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UKRAINIAN CONSONANT PHONES IN THE IPA CONTEXT WITH SPECIAL REFERENCE TO /v/ AND /gh/[*]

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Abstract: The acoustic and articulatory properties of Ukrainian consonant phones were investigated, and a full set of relevant IPA notations was proposed for these and compiled in a table. Acoustic correspondence of Ukrainian phones to those appearing in European languages was analyzed and discussed. Special attention was paid to the phonemes /v/ (represented in Cyrillic script as "/в/") and /gh/ (rendered in Cyrillic script as "/г/") that cause the most difficulties in their description. In particular, our experiments and observations suggest that a standard Ukrainian phoneme /v/ is realised as labiodental fricatives [v] and [vʲ] before vowels and also as sonorant bilabial approximants [β̞ β̞ʲ β̞ˠ] between a vowel and a consonant, in the initial position before consonants and after a vowel at the end of a word, and sometimes is devoiced to [v̥] in the coda after a voiceless consonant. In some utterances after a vowel (before a consonant and in the coda), a strongly rounded bilabial approximant [β̞ˠ] may approach a non-syllabic semivowel [u̯]. These conclusions are in good agreement with the consonantal status of the Ukrainian language and with the general tendencies of sound combinations in the world languages. The findings of this research contribute to better understanding of Ukrainian and its special features in comparison with other world languages that may have substantial practical use in various phonetic and translation studies, as well as in modern linguistic technologies aimed at artificial intelligence development, machine translation incorporating text-to-speech conversion, automatic speech analysis, recognition and synthesis, and in other areas of applied linguistics.

Key words: Ukrainian consonant phone set, International Phonetic Alphabet, visual analysis of articulation, bilabial approximant, text-to-speech technology.

Phonetic studies represent one of the most promising areas of modern linguistics because, in addition to their specific significance in the field, they produce important data for advanced speech technologies. In particular, the developers of modern multi-lingual translation tools need information on the phones of the world languages. Among these, the Ukrainian language remains one of the least investigated.

The combined investigation of Ukrainian vowels based on analysis of theoretical and experimental data, was presented in the recent article (Vakulenko, 2018). At the same time, the presence of palatalized consonantal cognates across different articulation classes signifies the consonantal character of the Ukrainian language (cf. Isachenko, 1963). This makes the Ukrainian consonantal subsystem perhaps more interesting and significant for comparative phonetic and speech studies.

[*] Previously unpublished. [Editor's note]

As emphasized in Vakulenko (2018), the major problem of Ukrainian phonetics and orthoepy is that modern judgments about them are based on outdated phonetic material received from but one speaker and processed with old-fashioned apparatus. The monograph "Contemporary standard Ukrainian. Phonetics" (Bilodid, 1969) appeared in Ukrainian decades ago (where the section "Consonants" was written by Larysa Prokopova), remains one of the major works in the Ukrainian phonetics presenting experimental data on the consonants. This material was used with minor changes (and without up-to-date experimental studies) in a number of later books and manuals, particularly in the monograph "Ukrainian" (Danylenko & Vakulenko 1995) oriented primarily at the English-reading audience.

The article "Ukrainian" (Pompino-Marschall, Steriopolo & Żygis, 2016) focuses on phonetic properties of Ukrainian speech sounds grounded on recordings of one speaker from Bukovyna (South-Western Ukraine). In particular, the labiodental pronunciation of a /v/ has been reported (here and in what follows, the corresponding Cyrillic graphemes are transliterated according to the simple-correspondent transliteration system of the Ukrainian Latinics presented in Vakulenko, 2015c)[1]. However, aiming to represent IPA notations necessitates not only observation of articulatory movements of a speaker, but also their instrumental recording and examination and comparison with the data obtained in other phonetic experiments. The authors follow, without any explanation, theoretical assumptions of Buk, Maczutek & Rovenchak (2008) not duly based on linguistic facts, experimental material and relevant references and including an ungrounded statement about velar approximant character of a Ukrainian sonorant sound of the Cyrillic grapheme "в". In addition, some important details of their phonetic experiment (including the method of determining articulation) were not described. In view of this, the status of phones outlined in the mentioned articles, still remains unclear.

Last but not least, the task to determine the most relevant International Phonetic Alphabet (IPA) symbol for the given Ukrainian sound is a complicated undertaking that requires collecting representative experimental data, performing profound comparative analysis of the multi-lingual phonetic material, and basing on good command in the IPA notations. For example, incorrect interpretation of the description of a Ukrainian voiced fricative sound of the Cyrillic grapheme "г" given in Bilodid (1969), Tocjka (1981) resulted in Danylenko & Vakulenko (1995), Press & Pugh (2015) in its wrong representation by the symbol "h" that denotes a voiceless sound in the IPA.

One should not expect much from the first studies of the Ukrainian phones that are heavily influenced by the general state of Ukrainian phonetics. This fact necessitates further experimental investigation in this area.

So, this article is aimed to analyze phonetic features of the Ukrainian consonants in the IPA notations context, and to present a table correctly accounting for these.

1. Investigation methods and material

The choice of investigation methods is affected by the current situation in Ukraine where phonetic studies receive no financial support. So, this investigation is based on the combined

[1] According to conventional Ukrainian notations, the phonemes and phones are denoted by Cyrillic letters in slashes and brackets, respectively. To avoid confusion with standard IPA signs when considering description of problematic sounds, we provide necessary explanations in the text.

use of auditory and visual comparative analysis, auditory observation, and oscillogram analysis.

The visual analysis was carried out to determine the degree of lips rounding and protrusion in the articulation of the Ukrainian sonorant sound of the Cyrillic letter “в” by specially trained native Ukrainian TV news announcers and program participants, in comparison with pronunciation of the approximant [w] by two native English speakers (British and American English variants). The most popular TV programs available in the Internet, were chosen. For comparison with the English sounds, similar sound environments were selected. The co-articulation effects were balanced by choice of different sound combinations for similar positions.

Such an assessment is important, first for phone mapping purposes needed for speech recognition automatic tools. Second, in view of the absence of sufficient and reliable data on Ukrainian articulation, this analysis may give certain insights in the nature of this phone in the Ukrainian context. In total, the visual acoustic material was collected from six native Ukrainians, where Speaker PR was born in Ternopil (Тернопіль), Western Ukraine; Speaker KhS was born in Lviv (Львів), Western Ukraine; Speaker OL was born in Chernighiv (Чернігів), Northern Ukraine; Speaker PK was born in Kropyvnycjkyj (Кропивницький), Central Ukraine; Speaker SZ was born in Zhashkiv (Жашків), Cherkasy region, Central Ukraine; Speaker EB was born in Sudak (Судак), Crimea, Southern Ukraine. Thus, the southwestern dialect group was represented by two speakers, and the southeastern dialect group that forms a base of the contemporary standard Ukrainian, was represented by four speakers. The moments of maximal lips closure / protrusion were chosen for visual analysis that was controlled both visually and acoustically.

The auditory observation was used to study the perceptional character of spontaneous Ukrainian speech heard in Kiev (Kyjiv) in 1991–2017.

The CD-quality recorded speech of a native Ukrainian professional actor (born in Dnipro, Central Ukraine) trained according to the orthoepic norms described in (Bilodid, 1969), was also used to examine acoustic realisations of the Ukrainian phoneme /gh/. Throughout the article, we use the conventional notion of the phoneme (Crystal, 2008: 361–363). This analysis was based on the oscillograms obtained with use of the special software Sound Forge 4.0.

The compliance of the obtained results with the general and Ukrainian phonetic laws governing language evolution (Isachenko, 1963), phone clusters formation (Kawasaki 1982), was checked.

2. Ukrainian consonants

2.1. General remarks

The detailed description of the Ukrainian consonants may be found in Zhovtobrjukh & Kulyk (1965: 120–127), Bilodid (1969: 134–179), Tocjka (1981: 62–88). In view of this, we will pay more attention to the most important or difficult issues such as palatalization, acoustic features of affricates, and consonants appearing when reading out Ukrainian letters “в” and “г” that cause much difficulty in their description and classification.

A phonemic opposition between plain („hard”) and palatalized („soft”) consonant phonemes has developed in the Ukrainian language (see Isachenko, 1963; Bilodid, 1969; Tocjka,

1981). Though three levels of palatalization may be distinguished: strong, moderate, and weak palatalization (see Bilodid, 1969: 179), – this gradation arises solely from articulation features of the given consonant. So, keeping in mind these subtleties, we will nevertheless supply all palatalized consonants with the same symbol "ʲ".

It is worth mentioning in this connection that the first element in the Ukrainian postalveolar affricates [t͡ʃ] and [d͡ʒ] (the standard readout of the Cyrillic graphemes "ч" and "дж", respectively) is found to be palatalized, as demonstrated in Vakulenko (2012: 232, 461), Vakulenko (2015b: 178, 322).

Let us note also that as the plain lateral sonorant sound corresponding to the Cyrillic letter "л" is articulated with a concave middle part of the tongue (see Bilodid, 1969: 167; Tocjka, 1981: 87), the IPA symbol **ɫ** for a velarized, or "dark" sound (articulated with a raised dorsum) is appropriate for it (cf. Pompino-Marschall et al., 2016: 4).

2.2. The readout of the Ukrainian "в"

The plain sound corresponding to the Ukrainian letter "в" (being latinized as "v") has been posited as a predominantly bilabial fricative and sonorant consonant that may be vocalized into a non-syllabic sound [ŭ] (Cyrillic [ў])[2] in a position before a consonant and in the end of a word after a vowel when a constriction is lost or weakened: *вдень* 'in the afternoon', *впасти* 'fall', *вхопити* 'grab', *вчора* 'yesterday', *мовчати* 'to be silent', *певно* 'probably', *правда* 'truth', *кров* 'blood', *лев* 'lion', *острів* 'island', *став* '(he) became' (Zhovtobrjukh & Kulyk, 1965: 121; Bilodid, 1969: 137, 386; Tocjka, 1981: 84–85). The latter sound is reported to differ from the corresponding bilabial consonant by lips rounding and protrusion and to diverge from a syllabic vowel [u] (Cyrillic [у]) by less amount and time of lips rounding (Zhovtobrjukh & Kulyk, 1965: 121; Tocjka, 1981: 85). It is characterized as "a sound intermediate between [v] and [u]" (Press & Pugh, 2015: 27).

