syllable onset.[19] Coda lenition is grounded in both perception and articulation. It is perceptually grounded since the perceptual cues of coda consonants are impoverished relative to the cues of onset consonants (Wright 2004). In contrast, lenition in the onset, a strong position, is not phonetically motivated. There is compelling evidence of articulatory differences between onset and coda realizations of consonants. For example, Kirchner (1998) and Blevins (2004) identify a phonetic tendency of gestural undershoot in the coda. Gick et al. (2006) report the results of a study of segments that involve both anterior and posterior gestures in six languages. They found that in the onset, the posterior gesture is delayed with respect to the anterior gesture. In contrast, in the coda, the posterior gesture is achieved prior to the anterior gesture. Proctor (2011) presents evidence that coda vocalization of laterals involves lenition of the tongue tip gesture. Relatedly, Howson et al. (2022) in an articulatory study of laterals in Brazilian Portuguese found that coda vocalization is a result of phonetic effects including lenition of the tongue tip gesture and retraction of the tongue body.

Debuccalization is a process of lenition that results in the loss of oral place features and commonly applies in weak positions. For example, in dialects of Spanish, /s/ became /h/ in the coda and was eventually lost (/s/ > /h/ > ∅). Debuccalization in the coda and subsequent deletion took place in English (/x/ > /h/ > ∅; Lass 1997). Glottals and coronals are common outputs of neutralization (e.g. Malay codas, Basque codas; see de Lacy 2006: 111). Such evidence has been used to argue that glottals are less marked than coronals and dorsals, as schematized in (18). De Lacy (2006: 128–133) makes a categorical claim that dorsals cannot be the output of neutralization or epenthesis.

(18) Markedness scale of place features based on neutralization patterns
dorsals > coronals > glottals

Suprasegmental structures may also be seen as more or less marked. Syllables without an onset are more marked than syllables with an onset, and syllables with a coda are more marked than

[19] A reviewer rightly points out that the current study does not investigate word-medial onsets. There is ample evidence that intervocalic onsets may be subject to different processes than word-initial onsets. For example, some lenition processes occur intervocalically, but not word-initially (e.g. intervocalic lenition in Florentine Italian, Kirchner 1998). However, it should be noted that lenition is more common in word-medial onsets than in word-initial onsets, which likely implies that if a given lenition pattern applies word-initially, it should also apply word-medially. The reverse is not necessarily true. This implicational relation can be applied to the Ukrainian back fricatives in the sense that lenition in word-initial onsets likely implies lenition in word-medial onsets. Yet, it is true that word-medial onsets deserve more attention in future research.

those without a coda. An onset of an unstressed syllable is weaker than an onset of a stressed syllable. In English voiceless stops are aspirated word-initially and word-medially before a stressed vowel, but not before an unstressed vowel (Hayes 2009: 90). Building on such insights, the theory of positional faithfulness has been developed (e.g. Beckman 1998). Constraints penalizing violations in marked positions are universally higher-ranked than general constraints against any given structure. For example, in the Chakavian example adduced above, labial nasals are not prohibited in general but rather they are excluded in the coda position only. The theory is not symmetric, that is, it predicts general constrains and constraints that are activated in the coda, the weak position, but it does not predict the existence of constraints which are active exclusively in the onset with the exception of the coda.

5.3 Markedness as articulatory difficulty and perceptual distinctiveness

Markedness has also been linked to articulatory difficulty and perceptual distinctiveness. The unmarked member of an opposition is predicted to be articulatorily less complex than the marked member (Hume 2011: 94). Kirchner (1998) argues that lenition processes are driven by the requirements to minimize effort. Thus, lenition produces less effortful, i.e. less marked, segments. On this view, debuccalization, the type of lenition which results in a loss of oral place features, is induced by effort minimization.

Flemming (2002) proposes that linguistic inventories and strings of speech are regulated by three conflicting demands: the need to maximize the distinctiveness of contrasts, the need to maximize the number of contrasts, and the need to avoid articulatory effort. Markedness constraints prefer sounds or sequences of sounds that involve less articulatory effort. Sounds that are articulatorily complex are not recruited unless effort minimization constraints are trumped by constraints that require sounds to be perceptually distinct.

