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# ACOUSTIC ANALYSIS OF THREE MARKED TRILLS: WELSH R̥ʰ, SLAVIC Rʲ AND CZECH R̝

## Introduction[1]

Trills are relatively common sounds in the world's languages. According to the UCLA Phonological Segment Inventory Database (UPSID) that lists the phonemic inventories of 451 languages, the plain dental/alveolar trill /r/ can be regarded as a prototype as it is found in 155 of them. Trills that have secondary articulatory features are much less frequent. For instance, the UPSID database does not list any languages that have a spirantised trill in their inventory, nor does it offer any information regarding fricated trills. With respect to the palatalised trill /rʲ/, the database includes only five languages that have the sound (Bulgarian, Lithuanian, Nenets, Saami and Russian).

A trilled sound is produced when the active articulator, either the apex or the uvula, is set in vibration by the airstream in the oral cavity. It follows that, rather than being controlled by muscular action, the vibration results from the aerodynamic conditions created by the airstream passing through the aperture between the active and passive organ[2]. As trilling crucially depends on the size and shape of the aperture, as well as on the volume of airflow, minimal changes to one of the factors can result in a non-

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1 I would like to thank two anonymous reviewers for their comments on an earlier draft of the paper.

2 Peter Ladefoged, Ian Maddieson, *The Sounds of the World's Languages*, 217 (Oxford: Blackwell Publishers); Maria-Josep Solé, "Aerodynamic characteristics of trills and phonological patterning", *Journal of Phonetics* 30 (2002): 655–688.

trilled realisation. It is for this reason that trills are highly prone to phonetic change as the utmost degree of articulatory precision can hardly be achieved in connected speech. Following this line of reasoning, trills with secondary features should exhibit a greater susceptibility to phonetic change due to involving an additional gesture that further enhances the inherent complexity of trills.

This paper reports the results of an acoustic study aimed at providing a comprehensive description of the phonetic properties of three cross-linguistically rare trills: (i) Welsh spirantised /r̥ʰ/, (ii) Russian and Ukrainian palatalised /rʲ/ and (iii) Czech fricated /r̝/[3]. Since the rhotics have a secondary articulatory feature, they are said to be marked and as such they should exhibit a considerable amount of variation in speech. Therefore, a secondary objective of the investigation is to ascertain the extent to which the trills undergo phonetic reduction in prosodically strong, word-initial position.

The article is structured as follows. Section 2 is meant to familiarise the reader with the difficulties involved in producing a trilled sound. Section 3 presents a detailed account of the acoustic characteristics of /rʰ/, /rʲ/ and /r̝/. Section 4 introduces the data collection method of the current study, which includes a phonetic experiment involving 35 native speakers of the above-mentioned languages, and presents the results of the investigation. Finally, several concluding remarks are formulated in Section 5.

## 1. The articulation of a trill

As noted above, the production of a trill constitutes an articulatory difficulty as it involves creating the appropriate aerodynamic conditions within the oral cavity. It implies that the physical properties of the aperture as well as the volume of airflow must fall within specified narrow limits if trilling is to be maintained. This assumption was fully confirmed by the results of an experiment conducted by Solé 2002 which indicate that a pressure drop across the lingual constriction within the range of 2.5–3.5 cm H2O is sufficient to impair trilling (see Figure 1)[4]. It has also been established that excessive airflow results in fricativisation irrespective of the place of articulation of a trill[5]. This finding may account for the sound's susceptibility to phonetic change as evidenced by synchronic and diachronic alterations of the phoneme /r/

3 In Slavic linguistics, the fricated trill is represented by the symbol [r̝], which also happens to be a letter of the Czech alphabet. However, throughout this work, the IPA symbol [r̝] is consistently used to stand for this sound.

4 Maria-Josep Solé, "Aerodynamic characteristics of trills and phonological patterning", *Journal of Phonetics* 30 (2002): 672.

5 See also Ryan Shosted, "An aerodynamic explanation for the uvularization of trills", in: *Proceedings of the 8th International Seminar on Speech Production* 2008, eds. Rudolph Sock, Susanne Fuchs, Yves Laprie, 421–424 (Strasbourg, INRIA, 2008).

to [ɹ] or [ɻ̥] that have been attested in many languages that have a trill in their sound inventory[6].