For unspecified reasons, the relevant bilabial sound was transcribed in Bezpaljko (1957: 166), Zhovtobrjukh & Kulyk (1965: 106), Tocjka (1981: 36, 84) by the Latin letter "w" that is assigned in the IPA to a labiovelar approximant (glide), thus having implied specific "Ukrainglish" accent. This resulted in further discrepancies, as this letter was used later to designate either a bilabial constrictive consonant (Danylenko & Vakulenko, 1995: 6), or a bilabial fricative sonorant sound (Press & Pugh, 2015: 23), and a labiovelar approximant (Buk, Maczutek, & Rovenchak, 2008: 66; Pompino-Marschall et al., 2016: 4). To avoid inconsistencies, an IPA symbol [β̞] should be used instead (see Laboratorio di Fonetica Sperimentale). At the same time, a non-syllabic semivowel [ў] has been marked with [u̯] (Danylenko & Vakulenko, 1995: 6; Buk et al., 2008: 66; Pompino-Marschall et al., 2016: 7), where diphthongization of a non-syllabic [u̯] following a vowel was claimed (Zhovtobrjukh & Kulyk, 1965: 120). We will discuss below both bilabial variants in detail.

A labiodental fricative variant of a sound of "в" has been also admitted to arise as an alternative to its bilabial correlate either before an [i] (Zhovtobrjukh & Kulyk, 1965: 121), or before an "и" (transliterated as "y"), "е", and "а" (Bilodid, 1969: 137). Later it was stated that this sound comes out in the word or syllable beginning (cf. Tocjka, 1981: 85): *вода* [vo̞-d̪ɑ⁺ˈ] 'water', *ваза* [vɑ⁺ˈ-z̪ɐ] 'vase', *вино* [vɨ̞⁺-n̪oˈ] 'wine'. Such wider occurrence of the

[2] The authors cited below did not use IPA notations, so this is transliteration, not an IPA symbol.

labiodental fricative likely resulted not from a sixteen-year language evolution (from 1965 till 1981) but rather from more accurate phonetic investigation. The corresponding palatalized consonant was also first considered as typically bilabial (Zhovtobrjukh & Kulyk, 1965: 121; Bilodid, 1969: 142), and afterwards as labiodental (Tocjka, 1981: 85). These phones, plain and palatalized, correspond to the IPA symbols **v** and **v^{j}**, respectively.

It is stated also in Bilodid (1969: 246) that in the word-final position after voiceless consonants, the phoneme /v/ (Cyrillic /в/) is realised in its voiceless variant: *багатств* [bɐ-ɦɑ$^{+}$ˈt͡ʂ̪tɣ̥] ‘of riches’, *видавництв* [vɨ̞$^{+}$-d̪ɐβ̞-n̪ɨ̞$^{+}$ˈt͡ʂ̪tɣ̥] ‘of publishing houses’, etc. The IPA designation [ɣ̥] should be used in this case.

The late acoustic research and observations of the contemporary spontaneous and specially trained standard Ukrainian speech introduce certain corrections to the earlier description of this consonant.

The labiodental fricative sounds [v] and [v^{j}] appear much more frequently than assumed in 1960-ies. Within this trend, new labiodental sounds – approximants [ʋ] and [ʋ^{j}] – were recently described (Pompino-Marschall et al., 2016: 4; see also Buk et al., 2008: 66). Such a difference between early and contemporary notions may be conditioned by a small number of informants involved in experiments of that time, by special instructions on pronunciation given to them, by inexact fixation of the moment of the sound articulation, by instrumental error, and by incorrect interpretation of the data obtained. Whenever the upper incisors approach the lower lip, so does the upper lip which may cause confusion in the description of such an articulation.

In general, the bilabial articulation of this sound in a position before vowels displays instability, at least in some languages. For example, the Spanish phoneme /v/ has two main allophones: a bilabial fricative [β] pronounced in the word-middle (in intervocalic position) as in *lavar* ‘to wash’, and a bilabial stop consonant [b] in initial position (before vowels) as in *ver* ‘to see’. Such a distribution is not known in Ukrainian that supports an idea of the predominantly labiodental character of the Ukrainian /v/ before vowels. Also, this allophone is observed to occur in other feasible positions.

As for possible allophones in positions before consonants and in the end of a word after a vowel, three bilabial candidates may be considered: a labiovelar approximant (glide) [w], a non-syllabic semivowel [u̯], and a bilabial approximant [β̞]. As we already noted, a comparison with other languages should be carried out with a great care, and special features of the contemporary standard Ukrainian language should be duly accounted for.

There are two types of approximants: glides and semivowels. The glides are classified as “consonants produced with a constriction that is not sufficiently narrow to cause a significant average pressure drop across the constriction during normal voicing” (Stevens, 1998: 513). In particular, the labiovelar glide [w] results from “forming a narrow lip opening with rounding of the lips, similar to the vowel /u/ but … with a narrower constriction … the tongue body is placed in a raised and backed position, and consequently this glide can be considered to be velar as well as rounded or labial” (Stevens, 1998: 516). The characteristic formant frequencies of this sound are *F1* = 270 *Hz*, *F2* = 700 *Hz* (Stevens, 1998: 517, 523).

In the English, French, Italian, Spanish, German and other languages, a labiovelar glide appears as a modified vowel [u] that approaches a strongly labialized consonant in a position before a next vowel: *what* (Eng.), *oui* (Fr.), *uomo* (It.), *agua* (Sp.), *bequem* (Ger.). Figs. 1, 2

present articulation of this sound in English *what*, *where*, *word*. The snapshots were made at the moment of the narrowest lip constriction.[**]

The articulation of this approximant "glides" from an *u*-position to a following vowel position, and its production is accompanied by energetic articulatory gestures. It has to be emphasized that historical origin of the Ukrainian phoneme /v/ from a non-accented vowel after another vowel and from the "smooth" [ł] (Cyrillic [л]) after a vowel before a consonant and in word final (see Zhovtobrjukh & Kulyk, 1965: 119) should be well distinguished from its contemporary realisation. The modern situation in Ukrainian is quite contrary to that of the English, French, Italian, Spanish, German and other vocalic languages: here a consonant phoneme /v/ partly acquires some vowel-like properties in the position before another consonant or in coda, with reduced articulation. Visual representations of facial articulation of different realisations of contemporary standard Ukrainian phoneme /v/ are given in Figs. 3-9. The snapshots were made at the moment of the narrowest lip constriction.

As can be seen from Figs. 2–9, there is a significant difference between an utterance of an English [w] in *what*, *where*, *word*, etc., and a Ukrainian [в] in all positions, including those before consonants and in the end of words. An English [w] is articulated with significant lip protrusion as in [u], whereas a Ukrainian [в] is not. During a Ukrainian [в] before consonants (where a non-syllabic semivowel [u̯] allegedly arises), the lips corners are just pressed to the teeth, and no strong lips protrusion is observed. At the same time, the Ukrainian [y] is articulated with significant lip protrusion (see Figs. 4, 7).

There are also more general differences. According to measurements of O. A. Kasjjanova (2015: 332–333), the second formant frequency of the allophone of /v/ appearing before a consonant, is 1007 Hz, and that of the allophone before a vowel makes 1310 Hz. These quantities are well higher than corresponding characteristics of a glide [w] residing near the value of 700 Hz (cf. Stevens, 1998: 517–532). This is an acoustic indication that a Ukrainian [в] is likely not a labiovelar approximant.

In turn, the appearance of a non-syllabic semivowel [u̯] after vowels (before consonants and pauses) would result in a diphthong rise, whereas the Ukrainian language manifests an opposite tendency of diphthongs fall (see Bezpaljko et al., 1957: 146; Zhovtobrjukh & Kulyk, 1965: 131–134). The sound appearing before consonants and after vowels in coda, is mostly a bilabial consonant articulated as during [b] but with the tongue slightly displaced backwards (cf. Tocjka, 1981: 84) that acquires some vowel-like properties (in particular, it can never be devoiced and is hardly ever palatalized) but normally is not accompanied with energetic articulation and strong lip protrusion. So, this sound cannot be regarded as a pure, full-fledged semivowel. Such description best corresponds to a rounded bilabial approximant [β̞].

As follows from Figs. 4–9, a labiodental fricative consonant [v] appears in all possible positions but prevalently before vowels; an unrounded, less rounded and more rounded bilabial approximants [β̞ β̞ β̞] arise between a vowel (and a pause) and a consonant and after a vowel in coda; and a constrictional bilabial consonant [β] may emerge between a front vowel [i] and a consonant.

[**] All the figures are placed at the end of the paper. [Editor's note]

2.3. The readout of the Ukrainian letter "г"

The sound of the Ukrainian phoneme /gh/ (Cyrillic /г/) is often rendered through English "h" (see Danylenko & Vakulenko, 1995; Press & Pugh, 2015) that is not advisable. In particular, it was posited that the Ukrainian /gh/ (/г/) is pronounced "close to English *h* in *house*, but with more voice and less aspiration" (Press & Pugh, 2015: 18). This description is not accurate. First of all, comparison to English is hardly suitable since the Ukrainian phoneme /gh/ (/г/), in contrast to the English /h/, can precede not only vowels but consonants as well. Unlike the English, German, and Latin /h/, the Ukrainian phoneme /gh/ (/г/) in a position before vowels has a distinctly voiced readout (modal voicing) without aspiration, whereas before consonants it gives rise to a velar fricative (non-aspirated) sound that may also be devoiced to a [ɣ̥] (more details will be given below). As for the sound closeness (phone mapping), a comparison with the readout of the Spanish "g" in *agua* 'water' is more appropriate.