The flip side of the coin is that sounds that are not sufficiently perceptually distinct are predicted to be subject to such phonological processes as assimilation, reduction, and deletion, when compared with sounds with robust cues (Kawasaki 1982). Hume (2011: 95) observes that the use of perceptual distinctiveness as a markedness diagnostic is “consistent with the claim that the target of phonological processes such as deletion is the unmarked member of the comparison set”. Weakly perceptually distinct sounds tend to be unmarked.

5.4 Markedness in light of the analysis of the Ukrainian back fricatives

Based on such evidence, various theories impose restrictions on the coda using a range of mechanisms, including feature delinking (autosegmental theory; Goldsmith 1976), element deletion (Government Phonology; Harris 1990) and positional markedness (Beckman 1998). With relevance to the discussion at hand, such theoretical frameworks offer appropriate tools to handle debuccalization in the coda (a weak position). However, due to the absence of a dedicated mechanism, they fail to predict the possibility of debuccalization in the onset (a strong position).

The Ukrainian data discussed in the previous sections offer evidence for debuccalization in the onset (/ɣ/ → /ɦ/). The data present a challenge to theories that argue for mechanisms dedicated to deriving debuccalization in the coda without allowing the possibility of debuccalization in the onset. Debuccalization, which is a markedness reducing process, is expected in the coda, a prosodically weak position. It is not expected in the onset. Yet, onset debuccalization has been found in Ukrainian.

In addition, the ultrasound analysis has shown that the two fricatives are neutralized to a more back place of articulation, possibly uvular, in the coda. Markedness has no obvious connection with this change. That is, neutralization in a weak position, such as a coda, is predicted to result in less marked segments. Assuming that there is a relationship between markedness and structural (and articulatory) complexity, more marked segments are more structurally (and articulatorily) complex than less marked segments (Cho 1990). The process of neutralization can be represented using the mechanism of feature delinking. Consider the three approaches to representing dorsals outlined in section 4. On the assumption that velars are [Dorsal], while uvulars are [Dorsal, –ATR] (Vaux 1999), uvulars are not less marked than velars. In Hayes' (2009) approach, velars are [+high, –low, –front, –back], while uvulars are [–high, –low, –front, +back]. Uvulars are as complex as velars. Similarly, it would be difficult to argue that uvulars are less marked than velars on the assumption of Zsiga's (2013) representational approach, in which velars are [–strident, +high], while uvulars are [+strident, +low, –high]. In sum, though there are different proposals regarding the representation of velars and uvulars, one thing seems evident. The coda neutralization of velars to uvulars cannot be insightfully accounted for by invoking markedness reduction in current feature theories. Neutralization to uvulars is not amenable to the familiar mechanism of feature delinking. Uvulars are not less marked than velars and thus are not predicted to be the outputs of neutralization. Therefore, markedness reduction is an unlikely driver of the coda neutralization to uvulars in Ukrainian.

5.5 Markedness as representational complexity

An important corollary of these findings is that representational complexity cannot be used as a predictor of synchronic alternations, contra many markedness-based approaches (e.g. Cho 1990; Arsenault 2008). As mentioned in the previous section, neutralizations are commonly derived using the feature delinking mechanism, which implies that the outputs of neutralization are less complex, i.e. less marked, less articulatorily complex, structures. However, the neutralization of the velar fricatives to the uvular fricatives cannot be viewed as an instance of reduction in representational (and articulatory) complexity. In the formulation of the neutralization /x/ɣ/

→ /χ/ʁ/ in (19), repeated from (12), a feature is added, which means that feature delinking is not an option. It follows that reduction in representational complexity cannot be used as a formal mechanism to induce neutralization. Neutralization can lead to more (or equally) representationally complex structures. By the same token, debuccalization (delinking of the place node) can occur in both weak and strong positions (although debuccalization is cross-linguistically more common in weak positions). We conclude that representations should not be tasked with restricting the possible range of synchronic alternations and diachronic changes.