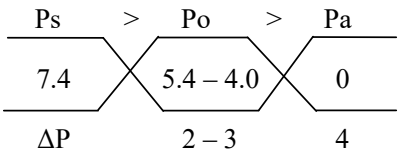



Figure 1. Values of subglottal pressure (Ps), oropharyngeal pressure (Po) and atmospheric pressure (Pa), expressed in cm H2O, across the lingual constriction required for trilling and voicing. The ΔP parameter indicates the minimal pressure difference at the glottal and lingual constrictions[7]

The articulation of a plain trill proves difficult, yet the difficulty seems to be doubled or even tripled when a trill with a secondary feature needs to be produced. Secondary features can be thought of as additional gestures that either change the internal configuration of the speech apparatus and/or affect the amount of airflow. The former scenario takes place in the articulation of the palatalised trill, while the latter occurs when spirantised and fricated trills are pronounced. The following sections provide basic information regarding the articulatory and acoustic properties of three unusual trills with secondary features.

### 1.1. The spirantised trill of Welsh

The spirantised trill /r̝ʰ/ of Welsh is something of a rarity cross-linguistically as, to the best of our knowledge, no other languages having such a speech sound have been reported in the phonetic literature. In the orthography of that language, the articulatory features of the sound are reflected, to a certain extent, in the spelling as it is represented by the digraph <rh>. As suggested by the digraph, the sound can be thought of as an apical trill pronounced simultaneously with audible glottal fric-

6 Beatriz Blecua, *Las vibrantes del Español: manifestaciones acústicas y procesos fonéticos* (Universidad Autonoma de Barcelona, 2005); Laura Colantoni, "Increasing periodicity to reduce similarity: An acoustic account of deassibilation in rhotics", in: *Selected Proceedings of the 2nd Conference on Laboratory Approaches to Spanish Phonetics and Phonology*, ed. Manuel Diaz-Campos, 22–34 (Somerville, MA: Cascadilla Proceedings Project, 2005); Richard Wiese, "The unity and variation of (German) /r/", in: *R-atics: Sociolinguistic, phonetic and phonological characteristics of /r/*, eds. Hans Van de Velde, Roeland van Hout, 11–26 (Brussels, Universite Libre de Brussels, 2001); Daniel Recasens, Aina Espinosa, "Phonetic typology and positional allophones for alveolar rhotics in Catalan", *Phonetica* 63 (2007): 1–28; Marzena Żygis, "(Un)markedness of trills: the case of Slavic r-palatalisation", *Zeitschrift fur Slawistik* 50 (2005): 383–407; Sylwester Jaworski, Edward Gillian, "On the phonetic instability of the Polish rhotic /r/", *Poznań Studies in Contemporary Linguistics* 47 (2011), 2: 380–398.

7 Maria-Josep Solé, "Aerodynamic characteristics of trills and phonological patterning", *Journal of Phonetics* 30 (2002): 675.

tion. The inherent complexity of the sound is the primary reason for which speaker of Welsh replace it with other sounds to the extent that some may not have it in their consonant inventory. As a result, the phonemic status of /r̥ʰ/ in Welsh is sometimes questioned[8].

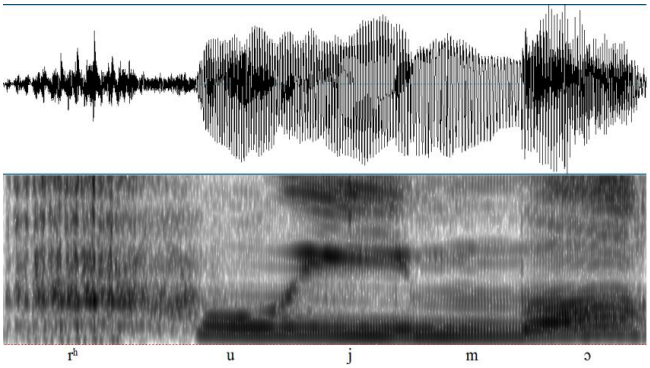



Figure 2. A hyperarticulated token of the spirantised trill of Welsh produced in the word *rhywmo* 'bind'

A hyperarticulated token of a spirantised trill, pronounced in the Welsh word *rhwymo* [rʰujˈmɔ] 'bind', is presented in Figure 2. In the spectrogram, the initial part of the sound is represented by a sequence of as many as seven incomplete constrictions (the light vertical stripes) separated by periods of friction. The final part of the sound, on the other hand, consists of a period of glottal friction, which is relatively strong in the low-frequency region. On average, the duration of the constrictions is on the order of 10 ms, with each consecutive constriction being slightly shorter than the previous one. As for the periods of friction, for this speaker, they are on average 18 ms long. In the light of the temporal data, it can be stated that the this token has a vibration rate of 37 Hz.

From an articulatory point of view, trills of this type are certainly highly marked as gestures produced with different organs must be executed with perfect timing. In addition to that, throughout the sound, the critical difference between subglottal pressure and oropharyngeal pressure must be maintained to allow for the repetitive movements of the apex to be made. Given the inherent articulatory difficulty of the sound, it is hardly surprising that spirantised trills tend to undergo phonetic reduction in speech. This claim is substantiated by the results of an acoustic study performed by Asmus and Jaworski (2016) which point out that, even in read careful speech, a majority of Welsh spirantised trills are pronounced as fricatives.