A Ukrainian sound [г] has been described as a voiced pharyngeal consonant (Zhovtobrjukh & Kulyk, 1965: 122; Bilodid, 1969: 176). It is stated that articulation of this sound is not characterized by a predetermined tongue position. During its production, the tongue root approximates the pharynx wall, and the tongue position depends on the next sound (Bilodid, 1969: 177; Tocjka, 1981: 83). This description corresponds to the IPA sign **ʕ** that may be regarded also as an approximant.

Velar variants of this sound (belonging to the hyper phoneme /kh gh/ (/х г/)) have been reported to emerge in a position before consonants and also in coda – both a voiced realisation [x̊], as in *тих (днів)* [t̪ɨ̞⁺ˈx̊] 'of those (days)', *широких (доріг)* [ʃɨ̞⁺-rɔˈ-kɨ̞⁺x̊] 'of wide (roads)' (cf. Zhovtobrjukh & Kulyk, 1965: 123), and a devoiced one (the sound [ɣ̥]) due to regressive assimilation, as in *кігті* [kʲiˈ-ɣ̥tʲi] 'claws', *нігті* [ɲiˈ-ɣ̥tʲi] 'nails', *вогко* [ʋɔˈ-ɣ̥ko] 'damp', *легко* [łɛ̞ˈ-ɣ̥ko] 'easily' (Bilodid, 1969: 257, 398). Its palatalized cognate [ɣ̥ʲ] is also possible, as in *гість* [ɣ̥ʲiˈs̪ʲtʲ] 'guest', *загін* [z̪ɐ-ɣ̥ʲiˈn̪] 'detachment' (cf. Bilodid, 1969: 391). The experimental data of B. Pompino-Marschall et al. (2016: 7) indicate appearance of the voiced velar fricative sound [ɣ] before consonants (produced by a male native speaker from Bukovyna, South-Western Ukraine) as in *них двох* 'of two of them'[3], *зігріло* 'warmed up'.

Also, the glottal fricative allophone [ɦ] of the phoneme /gh/ (/г/) was experimentally observed in the position before vowels: *одного* [ɔ̞-d̪n̪ɔ̞ˈ-ɦo] 'of the one', *того* [t̪ɔ̞ˈ-ɦo] 'of that' (Pompino-Marschall et al., 2016: 7).

Possible appearance of glottal ([ɦ] and [ɦʲ]), pharyngeal ([ʕ] and [ʕʲ]), and velar ([ɣ] and [ɣʲ]) variants was observed in our experiments (see Vakulenko, 2012: 229; Vakulenko, 2015b: 175), that supports the earlier statement about the variable articulation of this sound depending on the next vowel or consonant (see Bilodid, 1969: 177; Tocjka, 1981: 83). This is illustrated by Fig. 10 where oscillograms of the sound [г] in word-final and intervocalic positions are presented.

It can be seen from Fig. 10 that acoustic realisations of the Ukrainian phoneme /gh/ (/г/) are different in the coda and in intervocalic position. In the first case, a partly devoiced velar allophone [ɣ] with a significant noise component arises whereas in the latter, a glottal allophone ɦ with dominating voice component and minimal noise emerges. Plain velar and pharyngeal or glottal allophones enter the approximate complementary distribution relation: the

[3] Strictly speaking, the sound [x̊] appears here.

first one is met before consonants and in the coda (but may arise also before vowels), the last two appear before vowels. All of them are included in Table 1.

2.4. The Ukrainian consonantal inventory

The general inventory of the Ukrainian consonants is presented in Table 1.

		Bilabial	**Labio-dental**	**Alveolar**	**Post-alveolar**	**Palatal**	**Velar**	**Pharyn-geal**	**Glottal**
Plosive	**Plain**	p b		t̪ d̪			k *g*		
	Palat.	*pʲ* *bʲ*			tʲ dʲ		*kʲ* *gʲ*		
Nasal	**Plain**	m		n̪					
	Palat.	*mʲ*		ɲ					
Frica-tive	**Plain**		f (v)	s̪ z̪	ʃ ʒ		x ɣ	(ʕ)	(ɦ)
	Palat.		(*fʲ*) (*vʲ*)	s̪ʲ z̪ʲ	*ʃʲ* *ʒʲ*		*xʲ* *ɣʲ*	(*ʕʲ*)	(*ɦʲ*)
Affri-cate	**Plain**			t͡s̪ d͡z̪	t͡ʃ d͡ʒ				
	Palat.			t͡s̪ʲ d͡z̪ʲ	*t͡ʃʲ* *d͡ʒʲ*				
Trill	**Plain**			r					
	Palat.			*rʲ*					
Appro-ximant	**Plain**	(β̞ β̞ β̞)	ʋ						
	Palat.					j			
Lateral approx.	**Plain**			l					
	Palat.			lʲ					

Table 1: Ukrainian consonants (Note 1: sounds in parentheses are the allophones arising due different phoneme articulation; Note 2: sounds corresponding to peripheral phonemes, are rendered in *italic*)

It is remarkable that our experiments and observations revealed the fact that in the Ukrainian geminate affricates occurring in *обличчя* ‘face’ [o-bɨ̞ɨ̞⁺ˈ-tʲt͡ʃʲʲɐ], *робиться* [rọˈ-bɔ⁺-tʲt͡s̪ʲʲɐˌ] ‘is being done’, etc., lengthening results from the longer occlusion phase of the plosive component (see Fig. 11 for [tʲt͡s̪ʲ] in *хочеться* ‘is desired’).

It is seen from Fig. 11 that lengthening of the geminate affricate in *хочеться* is determined by a longer occlusion phase of the stop component. The relevant IPA transcription should be [xọˈ-t͡ʃʒ⁺-tʲt͡s̪ʲʲɐˌ].

Another regular Ukrainian sound assimilation phenomenon is environmental palatalization: the plain phonemes /t/ (Cyrillic /т/), /d/ (/д/), /n/ (/н/), /l/ (/л/), /s/ (/с/), /z/ (/з/), /c/ (/ц/), /dz/ (/дз/) having strongly and moderately palatalized cognates, are realised in the palatalized sounds if they follow the phoneme /i/ (/і/) and precede a strongly or moderately palatalized consonant. An example is presented in Figure 12 where the phoneme /z/ is shown to undergo such a palatalization when preceded by an [i] and followed by a [ɲ].

It is remarkable that in the last case, the palatalization is not complete because there is a weak sub-formant of 1630 Hz in the spectrum corresponding to the plain sound.

There may be exceptions from this rule for prefixes that are normally more stable in pronunciation and are subject of less assimilation. The exact palatalization degree for each sound combination is a separate task being a matter of future investigation.

3. Discussion

A number of outcomes of this research need special emphasis and discussion.

3.1. In the inventory of the Ukrainian consonant phonemes, the phoneme /g/ (Cyrillic /ґ/) which is realised in the chief allophone [g], should be referred to the peripheral subsystem as a rare plosive variant of the /gh/ (/ґ/). The frequency of /g/ (/ґ/) in modern Ukrainian is lower than 0.1% (Zhovtobrjukh, 2004: 765). This is a consequence of the tendency of Ukrainian to change the plosive sound [g] into the fricative velar [ɣ] and fricative glottal [ɦ] (see Bezpaljko et al., 1957: 82; Tocjka, 1981: 62). The works of S. Buk et al. (2008) and B. Pompino-Marschall et al. (2016) did not account for this tendency that allows us to assume that the relevant tables do not exactly reflect the Ukrainian consonant inventory.

3.2. The experimental facts indicate that in the absence of assimilation and devoicing, the Ukrainian phoneme /gh/ (/ґ/) is realised in three most frequent allophones: velar [ɣ], pharyngeal [ʕ], and glottal [ɦ], where the first is likely to occur before consonants and the other two probably arise before vowels. If so, this is a matter of complementary distribution. However, this assumption requires more detailed and comprehensive experimental investigation that should be presented elsewhere.

Deficiency of experimental data makes it difficult to select the chief allophone among the three based on their phonetic characteristics and occurrence. However, this problem may be solved by addressing the phonemic speculations. In the Ukrainian inclination paradigm, the phoneme /gh/ (/ґ/), as well as the /g/ (/ґ/), forms the triad with the /zh/ (/ж/) and /zʲ/ (/зʲ/): *ріг* ‘horn; corner’ – *наріжний* ‘corner’ – *на розі* ‘at the corner’, whereas its voiceless phonemic equivalent enters the triad /kh/ – /sh/ – /sʲ/ (/х/ – /ш/ – /сʲ/): *вухо* ‘ear’ – *вушний* ‘ear’ – *у вусі* ‘in the ear’. This is a strong motivation to consider the velar sound [ɣ] being an exact voiced equivalent of the [x], as the chief allophone of the Ukrainian phoneme /gh/ (/ґ/). This allophone is located between the [g] (representing the rare peripheral phoneme /g/ (/ґ/)) and [ʕ] and/or [ɦ]. The pharyngeal and/or glottal allophones are characterized by relatively small turbulent noise and significant vowel-like afterbreath that serves as a “bridge” to the next vowel (see more details about the afterbreath properties in Vakulenko, 2012: 232–237; Vakulenko, 2015b: 180–186). This difference in acoustic and articulatory characteristics from the main allophone [ɣ] may arise from a co-articulation effect conditioned by their appearance before vowels.