(19) [dorsal] → [dorsal, –ATR] / <u>in the coda</u>

6 More counterexamples to markedness universals

Numerous instances of phonological processes have been identified in the world's languages that cast doubt on markedness universals. Some of them are discussed in this section. Blevins (2008) provides counterexamples to the prohibition of dorsal epenthesis. In Chamorro there are synchronic alternations involving insertion of /dz/ and /gw/, the former an affricate and the latter a dorsal (Blevins 2008: 92). Neither of them is expected to function as an epenthetic consonant based on markedness universals.

(20) Chamorro synchronic obstruent ~ zero alternations

a.	a.mo.ti	'take away for'	cf. amot	'take away'
b.	ha.tsa.dzi	'lift for'	cf. ha.tsa	'lift'
c.	ha.na.gwi	'go for'	cf. ha.naw	'go'

Blevins (2008) offers a historical explanation for the unnatural epenthesis in Chamorro. Glide epenthesis was followed by glide strengthening, as represented schematically in (21). The two sound changes are natural, but the synchronic alternations that resulted from them are not.

(21) Sound changes in Chamorro
a. Vi > Vji, Vu > Vwu
b. j > dz, w > gw

The range of epenthetic consonants is considerably wider than what markedness universals would predict and includes uvular fricatives, labialized pharyngealized rhotic glides, laterals, flaps and velar nasals, as illustrated in (22) (Blevins 2008: 95).

(22) Epenthetic consonants (Blevins 2008: 95 and references therein)

Language	*Consonant*	*Epenthesis context*
Uradhi	ŋ	V#_V
English, RP, Boston, etc.	ɻ	V_i#_V (V_i = lax)

Bristol, Mid.At. etc.	l	V_i#_V (V_i = lax; V_i = ɔ)
Yupik	ʁ	V_i_-V (V_i = ə)
Anejom	ɾ	V_ #V

Outputs of neutralizations are not limited to relatively unmarked consonants. Somali provides an instance of final voicing. The Somali pattern of synchronic final voicing has resulted from the succession of two diachronic changes, each of them phonetically grounded: intervocalic voicing and final vowel loss, as shown in (23). The synchronic pattern of final voicing is illustrated in (24). The second column in (24) shows medial voiceless stops, as there is no context for intervocalic voicing. In the third column, the stops are voiced in word-final position. The Somali data furnish a case of a synchronic pattern of word-final voicing, where the outcome lacks phonetic motivation (Blevins 2006). Blevins (2006) discusses other cases of word-final voicing, including Tundra Nenets and Letzgian. Final voicing is predicted to be impossible by theories that rely on markedness universals, such as those proposed in Kiparsky (2006) and de Lacy (2006).

(23) Somali final voicing from historical intervocalic voicing and final vowel loss (Blevins 2006: 147)

a. Intervocalic voicing: p t k > b d g / V_V

b. Final vowel loss: V > t /_#

Proto-Southern Cushitic *k'ut- 'dig' Somali qod (< *qodV)

(24) Somali word-final voicing (Saeed 1999: 24, 27)

/arak-/ 'to see'	arkay '(I) saw'	árag 'see!'
/gunut-/ 'to knot'	guntay '(I) knotted'	gúnud 'knot it!'
/ilik-/ 'tooth'	ilkó 'teeth'	ílig 'tooth'
/adak-/ 'hard'	adkaa 'hard' pst	adág 'hard'

One can find more examples of neutralization towards the more marked segments. In many dialects of Spanish in America and Spain, word-final /n/ changes to [ŋ] syllable- and word-finally (Canfield 1962: 70–71). In a similar fashion, Japanese neutralizes place contrast in nasals to [ŋ] word finally. A coronal nasal changes to a velar in the coda, i.e., in a weak prosodic position.

Voiceless aspirated obstruents are commonly classified as marked in relation to voiceless unaspirated obstruents (e.g. Trubetzkoy 1958: 146–148; Greenberg 1966), which means that the latter, rather than the former, should be products of neutralization. However, German shows final fortition, whereby final stops, regardless of underlying voicing specification, are voiceless and (optionally) aspirated (e.g. /t/ → [t^h] word-finally) (Alber 2001; Wagner 2002). Vaux & Samuels (2005) provide multiple other examples of languages that neutralize to aspirates in the final position.