8 Martin Ball, "How many rhotic phonemes does Modern Welsh have?", in: *Representations and Interpretations in Celtic Studies*, eds. Tomasz Czerniak et al., 49–61 (Lublin: Wydawnictwo KUL, 2015).

### 1.2. The palatalised trill of East Slavic

Ladefoged and Maddieson argue that the difficulty speakers have in pronouncing /rʲ/ may stem from the fact that "the raising of the blade and front of the tongue that is required for the palatalisation may make it more difficult to maintain the aerodynamic conditions for trilling"[9]. As shown in the two panels of Figure 3, while pronouncing /rʲ/, the apex is usually used as the active articulator, the same as in the case of the plain /r/[10]. Judging from the position of the dorsum for /r/ and /rʲ/, the articulation of the latter sound requires a greater muscular effort than the former, which is not only due to the considerable mass of the dorsum that needs to be raised, but also to the increased stiffness of the tongue tip which cannot vibrate freely when it is accompanied by the raised pre-dorsum. As noted by Recasens and Pollarès, it is the antagonistic gestures that make palatalised trills difficult to pronounce[11].

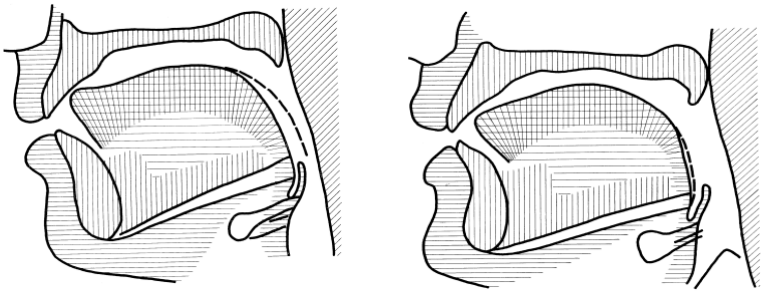


Figure 3. Articulation of Russian /r/ (left-hand panel) and /rʲ/ (right-hand panel)

As regards the acoustic properties of [rʲ], they typically consist of two closures separated by a vocalic element. A representative example of a fully voiced trill, produced in the word *різко* [ˈriskə] 'sharply', is presented in Figure 4. This particular token consists of two taps and a vocalic element[12]. The duration of the first tap is 18 ms, whereas the other is 2 ms shorter. The separating vocalic element is 20 ms long.

9 Ladefoged, Maddieson, *The Sounds of the World's Languages*, 221; see also Żygis, "(Un)markedness of trills", 383–407; Daria Kavitskaya, Khali Iskarous, Aude Noiray, Michael Proctor, "Trills and palatalisation: Consequences for sound change", in: *Proceedings of the Formal Approaches to Slavic Linguistics* 17, eds. Justin Reich, Maria Babyonyshev, Daria Kavitskaya, 97–110 (Ann Arbor: Michigan Slavic Publications, 2009).

10 It is claimed that, in Polish, contextually palatalised /r/ is articulated with the blade rather than with the apex (see Bożena Wierzchowska, *Fonetyka i fonologia języka polskiego*, (Wrocław: Ossolineum, 1980).

11 Recasens, Pollarès, „Phonetic typology and positional allophones for alveolar rhotics in Catalan", *Phonetica* 63(2007): 1–28; Ladefoged, Maddieson, *The Sounds of the World's Languages*; Solé, *Aerodynamic characteristics of trills*, 655–688.

12 As shown in the spectrogram, the vowel following the second constriction contains a substantial amount of friction that also results from the raised position of the dorsum.

One full cycle of vibration lasts approximately 38 ms, which translates into a vibration rate of 26.3 Hz. The values of the formants of the vocalic element measured at mid point are 460 Hz and 2040 Hz for F1 and F2, respectively. Judging from these acoustic parameters, the vocalic element should be labelled as a mid high front vowel. However, this finding is hardly surprising given that the trill is pronounced with the dorsum held close to the palate.