3.3. The problem of relating sounds in different languages is important for various theoretical and applied phonetic studies and, particularly, for **phone mapping** between world languages needed for automatic speech recognition. We would like to pay attention to the fact that the reason for the essential dissimilarity in articulation and acoustic properties between an English [w] and a Ukrainian [в] is not accidental. The languages where a labiovelar approximant [w] is usually met (and studied) are vocalic, i. e. they have a developed vowel

subsystem. Contrary to this, Ukrainian is a typical consonantal language where, in particular, a phonemic opposition between plain and palatalized consonants has emerged (see Isachenko, 1963). By this criterion, Ukrainian is close to Czech, Bulgarian and Russian, and distant from English, Serbian and Croatian. This suggests much weaker vocalization and diphthongization phenomena in Ukrainian than in English and other vocalic languages (cf. Zhovtobrjukh & Kulyk, 1965: 58) and historical evolution of diphthongs into monophthongs (cf. Bezpaljko et al., 1957: 146; Zhovtobrjukh & Kulyk, 1965: 131–134). Besides, the conversion of a non-syllabic semivowel [u̯] into its fricative cognate as in *чо*в̠*ен* [ʧ͡ʃo̞ˈ-vɘ̞⁺n̪] ‘boat’, *по*в̠*ен* [po̞ˈ-vɘ̞⁺n̪] ‘full’ was reported in Bezpaljko et al. (1957: 159). In turn, S. Buk et al. (2008: 66) note that diphthongs are non-phonemic in Ukrainian. So, the tentative emergence of a labiovelar glide [w] before vowels, as well as a semivowel [u̯] after vowels that would result in a diphthong, does not comply with a consonantal tendency of the Ukrainian language.

An analogy of a labiovelar approximant / glide with its palatal cognate may be drawn also, treating these as the grave and acute counterparts (see Andersen, 1962: 74; Stevens, 1998: 513–532). Both Ukrainian non-syllabic [ў] and [ĭ] arose from relevant non-stressed vowels in the position after a vowel (see Zhovtobrjukh & Kulyk, 1965: 119) that implies their similar further evolution. The Ukrainian phoneme /j/ (/й/) is represented by two allophones, where a consonant [j] appears before vowels, and a non-syllabic [i̯] that occurs after them, is fairly similar to [j] both in articulation and in acoustic perception (Zhovtobrjukh & Kulyk, 1965: 122). It is agreed that despite its origin, the Ukrainian [й] belongs to consonants that manifest a consonantal tendency of the Ukrainian language. The same tendency acts on the phoneme /v/ that is expected to acquire with time more and more consonantal features.

There exist general restrictions on the positional appearance of an approximant [w]. It was established in Kawasaki (1982: 169) that the most frequent are those phone sequences whose elements are maximally different in their acoustic properties. In view of this, combinations “[b] + [w]” and “[w] + back vowel” are disfavoured in the world languages (Kawasaki, 1982: 171–173). These restricted positions strongly overlap with those allegedly typical for a labiovelar approximant in the Ukrainian language that is an additional argument against this conjecture.

In addition, vocalization of the final /v/ after vowels contradicts the universal tendency to avoid long consonant clusters and long vowel clusters (see Kawasaki, 1982: 170). The appearance of a non-syllabic semivowel [u̯] is especially disfavoured after an acoustically close vowel [u] as in the verbs *був* ‘(he) was’, *кинув* ‘(he) threw’, etc.

Our conclusions concerning allophones of a /v/ differ from the conjectures of S. Buk et al. (2008) put forward without due theoretical grounding and experimental support (that might be speech recordings, palatograms, airflow data, etc.). In particular, it should be kept in mind that classification of a [v] (Cyrillic [в]) before back rounded vowels [o] and [u] that have a flatting effect on preceding consonants, may be incorrect due to wrong interpretation of the tongue position in the transeme between both sounds. It is remarkable that B. Pompino-Marschall et al. (2016) indicated such a co-articulation influence but, for some reason, did not move further in their conclusions, having just restricted themselves by repeating the conjectures of S. Buk et al. (2008).

The cue feature here is lips protrusion that is strong in the case of a labiovelar glide and weak in the case of a bilabial or labiodental fricative. In terms of S. Buk et al. (2008) and B.

Pompino-Marschall et al. (2016), the allophone of /v/ appearing before an [o] in *приводу* ‘occasion’, *двох* ‘of two’, *вони* ‘they’, *своє* ‘their’, might had been better marked as a lowered labiodental approximant [ʋ̞] (cf. Laboratorio di Fonetica Sperimentale).

It is remarkable that the appearance of a labiodental fricative consonant [v] between a front vowel [i] and a consonant was detected in our audiovisual experiments (see Fig. 9) and also observed by B. Pompino-Marschall et al. (2016: 7).

One may expect, however, the possible appearance of a labiovelar approximant in a fluent utterance of the sound combination *-овува-* as in Ukrainian verbs of imperfect aspect: *застосовувати* ‘to apply’, *скасовувати* ‘to cancel’, etc. In some Western Ukrainian dialects, a strongly rounded bilabial approximant [β̞ʷ] may approach a non-syllabic semivowel [u̯] in a position after a vowel (before a consonant and in the coda).

As B. Pompino-Marschall et al. (2016) suggested, we use the IPA symbol **ʋ** to render the Ukrainian phoneme /v/ (/в/). However, we treat this sign as a notation of the hyperphoneme being realised in the differently articulated allophones [β̞ β̞ β̞ʷ] and a [v] (and its devoiced cognate), and a [vʲ].

So, we propose more detailed and precise description of the Ukrainian phoneme /v/ than presented in the earlier works that is important for further progress in contemporary phonetic and related studies.

3.4. The problem to render the loaned European (mostly English and German) /h/ in Ukrainian and to transliterate a Ukrainian grapheme “г” into the Latin script is somewhat intricate because there is no exact correspondence between relevant sounds, and different approaches should be applied in the first and latter cases – invariant transcription and transliteration (see Vakulenko, 2015b: 229–254; Vakulenko, 2015c). The English and German [h] is considered either as a voiceless aspirated fricative, or glide, or vocoid sound with no determined point of noise generation (see Boase-Beier & Lodge, 2003: 98–127; Stevens 1998: 448–449, 513) that always precedes a vowel. The Ukrainian sounds [x] and [г] are respectively voiceless and voiced consonants forming a correlation pair (Tocjka 1981: 93) that may appear anywhere in a word. So, an English and German [h] differs from a Ukrainian pair in position and articulation, and is similar to [x] by absence of voice.

This similarity is evidently manifested in the words that have arisen from imitation of aspirated voiceless sounds in Ukrainian: *ха-ха-ха* ‘ha ha ha’, *хе-хе* ‘he he’, *хі-хі* ‘hee hee’, *хо-хо* ‘ho ho’, *хукати* ‘to blow’, *тьху* ‘pooh, faugh’, *кахикати* ‘to cough’, *чхати* ‘to sneeze’, *хап* ‘snatch’, *пхикати* ‘to whimper, to snivel, to pule’.

It is important to note that a Ukrainian sound [x] is pronounced differently before consonants and vowels and acquires in the latter case a glottal vocalized afterbreath (Vakulenko, 2012: 234–237; Vakulenko, 2015a: 11; Vakulenko, 2015b: 180–186) that enhances its similarity with an English and German [h]. In turn, our phonetic experiments within the 2003–2004 Fulbright program demonstrate that an isolated American English [h] is uttered with significant friction in the velum area, as a separate Ukrainian [x]. This may be explained by the fact that the human vocal tract is bent right above velum, so turbulence is located mainly in this area. The recording of an American English sound [h] in different positions pronounced by a female native speaker is available here:
<https://drive.google.com/file/d/0Bw44-ZBHniK_b0hYa2o1eWN6bGc/view?usp=sharing>.

It was illustrated in Vakulenko (2015a: 9) that in the last decades, a tendency emerged to render an English (and also German) [h] by a Ukrainian letter х: *Hooligan* (Eng.) – *хуліган*, *know how* (Eng.) – *ноу-хау*, *hacker* (Eng.) – *хакер*, *Hände hoch* (Ger.) – *хенде хох*, *Heidegger* (Ger.) – *Хайдеггер*.

Following H. Kawasaki (1982: 169), we may state that a combination "[x] + vowel" is favoured in comparison to "[г] + vowel" because a voiceless consonant [x] has more pronounced acoustic contrast with a vowel than a voiced [г] that, in addition, is characterized by variable tongue position depending on the next vowel (see Bilodid, 1969: 177; Tocjka, 1981: 83).

Whenever a Ukrainian word (mostly a proper name or a word denoting some specific Ukrainian entity) has to be used in the international context, a simple-correspondent transliteration should be applied (Vakulenko, 2004; see also Vakulenko, 2015b: 229–254; Vakulenko, 2015c). Thus, Ukrainian Cyrillic letters are converted into Latin graphemes without reference to their sound in any other language. Unfortunately, these requirements, as well as a Ukrainian alphabet history, are often ignored. As the letter "г" is a historical descendant of the Hellenic grapheme "ɣ" that corresponds to a Latin "g" as in *grammar*, *Gregory*, *geography*, *goniometer*, etc., this symbol should be kept in transliteration of a "г": gh, ǧ – thus warranting also correct information transfer in the transliterated text (see details in Vakulenko, 2004; Vakulenko, 2015b: 229–254; Vakulenko, 2015c).

3.5. The phonemic status of the weakly palatalized cognates of Ukrainian consonant phonemes /b/, /v/, /gh/, /zh/, /k/, /m/, /p/, /f/, /kh/, /ch/, /sh/ has been not clearly determined heretofore. Such sounds usually appear before an /i/ (Cyrillic /і/), and as it was recognized that an /i/ (/і/) and an /y/ (Cyrillic /и/) are independent phonemes[4], they have been considered just as positional allophones of corresponding plain phonemes (see Bilodid, 1969: 239–241; Tocjka, 1981: 46). However, there is a number of phonemic oppositions between such plain and palatalized counterparts before back vowels: *бюргер* [bʲʊˈr-ɦə̟⁺r] 'burgher' – *бургер* [buˈr-ɦə̟⁺r] 'burger', *бюст* 'bust' – *буст* 'boost', *бязі* '(of, to, from) unbleached calico' – *базі* '(to) the base', *кюре* 'cure, parish priest' – *Куре* '1. Kure; 2. Couret', *мюль* 'mule' – *Муль* 'Moulle' (a municipality in France), *Мюрат* 'Murat' – *Мурат* 'Murat', *ревю* 'revue' – *реву* '(I) roar', *свят* [s̪vʲɐˈt̪] 'of holidays'– *сват* [s̪vɑ⁺ˈt̪] '1. matchmaker; 2. marriage broker; 3. father of the son-in-law; 4. father of the daughter-in-law'. This fact makes it possible to regard these palatalized sounds as chief realisations of corresponding palatalized phonemes of the peripheral subsystem, as M. Zhovtobrjukh proposed in 1965 (see Tocjka 1981: 63–64).