In a quantitative study, Czaplicki (2019) finds that consonant mutations (historical palatalizations) in modern Polish are primarily morphologically conditioned. Phonological conditioning (e.g. the context of front vowels), though historically relevant, no longer plays an important role. For example, an /ɛ/-initial suffix triggers palatalization of preceding velars, but depalatalization of labials and coronals. On the other hand, an /a/-initial suffix causes palatalization of coronals. Such generalizations cannot be insightfully derived from the featural composition of the segments involved in the interactions. Czaplicki (2021) provides more evidence for the selective application of consonant mutations in Polish. He concludes that the mutations are morpheme-specific and to a large extent phonologically arbitrary.

Such data indicate that reduction of markedness cannot be reliably viewed as the primary motivation for sound change and synchronic phonological alternations. While it is true that phonological processes often result in less marked structures, there are also those that do not. Languages may show preference for more marked articulations to better support perceptual distinctiveness of phonemic contrasts (Arsenault 2008: 5). The requirements of maintaining lexical contrasts may also result in neutralization and lenition processes in contexts in which such processes are not predicted – while the positions where lenition is expected to occur remain unaffected. An important upshot of this discussion is that phonological theories modeling synchronic systems must be equipped with adequate tools to generate the full range of attested segments as outputs of phonological processes in any position. This view dovetails with the discussed evidence for debuccalization in the onset and non-markedness reducing neutralization in the coda in Ukrainian.

The concept of markedness falls short of explaining the full range of the attested data. The observable typological asymmetries in linguistic patterns are due to common trajectories of sound change, rather than due to markedness-induced pressures (Blevins 2004). For example, the fact that final devoicing is found in many unrelated languages results from the impoverished perceptual cues to voicing of word-final obstruents (Blevins 2006). Final devoicing can also be explained using aerodynamic factors. Phrase-final lengthening, which is a precursor of word-final devoicing (Blevins 2004), results in longer closure durations (Berkovits 1993). Voiced obstruents require continuous air-flow to sustain vocal fold vibration. After obstruent closure, voicing ceases due to an increase in supralaryngeal pressure. Insofar as final obstruents tend to be longer than non-final obstruents, devoicing is more likely to accompany the production of final than non-final obstruents (Ohala 1997; Blevins 2004: 105). Thus, voicing may be inhibited in final positions due to both perceptual factors (impoverished cues) and aerodynamic factors (longer closure durations).

Using the same line of reasoning, final voicing as a synchronic pattern is extremely rare not because there is a universal bias (markedness) preventing its emergence, but because the sequence of changes that would lead to its establishment in a language is rare, in contrast to the typologically common perceptually grounded changes leading to the synchronic pattern of final devoicing (Blevins 2006).

7 Conclusion

This articulatory study has provided evidence that the voiced velar fricative /ɣ/ in Ukrainian has two positional allophones: a dorsal (uvular) one in the coda and a laryngeal one in the onset. In addition, the two back fricatives, /x/ and /ɣ/, are neutralized to post-velar or uvular variants, [χ] and [ʁ], in the coda. Palatalized variants of the two fricatives consistently appear in the context of the vowel /i/. An important conclusion is that impressionistic descriptions based on auditory perception require confirmation that employs instrumental analyses of articulatory data.

The findings have theoretical implications. The fact that a velar fricative shows debuccalization (lenition) in the onset is potentially problematic for theories that base their predictions on markedness universals. Neutralizations should result in a decrease of markedness in weak positions, in the sense that more marked segments should become less marked in weak positions. Along these lines, velars are predicted to become laryngeals in the coda. The onset, being a prosodically strong position, should not be the site of lenition if codas are not lenited. Yet, this is exactly what happens in Ukrainian. A more marked segment (/ɣ/) becomes less marked ([ɦ]) in the onset. The second important finding of this articulatory study, neutralization to uvular fricatives in the coda, is also problematic for analyses that rely on markedness universals. A more marked segment is the output of neutralization in the weak position. The historical changes are identifiable in the synchronic system of modern Ukrainian as contextually dependent synchronic alternations. It follows that phonological models of synchronic grammars must accommodate patterns that are arbitrary from the perspective of markedness principles. Relatedly, markedness reduction construed as reduction of representational complexity cannot be reliably used as a factor motivating synchronic alternations and diachronic change.