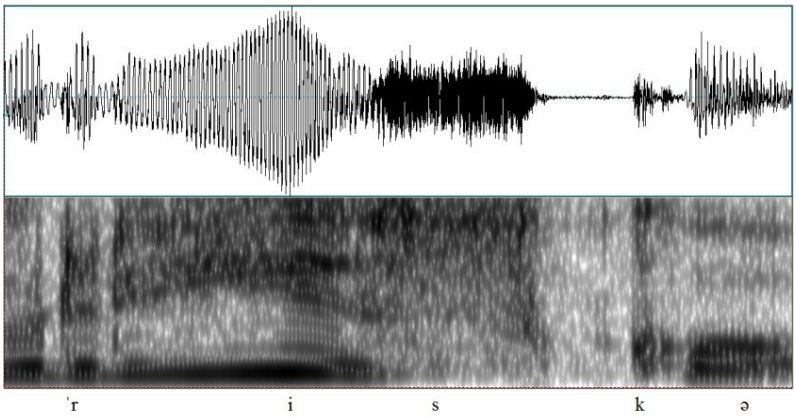



Figure 4. A trilled variant of the Ukrainian /rʲ/ produced in the word різко ‘sharply’

### 1.3. The fricated trill of Czech

The fricated trill that constitutes a phoneme of the Czech language definitely belongs to the rarest speech sounds and, therefore, must be regarded as marked. Ladefoged and Maddieson claim that Czech is the only language they know of that is produced with the blade of the tongue[13]. However, conservative speakers of Kashubian are also said to produce fricated trills which tend to be replaced with plain trills in running speech[14]. Also, according to the *Multimedial Handbook of Polish Dialects* published online by a group of scholars at Warsaw University and available at www.gwarypolskie.uw.edu.pl, the fricated trill can still be heard in several regions including southern Silesia, the South-West of Minor Poland and the North of Great Poland.

Figure 5 depicts a fricated trill produced by a native speaker of Czech in the word řekl ‘he said’. The spectrogram shows clearly that the informant managed to produce one complete closure that is followed by a certain amount of friction. This realisation is consistent with descriptions of the segment in the phonetic literature. For example,

13 Ladefoged, Maddieson, *The Sounds of the World’s Languages*, 227.

14 Zofia Topolińska, *A Phonological History of the Kashubian Language*, (The Hague: Mouton & Co. N.V., Publishers, 1974); Zdzisław Stieber, *Zarys gramatyki porównawczej języków słowiańskich*, (Warszawa: Wydawnictwo Naukowe PWN, 1979).

the fricated trill /r̝/ is described as "a period of friction interrupted at the beginning by a contact or contacts created by a retracted apico-alveolar gesture"[15]. In spontaneous speech, however, this highly complex sound is likely to undergo phonetic reduction by eliminating the closure phase. If this happens, a fricative is produced instead. A similar sequence of events may be assumed to have taken place in the Middle Ages in Polish and eventually led to replacing the rhotic with the sibilant [ʒ][16].

The physical properties of the sound in Figure 5 hardly justify labelling the sound as a trill as no repetitive gestures can be seen in the spectrogram. However, realisations involving several, typically two, less frequently three, closing gestures are encountered in onset clusters, especially ones that begin with a bilabial plosive, e.g. in the word *přišla* 'she came'. In other contexts though, the sound is extremely prone to phonetic reduction which normally results in the articulation of a fricative. Allophones of /r̝/ that consist of a tap followed by a period of friction will be referred to as one-tap trills.

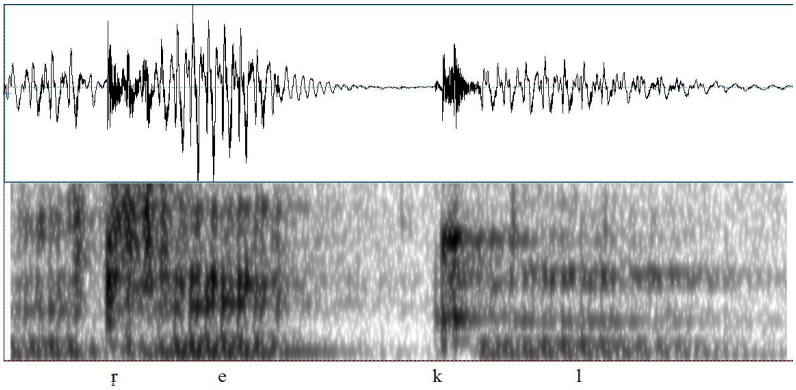



Figure 5. Fricated trill in the Czech word řekl [r̝ekl] 'he said'

Trilled rhotics including a substantial amount of friction, similar to the sound presented in Figure 5, may also results from the speaker's failure in articulating a plain apical /r/ of any language. By virtue of their articulatory and acoustic properties, allophones of that type could also be referred to as fricated rhotics, the same as the Czech phoneme /r̝/. If the same label were applied to denote the Czech phoneme as well as reduced allophones of /r/, it would inevitably give rise to a great deal of terminological confusion. In order to avoid the likely scenario, the term *fricativised trill* should probably be used to refer to phonetically reduced tokens of trills, while *fricated trill* should be applied exclusively to the Czech phoneme /r̝/.