4. Conclusions

In this article, we have investigated some acoustic and articulatory properties of Ukrainian consonants based on earlier studies of Ukrainian reports of well-known phoneticians and on our own experimental material, and we have proposed a full set of relevant IPA notations for the consonant phones of contemporary standard Ukrainian compiled in the table. Acous-

[4] acoustic and morphological proofs for this are given in Tocjka (1981: 46–48)

tic correspondence of Ukrainian phones to those appearing in European languages was analyzed and discussed. We applied here auditory and visual comparative analysis, auditory observation, and speech analysis based on the use of special software, and also general and Ukrainian phonetic laws governing language evolution and phone clusters formation. The research is illustrated with visual images and oscillograms. Such a combined approach resulted in a more detailed phone inventory than proposed before.

The sound [g] was referred to the peripheral system of Ukrainian phones since it is the chief allophone of the rare phoneme /g/ (Cyrillic /ґ/). Based on phonemic speculations, the sound [ɣ] was selected as the chief allophone of the /gh/ (/ґ/).

It was demonstrated that the allophones of the standard Ukrainian phoneme /v/ significantly differ in their acoustic characteristics from those of a labiovelar glide (approximant) [w], as well as in relevant articulation by native American English and British English speakers. Our experiments and observations suggest that a standard Ukrainian phoneme /v/ is realised as labiodental fricatives [v] and [vʲ] before vowels and also as sonorant bilabial approximants [β̞ β̞ˠ β̞ʷ] between a vowel and a consonant, in the initial position before consonants and after a vowel at the end of a word, and sometimes is devoiced to [v̥] in the coda after a voiceless consonant. In some western Ukrainian dialects, a strongly rounded bilabial approximant [β̞ʷ] may approach a non-syllabic semivowel [u̯] in a position after a vowel (before a consonant and in the coda). These conclusions are in good agreement with the consonantal status of the Ukrainian language and with the general tendencies of sound combinations in the world languages.

It was shown also that the velar [ɣ] and pharyngeal [ʕ] and/or glottal [ɦ] allophones of the Ukrainian phoneme /gh/ (/ґ/) probably obey the complementary distribution relation: the first one is likely to be met mostly before consonants and in the coda (but may also arise before vowels), the last two appear before vowels.

Having investigated linguistic facts stating that the English and German [h] is acoustically close to the Ukrainian [x] and accounting for preferred contrasting sound combinations, we recommend using the letter x in place of this phone in relevant loanwords.

These findings are more precise, comprehensive, grounded and detailed, and give rise to more systematic consonant inventory than the relevant results of Bilodid (1969). Buk et al. (2008), Pompino-Marschall et al. (2016).

We suggest also that the weakly palatalized phones [bʲ], [vʲ], [ɣʲ], [ʒʲ], [kʲ], [mʲ], [pʲ], [rʲ], [fʲ], [xʲ], [ɡ̊ʲ], [ɲʲ], as well as the [g] and its palatalized cognate, may be regarded as chief allophones of relevant peripheral phonemes.

The more detailed and comprehensive study of modern Ukrainian speech may result from due financial support.

The results of this research may be useful in various phonetic and translation studies and in modern linguistic technologies.

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Figures

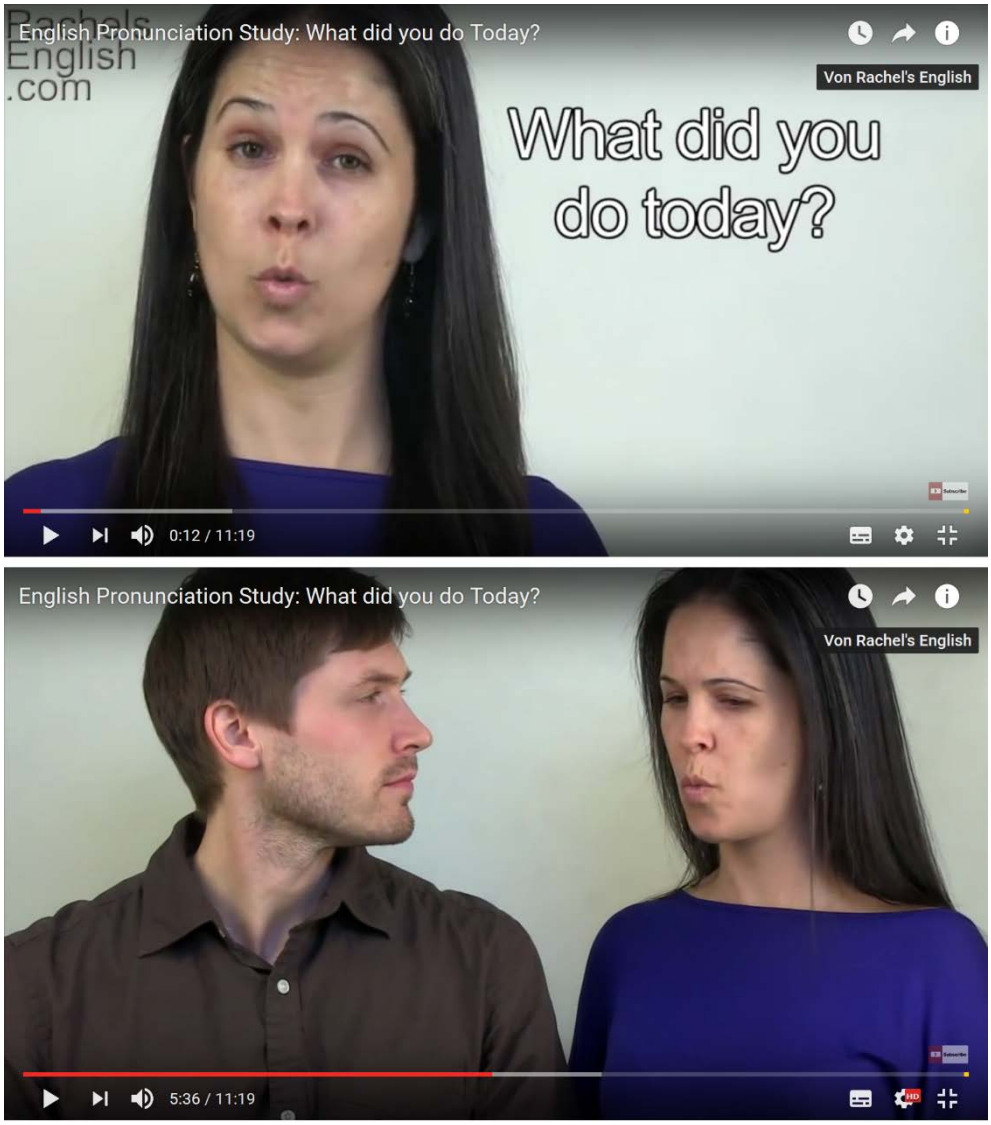

Figure 1
A visual representation (vizeme) of facial articulation of a labiovelar glide [w] in American English *what* (top) and *where* (bottom). Strong lips protrusion with a narrow orifice is formed, as in an [u].

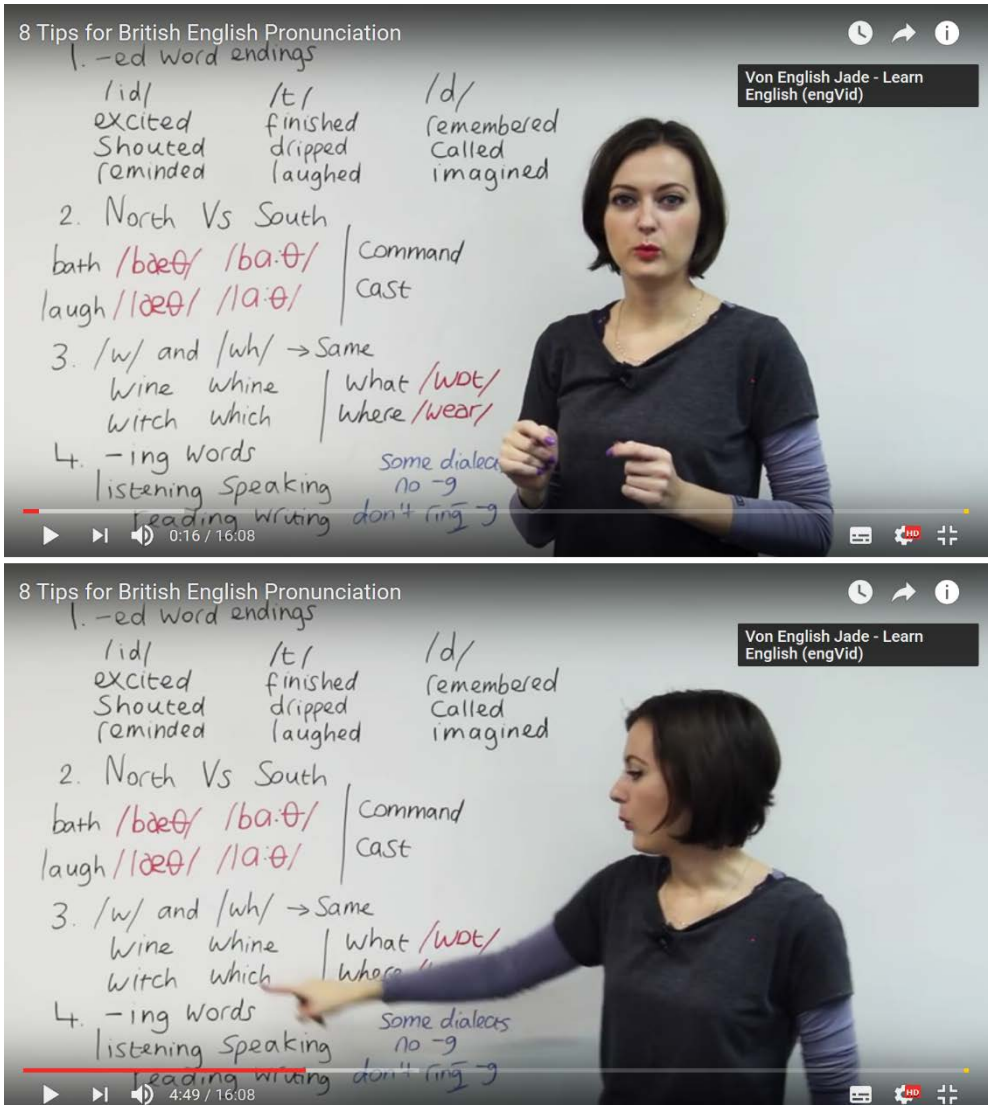

Figure 2

A visual representation (vizeme) of facial articulation of a labiovelar glide [w] in British English *word* from the front (top) and in profile (bottom). Significant lips protrusion with a narrow orifice is formed, as in an [u].