We cannot rule out the possibility that there is a qualitative or quantitative difference between synchronic processes and synchronic universal tendencies. While markedness scales are relevant for synchronic universal tendencies, synchronic processes reflect diachronic development of a language, and may not be similarly constrained by universal scales. Along these lines, Hayes & White (2013) argue that markedness is better viewed as a learning bias, as opposed to a set of inviolable constraints. This view, however, does not obviate the need to generate the attested markedness-offending patterns in synchronic grammars using dedicated constraints.

Supplementary file

Appendix A with the stimuli, and Appendix B providing the results of the statistical analyses can be found here: https://doi.org/10.16995/glossa.9795.s1

Ethics and consent

The research involving ultrasound has been reviewed and approved by the Human Subjects and Institutional Review Board at Indiana University study no 1708667569. The identity of the research subjects has been anonymized and informed consent has been obtained from all the participants.

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Competing interests

The authors have no competing interests to declare.

References

Alber, Birgit. 2001. Regional variation at edges: glottal stop epenthesis and dissimilation in Standard and Southern varieties of German. *Zeitschrift fur Sprachwissenschaft* 20. 3–41. DOI: https://doi.org/10.1515/zfsw.2001.20.1.3

Alwabari, Sawsan. 2020. *Phonological and Physiological Constraints on Assimilatory Pharyngealization in Arabic: Ultrasound Study*. Ph.D. Dissertation. University of Ottawa.

Arsenault, Paul. 2008. On feature geometry of coronal articulations. *Toronto Working Papers in Linguistics* 29.

Barr, Dale J. & Levy, Roger & Scheepers, Christoph & Tily, Harry J. 2013. Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language* 68. 255–278. DOI: https://doi.org/10.1016/j.jml.2012.11.001

Bates, Douglas & Maechler, Martin & Bolker, Ben & Walker, Steve. 2015. Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software* 67(1). 1–48. DOI: https://doi.org/10.18637/jss.v067.i01

Beckman, Jill N. 1998. *Positional Faithfulness.* Ph.D. dissertation, University of Massachusetts, Amherst.

Beckman, Mary & Edwards, Jan. 1994. Articulatory evidence for differentiating stress categories In Keating, Patricia A. (ed.), *Papers in laboratory phonology III: Phonological structure and phonetic form*, 7–33. Cambridge: Cambridge University Press. DOI: https://doi.org/10.1017/CBO9780511659461.002

Berkovits, Rochele. 1993. Utterance-final lengthening and the duration of final-stop closures. *Journal of Phonetics* 21. 479–89. DOI: https://doi.org/10.1016/S0095-4470(19)30231-1

Blevins, Juliette. 2004. *Evolutionary Phonology: The Emergence of Sound Patterns.* Cambridge: Cambridge University Press. DOI: https://doi.org/10.1017/CBO9780511486357

Blevins, Juliette. 2006. A theoretical synopsis of Evolutionary Phonology. *Theoretical Linguistics* 32. 117–165. DOI: https://doi.org/10.1515/TL.2006.009

Blevins, Juliette. 2008. Consonant epenthesis: natural and unnatural histories. In Good, John (ed.), *Language universals and language change.* Oxford: Oxford University Press. DOI: https://doi.org/10.1093/acprof:oso/9780199298495.003.0004

Canfield, Delos Lincoln. 1962. *La pronunciación del español en América.* Bogotá, Colombia: Imprenta Patriótica del Instituto Caro y Cuervo.