15 Šarka Šimáčková, Vaclav Podlipský and Katerina Chládková, "Czech spoken in Bohemia and Moravia", *Journal of the International Phonetic Association* 42 (2002): 225–232.

16 Zenon Klemensiewicz, *Historia języka polskiego* (Warszawa: Państwowe Wydawnictwo Naukowe, 1999).

## 2. The concept of markedness

The three articulatorily complex rhotics have been referred to as marked; therefore, some space needs to be devoted to the concept of markedness. Żygis argues that the notion of markedness includes the following aspects of linguistic analysis: (i) the frequency of occurrence in the world's languages, (ii) articulatory properties, (iii) perceptual characteristics, (iv) emergence in the process of acquisition, (v) phonetic stability from a diachronic point of view and (vi) distribution within the syllable. However, given the limited scope of this paper, the present discussion focuses on points (i), (ii) and (vi)[17].

With respect to (i), the three rhotics are undoubtedly marked. It is sufficient to note that the Czech language is said to be the only one that has the fricated trill /r̝/[18]. It is also possible, but by no means certain, that the spirantised /r̝ʰ/ is only found in Welsh. Importantly, the sound is not listed in the UCLA Phonological Segment Inventory Database, but this is due to the sound inventory of Welsh not being included in the database. By contrast, the palatalised /rʲ/ appears to be a little more common cross-linguistically as five languages listed in the UPSiD database have such a phoneme. However, the list should be extended by including Irish, Ukrainian, Upper Sorbian and Lower Sorbian also have a phonemic palatalised rhotic in their sound system[19].

Marked sounds are said to be more complex in terms of articulation than their unmarked counterparts due to having an additional, or secondary, articulatory feature. In classical structuralist theory, it was assumed that the existence of a marked sound in the phonemic inventory of a language implies the presence of its unmarked counterpart. The three rhotics in question fulfill the criterion as there is a phonological contrast between /r̝ʰ/ and /r/ in Welsh, /rʲ/ and /r/ in Russian and /r̝/ and /r/ in Czech.

Another criterion that can be used to determine the markedness of a speech sound is its distribution within the syllable. The two Slavic rhotics do not really meet the phonotactic criterion as they occur in exactly the same positions as their plain counterparts. The contexts include word-initial, intervocalic and word-final positions as well as vowel-adjacent slots in onset and coda clusters. Occasionally, they also occupy positions that are not contiguous with a vowel as in Cz. *pohřbu* 'funeral' (gen. sg.) or R. декабрь 'December'. It can be argued then that their phonotactic properties do not differ significantly from those of their plain counterparts. On the other hand, the phonotactic distribution of the Welsh rhotic is definitely restricted in comparison to that of /r/ as it only occurs in onset positions.

17 Żygis, "(Un)markedness of trills", 387.

18 The sound is still heard in the speech of some Kashubians (Werner personal communication, June 2017).

19 Żygis, "(Un)markedness of trills", 383–407.

## 3. The study

The objectives of the current study are fourfold: (i) to describe the acoustic properties of the spirantised rhotic of Welsh, (ii) to determine the range of allophonic variation of /r̥ʰ/ by specifying which sounds are substituted for /r̥ʰ/ in speech, (iii) to establish whether speakers coming from the South and the North of Wales produce the same allophones of /r̥ʰ/ and (iv) to ascertain whether the spirantised trill /r̥ʰ/ of Welsh, the palatalised /rʲ/ of Russian and Ukrainian, and the fricated /r̝/ of Czech exhibit a similar amount of variation.

### 3.1. The participants and data collection methods

In order to achieve the objectives of the study, different methods of data collection had to be used. In the case of Welsh, 23 native speakers of the language participated in the experiment. There is a considerable difference between representatives of the northern variety of Welsh and those who speak the southern dialect of the language. The informants were asked to read a list composed of 16 target words, embedded in the carrier phrase *Dw i heb ddweud* X*, ond* Y*!,* which translates into English as 'I didn't say X, but Y!'[20]. The list was read twice so that each item occurred in the X and Y slots[21]. Altogether, the participants produced 736 tokens of /rʰ/, seven of which had to be excluded from analysis for technical reasons. The recordings were made in Szczecin, Poland, 2014 and Leipzig, Germany, 2014/2015[22]. The Praat software (version 4.2.21) was used to make the recordings, digitise the data and produce the spectrograms and oscillograms.