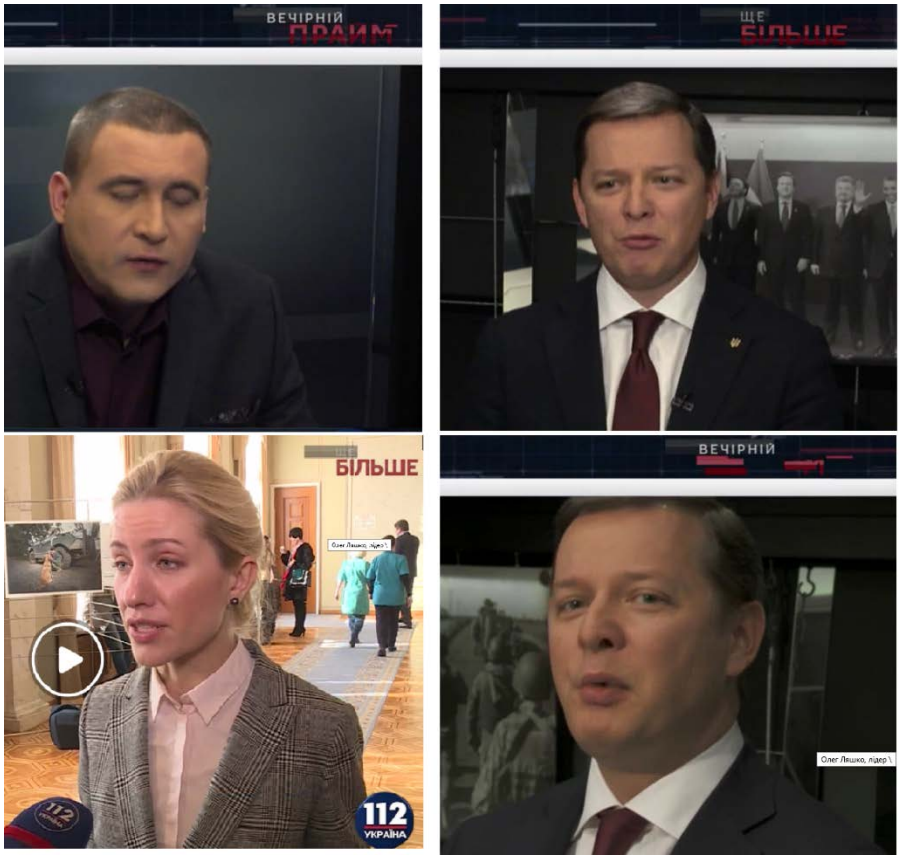

Figure 3

[From the TV channel “112 Ukrajina”]. Top left: A visual representation (vizeme) of facial articulation of the Ukrainian phoneme /v/ after a vowel at the end of *мовляв* [m̩o̞β̞-lʲɐˈv] ‘say’ (Speaker MK). The lower lip is near the upper incisors, without lips rounding and protrusion that is characteristic to the labiodental fricative consonant [v].

Bottom left: A visual representation (vizeme) of facial articulation of the Ukrainian phoneme /v/ between a vowel and a consonant in *лаявся* [ɫɑ⁺ˈ-jɐβ̞̊-s̪ʲɐˌ] ‘(he) cursed’ (Speaker SZ). The lip corners are pressed to the front teeth resulting in lips rounding without protrusion that is typical to a more rounded bilabial approximant [β̞̊].

Top right: A visual representation (vizeme) of facial articulation of the Ukrainian phoneme /v/ between a back vowel and a consonant in *мавпи* [mɑ⁺ˈβ̞-pɵ⁺] ‘of the monkey’ (Speaker OL). The lip corners are pressed to the front teeth while lips are approaching each other without rounding and protrusion, that is characteristic to a bilabial approximant [β̞].

Bottom right: A visual representation (vizeme) of facial articulation of the Ukrainian phoneme /v/ after a vowel at the end of *купив* [kʊ-pɨ̞⁺ˈβ̞̊] ‘(he) bought’ (Speaker OL). The lip corners are pressed to the teeth resulting in lips rounding without noticeable protrusion that is typical to a more rounded bilabial approximant [β̞̊].

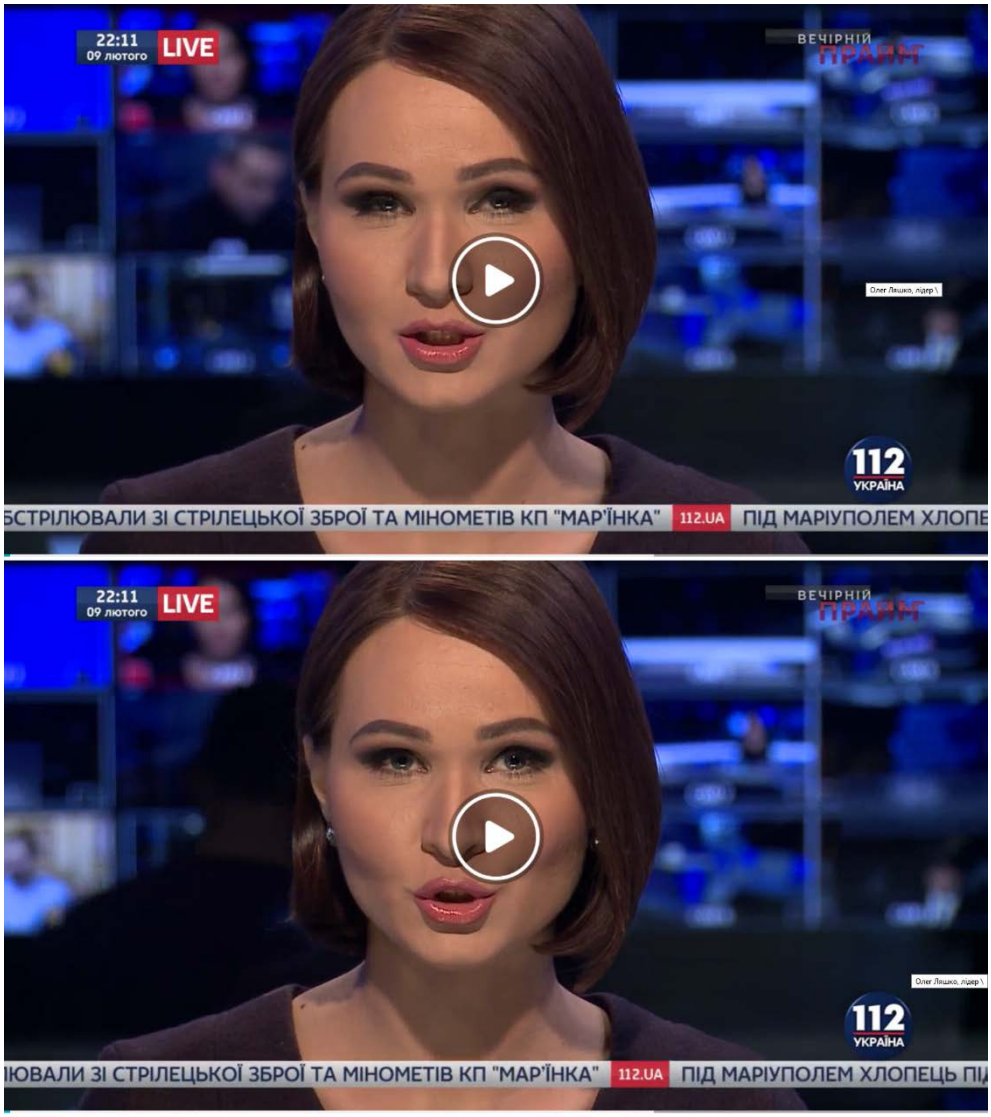

Figure 4

[From the TV channel “112 Ukrajina”]. Top: A visual representation (vizeme) of facial articulation of the Ukrainian phoneme /v/ between a vowel and a consonant in *Левченко* [łɛ̞ˈβ̞ɔ-ʃʲʒ̺ʲn̪-koˌ] ‘Levchenko’ (Speaker EB). The lips are rounded without noticeable protrusion that is characteristic to a more rounded bilabial approximant [β̞].

Bottom: A visual representation (vizeme) of facial articulation of an accented vowel [u] in *Мельничук* ‘Meljnychuk’ [mə̹ˠlʲ-n̪ɨˠ- ʃuˈk] (Speaker EB). The lips are strongly rounded and protruded.

Figure 5

[From the TV channel “112 Ukrajina”]. Top: A visual representation (vizeme) of facial articulation of the Ukrainian phoneme /v/ before a central vowel [ɐ] in *розірваного* [ro-ʒ̪ʲiˈr-vɐ-n̪o̞-ɦo˧] ‘of the torn’ (Speaker EB). The lower lip is touching the upper incisors without lips rounding and protrusion that is characteristic to a labiodental fricative consonant [v].

Bottom: A visual representation (vizeme) of facial articulation of the Ukrainian phoneme /v/ between a front vowel [i] and a consonant in *Рівне* [rʲiˈβ-n̪ɔ̞⁺] ‘Rivne’ (Speaker KhS). A narrow constriction between the lips is formed without their rounding and protrusion that is typical for an unrounded bilabial fricative consonant [β].