Cho, Taehong & McQueen, James. 2005. Prosodic influences on consonant production in Dutch: Effects of prosodic boundaries, phrasal accent and lexical stress. *Journal of Phonetics* 33(2). 121–157. DOI: https://doi.org/10.1016/j.wocn.2005.01.001

Cho, Young-Mee Yu. 1990. *Parameters of consonantal assimilation.* Ph.D. dissertation. Stanford University.

Clements, G. Nick. 2003. Feature economy in sound systems. *Phonology* 20. 287–333. DOI: https://doi.org/10.1017/S095267570400003X

Czaplicki, Bartłomiej. 2006. Laryngeals and Velars in Ukrainian. *The Slavonic and East European Review* 84. 1–15. DOI: https://doi.org/10.1353/see.2006.0136

Czaplicki, Bartłomiej. 2019. Measuring the phonological (un)naturalness of selected alternation patterns in Polish. *Language Sciences* 72. 160–187. DOI: https://doi.org/10.1016/j.langsci.2018.10.002

Czaplicki, Bartłomiej. 2021. The strength of morphophonological schemas: Consonant mutations in Polish. *Glossa: A Journal of General Linguistics* 6(1). 25. 1–34. DOI: https://doi.org/10.5334/gjgl.1255

Danylenko, Andrii & Vakulenko, Serhii. 1995. *Ukrainian*. Munich: Lincom Europa.

De Jong, Kenneth. 1995. The supraglottal articulation of prominence in English: Linguistic stress as localized hyperarticulation. *Journal of the Acoustical Society of America* 97. 491–504. DOI: https://doi.org/10.1121/1.412275

De Lacy, Paul. 2006. *Markedness: Reduction and Preservation in Phonology*. Cambridge: Cambridge University Press. DOI: https://doi.org/10.1017/CBO9780511486388

Delattre, Pierre. 1972. Pharyngeal features in the consonants of Arabic, German, Spanish, French, and American English. *Phonetica* 23(3). 129–155. DOI: https://doi.org/10.1159/000259336

Flemming, Edward. 2002. *Auditory representations in phonology.* New York: Routledge.

Galović, Filip & Jutronić, Dunja. 2021. Phonological and morphological characteristics in the speech of older generation in Split. *Kroatologija* 12(1). 29–66.

Gick, Bryan & Campbell, Fiona & Oh, Sunyoung & Tamburri-Watt, Linda. 2006. Toward universals in the gestural organization of syllables: A cross-linguistic study of liquids. *Journal of Phonetics* 34(1). 49–72. DOI: https://doi.org/10.1016/j.wocn.2005.03.005

Goldsmith, John. 1976. Autosegmental Phonology. Ph.D. Dissertation, Cambridge, MA: MIT.

Greenberg, Joseph H. 1966. *Language universals, with special reference to feature hierarchies*. The Hague and Paris: Mouton.

Harris, John. 1990. Segmental Complexity and Phonological Government. *Phonology* 7(2). 255–300. DOI: https://doi.org/10.1017/S0952675700001202

Hayes, Bruce. 2009. *Introductory phonology*. Malden, MA: Wiley-Blackwell.

Hayes, Bruce & White, James. 2013. Phonological naturalness and phonotactic learning. *Linguistic Inquiry* 44. 45–75. DOI: https://doi.org/10.1162/LING_a_00119

Hooper, Joan B. 1972. The syllable in phonological theory. *Language* 48. 525–540.

Hooper, Joan B. 1976. *An introduction to natural generative phonology*. New York: Academic Press.

Howson, Phil & Moisik, Scott & Żygis, Marzena. 2022. Lateral vocalization in Brazilian Portuguese. *Journal of the Acoustical Society of America* 152(1). 281. DOI: https://doi.org/10.1121/10.0012186

Hume, Elizabeth. 2011. Markedness. In van Oostendorp, Marc & Ewen, Colin J. & Hume, Elizabeth & Rice, Keren (eds.), 79–106. *The Blackwell Companion to Phonology*. Oxford: Wiley-Blackwell. DOI: https://doi.org/10.1002/9781444335262.wbctp0004

Kawasaki, Haruko. 1982. *An acoustical basis for universal constraints on sound sequences*. Ph.D. dissertation. MIT.