With regard to the Slavic languages, audiobook recordings of the Old Testament were used to obtain material for analysis. The acoustic properties of one hundred tokens of /rʲ/ pronounced by two native speakers of Russian, Ukrainian and the same number of tokens of /r̝/ pronounced by two Czech speakers were examined for the purposes of the paper. Since audiobooks are sold commercially, an assumption is made that the analysed speech samples represents the standard variety of the languages in question.

Despite differing significantly, the two data collection methods also have certain things in common. In the four languages in question (Welsh, Russian, Ukrainian and Czech), samples of read speech were analysed. Also, only word or morpheme-initial

20 Literally, 'I am without say(ing) X, but Y'.

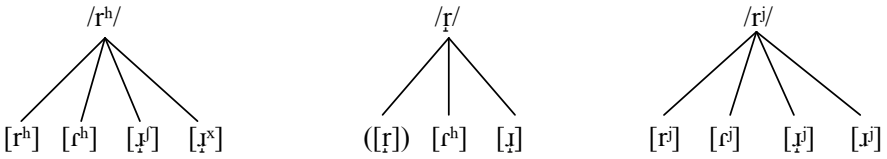
21 Sabine Asmus prepared the wordlist, while Sven Grawunder designed the experiment. The acoustic analyses were conducted by the present author.

22 For participation I would like to thank Aled, Andrew, Bryn, Catrin, Delyth, Dewi, Eiri, Fflur, Guto, Gwyer, Hywel, Ifan, Judith, Lowri, Lois, Marian, Nia, Peredur, Rhiannon, Rhys and Eleri. For technical assistance, we also express our gratitude to Sven Grawunder, Unieversity of Kiel/Germany and Max-Planck Institute for Evolutionary Anthropology, Leipzig/Germany.

rhotics were taken into consideration as the distribution of the Welsh spirantised rhotic is restricted to a greater extent than that of the Slavic complex rhotics /rʲ/ and /r̝/. However, there is a considerable difference regarding the number of lexical items in which the rhotics occur. In the case of Welsh, there is a great disproportion between the numbers of informants speaking the northern and southern dialects, yet the numbers of rhotics are sufficiently high to conduct a statistical analysis.

## 4. Results and discussion

An analysis of the acoustic properties of the three complex rhotics provides evidence that they differ with respect to the amount of allophonic variation observable in the examined recordings. As shown in (1), four articulatory variants of the Welsh spirantised rhotic were distinguished. These include: spirantised trills [r̝ʰ], one-tap spirantised trills [ɾʰ], sibilant fricatives [ɹ̝ʃ] and non-sibilant fricatives [ɹ̝x][23]. As far as the Czech rhotic phoneme /r̝/ is concerned, all the examined tokens were classified either a one-tap trill [ɾʰ] or fricative [ɹ̝˺. Interestingly, the trill is said to involve two or three closures, but such realisations were not encountered in the examined recordings[24]. Therefore, the trilled variant was bracketed to denote possible, but unattested allophone. It is worth pointing out that the one-tap trills of Welsh and Czech differ with respect to the feature [VOICE]. In our data, the Welsh sound is always [-VOICE], whereas the Czech segment is always [+VOICE], at least in word-initial position. Finally, the palatalised rhotic of Russian and Ukrainian also has four major articulatory variants that fall into the following phonetic categories: the palatalised trill [rʲ], palatalised tap [ɾʲ], palatalised fricativised rhotic [ɹ̝ʲ] and palatalised approximant [ɹʲ]. Given that approximantised, vowel-like variants of /rʲ/ were encountered in the East Slavic languages, which happened neither in Welsh nor Czech, it may be argued that the palatalised rhotic of East Slavic undergoes more radical reduction than the other marked r-sounds.




23 For lack of phonetic symbols representing natural classes of speech sound, [ʃ] and [x] were selected arbitrarily to stand for sibilant and non-sibilant fricatives, respectively. By no means, however, should it be understood that the trills are realised either as [ʃ] and [x].

24 Jana Dankovičová, "Czech", *Handbook of the International Phonetic Association: A guide to the use of the International Phonetic Alphabet*, 70–74 (Cambridge: Cambridge University Press, 1999).