Figure 6

[From the TV channel “24th channel”]. Top: A visual representation (vizeme) of facial articulation of the Ukrainian phoneme /v/ between vowels in *зловили* [ʐ̪ło-vi̯˖ˈ-łi̯˖] ‘(they) caught’ (Speaker KhS). The lower lip is touching the upper incisors without lips rounding and protrusion indicating a labiodental fricative consonant [v].

Bottom: A visual representation (vizeme) of facial articulation of the Ukrainian phoneme /v/ after a back vowel at the end of *знав* [ʐ̪ɲɑ˖ˈβ̞] ‘(he) knew’ (Speaker KhS). The lips are slightly rounded that is characteristic to a less rounded bilabial approximant [β̞].

Figure 7
[From the TV channel “24th channel”]. Top: A visual representation (vizeme) of facial articulation of the Ukrainian phoneme /v/ between a vowel and a consonant in *Пав̲ло* [pʋv̞ˈło] ‘Pavlo’ (Speaker PR). The lips are not rounded indicating a labiodental fricative consonant [v].

Bottom: A visual representation (vizeme) of facial articulation of a stressed vowel [u] in *̲участь* [uˈ-t͡ʃʋs̪tʲ] ‘part’ (Speaker PR). The lips are strongly rounded and protruded.

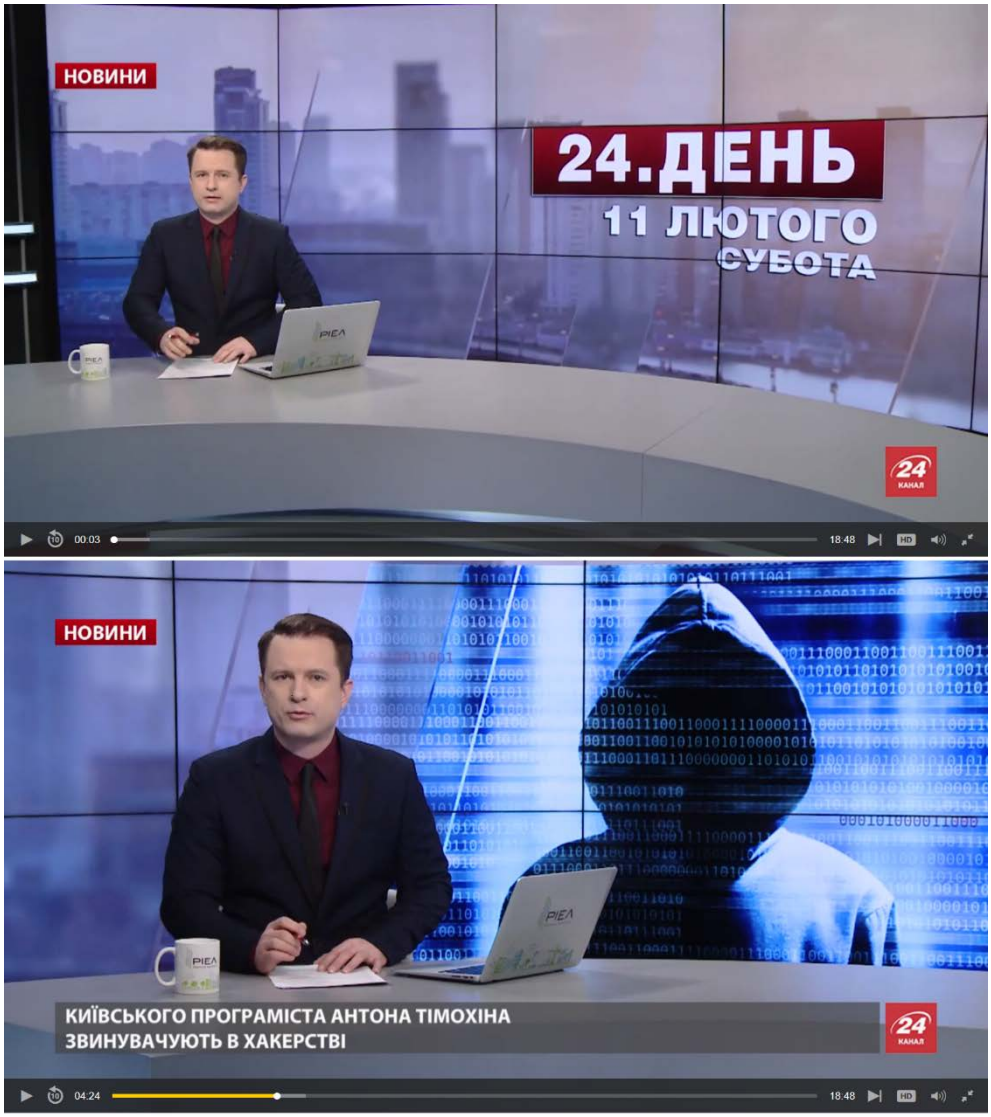

Figure 8

[From the TV channel “24th channel”]. Top: A visual representation (vizeme) of facial articulation of the Ukrainian phoneme /v/ in intervocalic position in *триває* [t̪rɔ̞⁺-vɑ⁺ˈ-jɛ̞⁻] ‘is going on’ (Speaker PR). The lower lip is touching the upper incisors without lips rounding and protrusion indicating a labiodental fricative consonant [v].

Bottom: A visual representation (vizeme) of facial articulation of the Ukrainian phoneme /v/ between a vowel and a consonant in *активну* [ɐ-kt̪i̞⁺ˈβ̞-n̪ʊ] ‘active’ (Speaker PR). The lip corners are slightly pressed to the teeth and a narrow constriction between slightly rounded lips is formed, that is characteristic to a less rounded bilabial approximant [β̞].

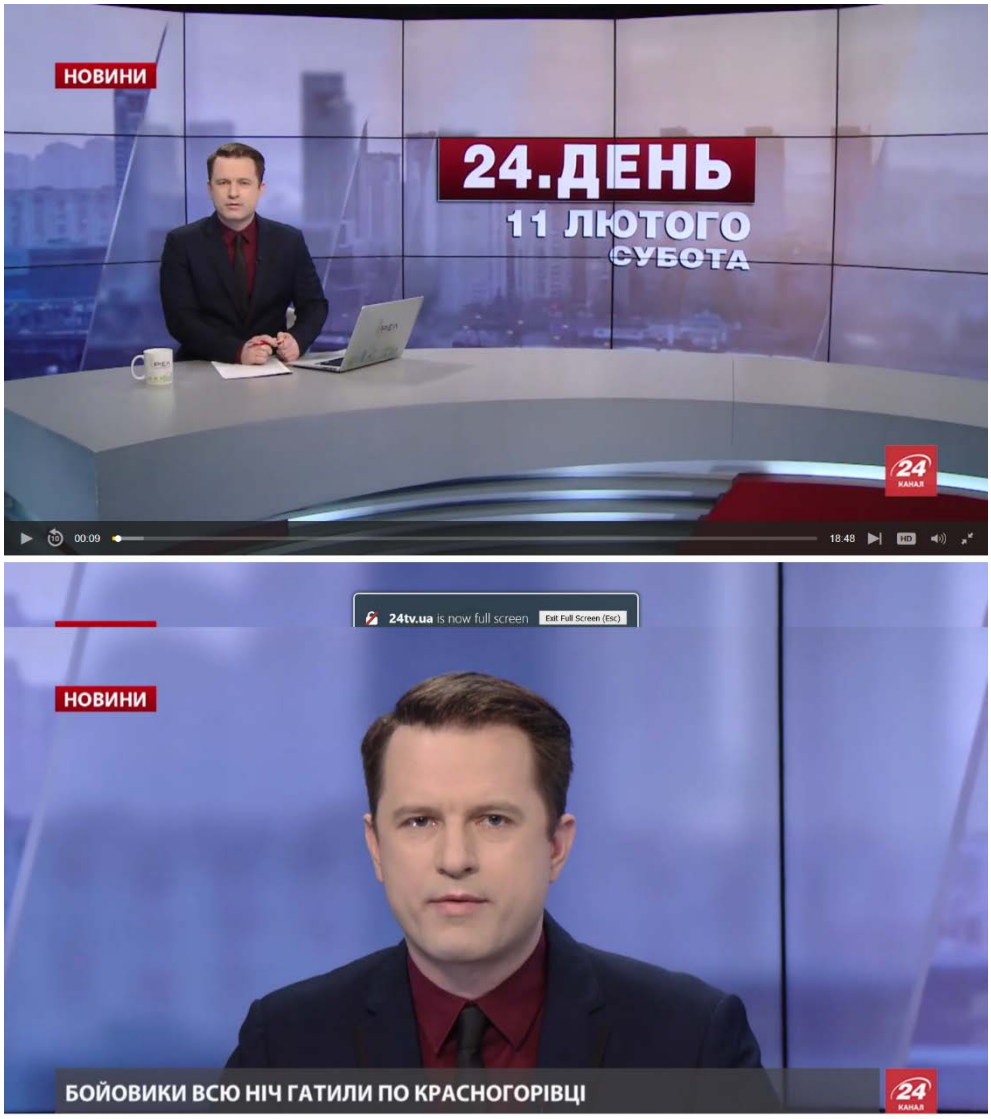

Figure 9

[From the TV channel “24th channel”]. Top: A visual representation (vizeme) of facial articulation of the Ukrainian phoneme /v/ after a front vowel [i] in the end of *журналістів* [ʒʊr-n̪ɐ-lʲiˈ-s̪ʲtʲiβ̞] ‘of the journalists’ (Speaker PR). A narrow constriction between the lips is formed that is characteristic to an unrounded bilabial approximant [β̞].

Bottom: A visual representation (vizeme) of facial articulation of the Ukrainian phoneme /v/ between a high front vowel [i] and a consonant in *Красногорівка* [krɐˌ-s̪n̪o̞-ɦo̞ˈ-rʲiv-kɐˌ] ‘Krasnoghorivka’ (Speaker PR). The lower lip is touching the upper incisors without lips rounding and protrusion, that is typical to a labiodental fricative consonant [v].