Keating, Patricia A. 1988. Underspecification in phonetics. *Phonology* 5. 275–292. DOI: https://doi.org/10.1017/S095267570000230X

Kiparsky, Paul. 2006. The amphichronic program vs. evolutionary phonology. *Theoretical Linguistics* 32. 217–236. DOI: https://doi.org/10.1515/TL.2006.015

Kirchner, Robert. 1998. *An effort based approach to consonant lenition*. Ph.D. Dissertation. University of California.

Kuznetsova, A. & Brockhoff, P. B. & Christensen, R. H. B. 2015. *Package "lmerTest". R package version 2*. 0–29.

Ladefoged, Peter & Johnson, Keith. 2011. *A Course in Phonetics. 6th ed. International Student Edition.* Boston: Wadsworth Cengage Learning.

Ladefoged, Peter & Maddieson, Ian. 1996. *The Sounds of the World's Languages*. Oxford and Cambridge, MA: Blackwell Publishers.

Lass, Roger. 1997. *Historical Linguistics and Language Change.* Cambridge: Cambridge University Press. DOI: https://doi.org/10.1017/CBO9780511620928

Lawson, Eleanor & Stuart-Smith, Jane & Scobbie, James M. & Nakai, Satsuki. 2018. Seeing Speech: An articulatory web resource for the study of Phonetics.

Lombardi, Linda. 1999. Positional Faithfulness and Voicing Assimilation in Optimality Theory. *Natural Language and Linguistic Theory* 17. 267–302. DOI: https://doi.org/10.1023/A:1006182130229

Lulich, Steven M. 2020. Ultrasound visualization and analysis using WASL. *UltraFest IX*.

Lulich, Steven M. & Berkson, Kelly H. & de Jong, Kenneth. 2018. Acquiring and visualizing 3d/4d ultrasound recordings of tongue motion. *Journal of Phonetics* 71. 410–424. DOI: https://doi.org/10.1016/j.wocn.2018.10.001

Lulich, Steven M. & Naga Karthik, Enamundram M. V. & Laporte, Catherine. 2020. Automatic tongue surface extraction from 3D ultrasound using 3D SLURP. *UltraFest IX*. DOI: https://doi.org/10.1121/10.0000891

Maddieson, Ian & Gandour, Jack. 1976. Vowel length before aspirated consonants. *UCLA Working Papers in Phonetics* 31. 46–52.

Martinet André. 1939. Rôle de la corrélation dans la phonologie diachronique. In *Travaux du Cercle linguistique de Prague VIII*. Prague: Cercle Linguistique de Prague, 273–288.

McCarthy, John. 1994. The Phonetics and Phonology of Semitic Pharyngeals. In Keating, Patricia (ed.), *Papers in Laboratory Phonology III: Phonological Structure and Phonetic Form*. London: Cambridge University Press. DOI: https://doi.org/10.1017/CBO9780511659461.012

Murray, Robert W. & Vennemann, Theo. 1983. Sound change and syllable structure in Germanic phonology. *Language* 59. 514–528. DOI: https://doi.org/10.2307/413901

Naga Karthik, Enamundram M. V. & Karimi, Elham & Lulich, Steven M. & Laporte, Catherine. 2020. Automatic tongue surface extraction from 3D ultrasound vocal tract images. *Journal of the Acoustical Society of America* 147. 1623–1633. DOI: https://doi.org/10.1121/10.0000891

Ohala, John J. 1997. Aerodynamics of phonology. In *Proceedings of the 4th Seoul International conference in Linguistics*, 92–97. Seoul: Linguistic Society of Korea.

Paradis, Carole & Prunet, Jean-François (eds.) 1991. *The special status of coronals: internal and external evidence. (Phonetics and Phonology 2)*. San Diego: Academic Press.

Payne, David L. 1981. *The phonology and morphology of Axininca Campa*. Arlington: Summer Institute of Linguistics and University of Texas.