The four spectrograms presented in the four panels of Figure 6 depict representative tokens of the most common phonetic realisations of the rhotics investigated in this study. The left-top panel presents a fricativised realisation of the Welsh spirantised /r̥ʰ/ produced in the word *rhy* 'too'. The resultant fricative sound has an important feature of a sibilant, namely a distinct cut-off point at the level of the third formant of the following vowel. Also, the friction is a considerably more intense in the high frequencies. The spirantised rhotic is totally voiceless as the voice bar is not present at the bottom of the spectrogram. A different type of fricative, presented in the right-top panel, resulted from the reduction of the Czech trill /r̝/ in the word řekl 'he said'. Unlike the previous sound, this token is fully voiced. Not only is the voice bar visible throughout the sound, but it also has an indistinct formant structure. It is worth pointing out that the friction component appears to be very strong as indicated by the corresponding part of the oscillogram. This finding is hardly surprising though as the Czech phoneme is laminal, i.e. produced with the front part of the tongue rather than with the apex. On the other hand, the Russian and Ukrainian rhotics are apical. An example of a fricativised Russian /rʲ/, produced in the word реки 'river' (gen. sg.), shows that the friction is less intense and occurs over a lesser range of frequencies. This is due to the shape of the aperture occurring between the articulating organs, i.e. the tip of the tongue and the alveolar ridge. The rhotic is undoubtedly voiced as evidenced by the distinct voice bar at the bottom of the spectrogram. A similar quality of friction, produced in the word ризних 'different' (gen. pl.) is also found in the case of the Ukrainian fricativised allophone of /rʲ/, which is hardly surprising given the close genetic relationship between Ukrainian and Russian.

As far as trilled allophones encountered in the recordings are concerned, it must be stated that Welsh trilled variants differ significantly from those of Russian and Ukrainian with respect to their temporal characteristics. If trilled, the Welsh spirantised /r̥ʰ/ is made up of two or three constriction phases separated by periods of friction. The mean duration of the first constriction phase, based on the 92 trilled tokens found in the examined recordings, is 10.2 ms (± 1.3). The second constriction phase is slightly shorter (10.1 ms; ± 1.1) and if there is a third one, it tends to be even shorter (9.9 ms, ± 0.7). The periods of friction also differ in duration with the first one being slightly longer than the next, 21.8 ms (± 2.7) and 20.9 (± 2.1), respectively. In the light of the data, the full period of vibration of a spirantised trill is approximately 32 ms long, which translates into a vibration rate of 31.3 Hz[25].

25 As noted above, twenty three speakers of Welsh took part in the experiment. The numbers of trilled allophones they produced differed to such an extent that making a reliable statistical analysis of the obtained results was out of the question.

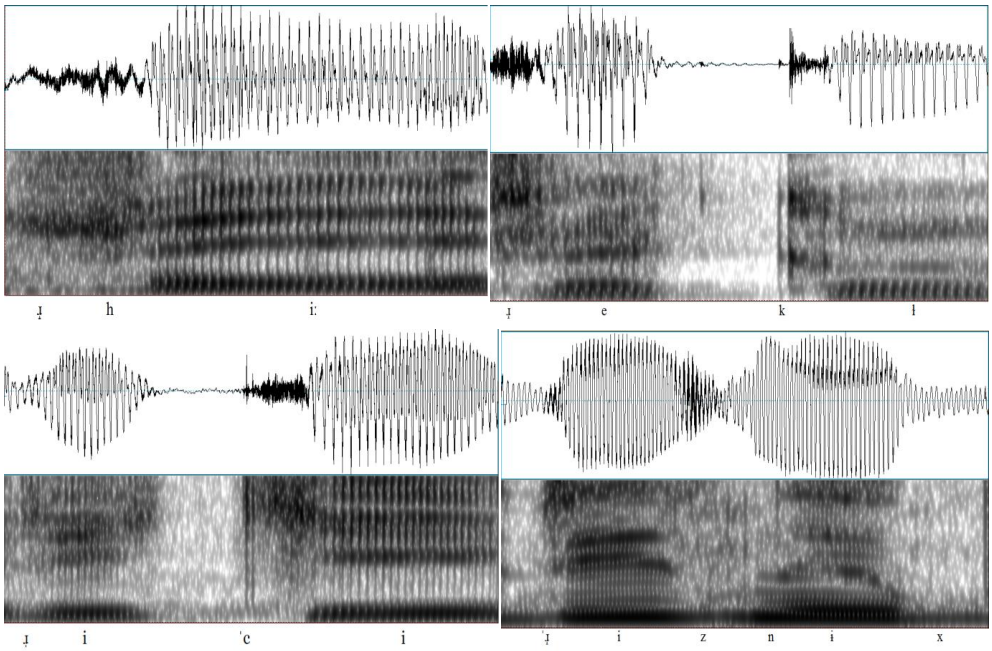



Figure 6. Fricativised word-initial rhotics of Welsh (top-left), Czech (top-right), Russian (bottom-left) and Ukrainian (bottom-right)