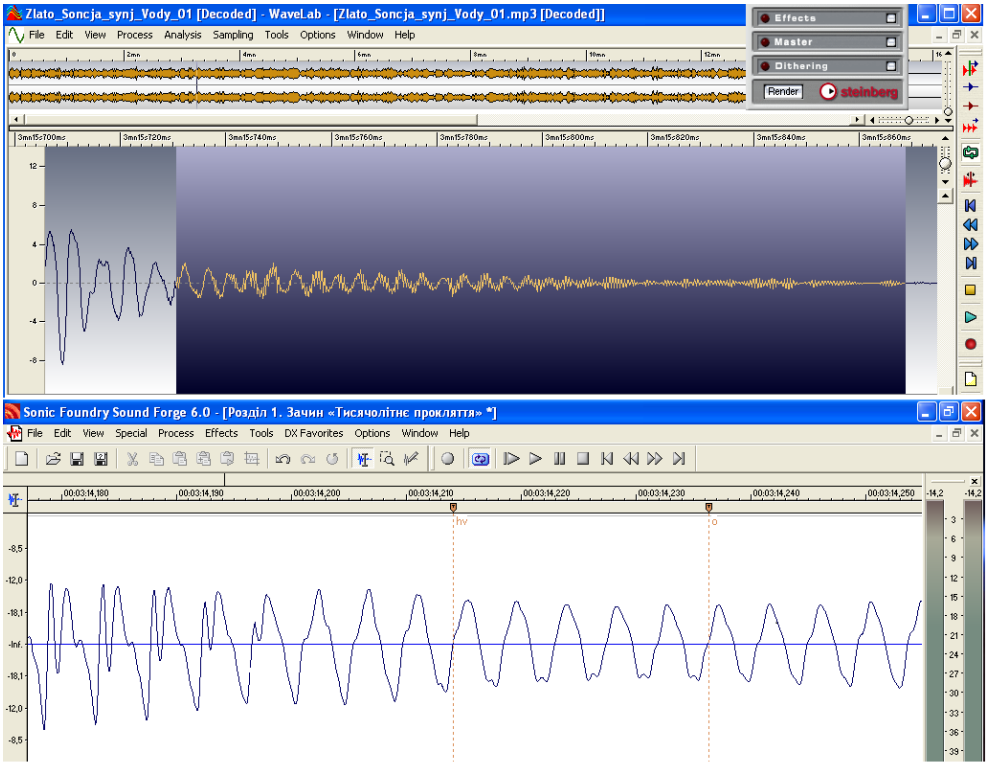

Figure 10

Oscillograms of different acoustic realisations of the Ukrainian phoneme /gh/ (Cyrillic /г/). Top: the end of *міг* [mʲiˈɣ] ‘(he) could’. The pattern is characterized by a distinctive high-frequency noise component inherent to a partly devoiced velar fricative allophone [ɣ]. Bottom: intervocalic position in нього [ɲo̞ˈ-ɦo] ‘him’. The prevalently harmonic character of the oscillogram without a noticeable noise component indicates a glottal sound [ɦ].

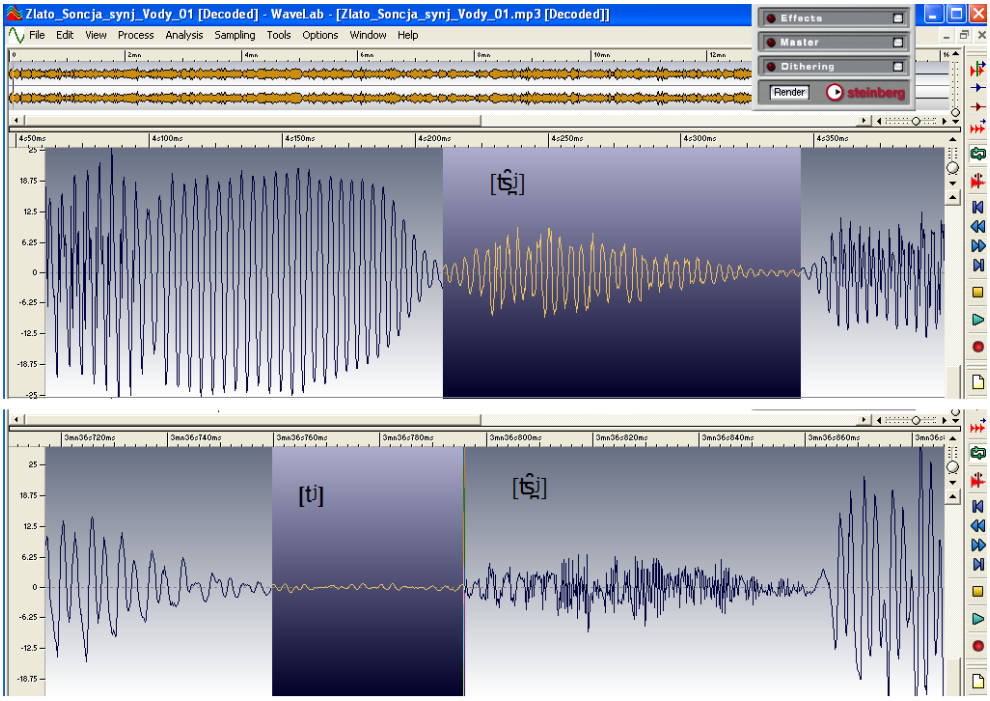

Figure 11

Oscillograms of an affricate [**t͡ʂʲ**] in *сонця* [s̪o̞ˈn̪-t͡ʂʲɐ] ‘of the sun’ (top) and geminate affricate [**tʲt͡ʂʲ**] in *хочеться* [xo̞ˈ-ʃ͡ʒ̩⁺-tʲt͡ʂʲɐˌ] ‘is desired’ (bottom).

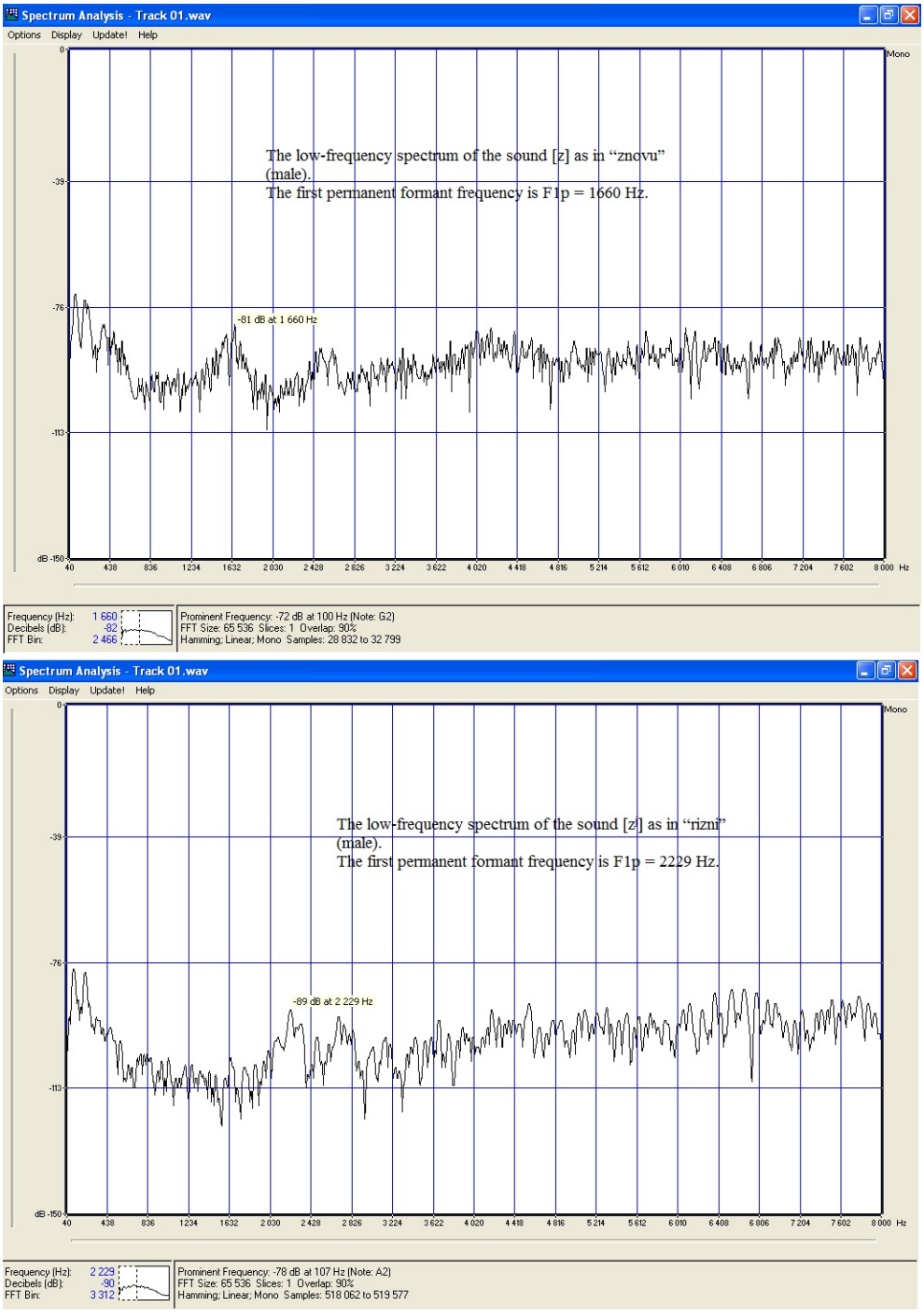

Figure 12

Low-frequency behaviour of the sound [z̪] as in *znovu* [z̪n̪o̪ˈ-vʊ] 'again' (top) and [z̪ʲ] as in *rizni* [rʲiˈ-z̪ʲni] 'different' (bottom), speaker AZ (male). In the palatal environment, the first permanent formant moves up from the value of F1p = 1660 Hz to the value of F1p = 2229 Hz.