Piepho, Hans-Peter. 2004. An algorithm for a letter-based representation of all pairwise comparisons. *Journal of Computational and Graphical Statistics* 13(2). 456–466. DOI: https://doi.org/10.1198/1061860043515

Pompino-Marschall, Bernd & Steriopolo, Elena & Żygis, Marzena. 2016. Ukrainian. *Journal of the International Phonetic Association* 47(3). 349–357. DOI: https://doi.org/10.1017/S0025100316000372

Proctor, Michael I. 2011. Towards a gestural characterization of liquids: Evidence from Spanish and Russian. *Laboratory Phonology* 2(2). 451–485. DOI: https://doi.org/10.1515/labphon.2011.017

R Development Core Team. 2010. *R: A language and environment for statistical computing.* Vienna: R Foundation for Statistical Computing.

Rice, Keren. 1999. Featural markedness in phonology: Variation. *Glot International* 4(7). 3–6.

Rice, Keren. 2007. Markedness in phonology. In de Lacy, Paul (ed.), *The Cambridge Handbook of Phonology*, 79–97. Cambridge: Cambridge University Press. DOI: https://doi.org/10.1017/CBO9780511486371.005

Rusanovskij, V. M. & Zhovtobryux, M. A. & Gorodenskaja, E. G. & Grishchenko, A. A. 1986. *Ukrainskaja grammatika*. Kiev: Naukova Dumka.

Saeed, John. 1999. *Somali.* Amsterdam: John Benjamins.

Shevelov, George Y. 1977. On the chronology of h and the new g in Ukrainian. *Harvard Ukrainian Studies* 1(2). 137–152.

Steriade, Donca. 1995. Underspecification and markedness. In Goldsmith, John (ed.), *The Handbook of Phonological Theory*, 114–174. Oxford: Basil Blackwell.

Toc'ka, N.I. 1981. *Suchasna ukrayinska literaturna mova: Fonetyka, orfoepiya, grafika, ortografiya.* Kyiv: Vyshha shkola.

Trubetzkoy, Nikolai S. 1924. Einiges über die russische Lautentwicklung und die Auflösung der gemeinrussischen Spracheinheit. *Zeitschrift Für Slavische Philologie* 1(3/4). 287–319.

Trubetzkoy, Nikolai S. 1958. *Grundzüge der Phonologie*. 2nd edn. Göttingen: van der Hoeck and Ruprecht.

Vakulenko, Maksym O. 2019. Ukrainian consonant phones in the IPA context with special reference to /v/ and /gh/. *Linguistica ONLINE.* Issue 22.

Vaux, Bert. 1999. A Note on Pharyngeal Features. In Kuno, Susumu & Vaux, Bert (eds.), *Harvard Working Papers in Linguistics 7*, 39–63. Cambridge, MA: Harvard University Linguistics Department.

Vaux, Bert & Samuels, Bridget. 2005. Laryngeal markedness and aspiration. *Phonology* 22. 395–436. DOI: https://doi.org/10.1017/S0952675705000667

Vennemann, Theo. 1972. On the theory of syllabic phonology. *Linguistische Berichte* 18. 1–18.

Vennemann, Theo. 1988. *Preference Laws for Syllable Structure and the Explanation of Sound Change*. Berlin: Mouton de Gruyter. DOI: https://doi.org/10.1515/9783110849608

Wagner, Michael. 2002. The role of prosody in laryngeal neutralization. *MIT Working Papers in Linguistics* 42. 357–376.

Wright, Richard. 2004. A review of perceptual cues and cue robustness. In Hayes, Bruce & Kirchner, Robert & Steriade, Donca (eds.), *Phonetically based phonology*, 34–57. Cambridge: Cambridge University Press. DOI: https://doi.org/10.1017/CBO9780511486401.002

Zhovtobryux, M.A. & Kulyk, B.M. 1972. *Kurs suchasnoyi ukrayins'koyi literaturnoyi movy*. Kyiv: Vyshha shkola.

Ziłyński, Jan. 1932. *Opis fonetyczny języka ukraińskiego*. Kraków: Polska Akademia Umiejętności.

Zsiga, Elizabeth C. 2013. *The sounds of language: An introduction to phonetics and phonology.* Malden, MA: Wiley-Blackwell.