The vibration rate of the trilled allophones of /rʲ/ is much lower due to the different aerodynamic conditions that make the apex vibrate. The palatalised trills encountered in the examined recordings consist of two closure phases separated by an intrusive vocalic element whose formant structure is sufficiently distinct to determine its spectral properties. These happen to mirror those of the following vowel[26]. As for their temporal characteristics, Russian and Ukrainian trills appear to differ to a certain extent. In the case of Russian, the mean duration of the first constriction is 16.7 ms (± 1.1), while the other is, as a rule, slightly shorter (15.8 ms, ± 0.97). The vocalic element between the constrictions is on the order of 21 ms, with the average duration of 20.8 ms (± 1.2). The temporal parameters of trills produced by the Ukrainian speakers follow the same pattern in that the first constriction is longer than the other, and the duration of the vocalic element is greater than the length of both constrictions. The mean durations of the three elements equal, respectively, 17.9 ms (± 1.1), 16.1 ms (± 0.84) and 22.3 ms (± 0.71) long. Given the temporal characteristics, the average vibration rates of the trilled variants are 26.7 Hz and 24.9 Hz for Russian and Ukrainian, respectively[27].

26 A comprehensive description of the acoustic properties of Slavic rhotics is presented in Sylwester Jaworski, *Rhotic Sounds of the Slavic Languages*, (Hamburg: Dr. Kovač, 2018).

27 The difference in vibration rate obtained in this study can be due to speaker-specific features. The results need to be verified in a follow-up study involving a larger number of speakers.

With regard to the tapped variants, it is necessary to explain that taps occurring in Welsh and Czech are followed by a period of friction. Despite belonging to different branches of Indo-European languages, tapped allophones of /r̥ʰ/ and /r̝/ show certain similarities, as evidenced in Figure 7, which depicts the tapped allophone of the Czech rhotic produced in the word řekl 'he said' (left-hand panel) and a tapped allophone of the Welsh /r̥ʰ/ in produced in the word *rhan* 'part'. The main point of similarity is the presence of a tap closure that lasts, on average, 12.1 ms (± 1.9) ms in the former and 11.3 ms (± 1.6) in the latter word. However, they differ significantly with respect to voicing and the duration of the following period of friction. The presence of the voice bar throughout the Czech sound provides evidence that the rhotic is fully voiced, whereas the Welsh rhotic is definitely voiceless. The two sounds also differ in the duration of the following period of friction. The friction is 31 ms long in the former and 64 ms in the latter.

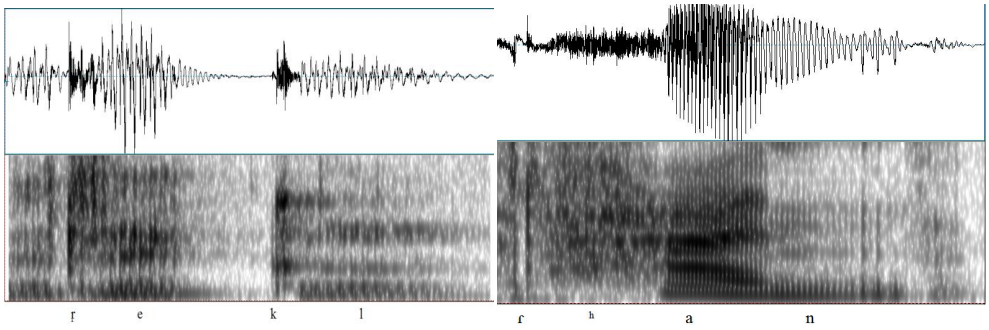



Figure 7. A tapped allophone of the Czech rhotic produced in the word řekl 'he said' (left-hand panel) and a tapped allophone of the Welsh /r̥ʰ/ in produced in the word *rhan* 'part'

Tapped variants of Russian and Ukrainian are considerably longer and are never followed by such long periods of friction. Their tap closures are comparable with those of tapped variants of the plain rhotic /r/. In the case of Russian, closure phases ranged from 12 ms to 20 ms, whereas the mean value was 16.3 ms (± 3.21). The data obtained from the Ukrainian informants differ substantially with the mean duration of 17.1 ms (± 1.73).

Finally, the palatalised /rʲ/ can also be realised as an approximant. Since word-initial position is said to be prosodically strong, phonetic reduction to an approximant can be considered as a consequence of connected speech process as many of the rhotics examined for the purposes of this study were preceded by a vowel, thus they were, de facto, intervocalic. Approximantised rhotics are vowel-like sounds with a distinct formant structure. The formants of approximantised rhotics are normally less intense than those of vowels, yet their values are strongly correlated with the spectral properties of the following vowel.

The allophones presented above are not equally frequent, though. General statistical information regarding the frequency of occurrence of the allophones of the marked rhotics investigated in the study is presented in Table 1. The first conclusion that emerges from the analysis is that fricativised allophones, i.e. those that consist of a period of friction without any closure, constitute the majority variant in each language[28]. This finding strongly suggests that the three trills constitute an articulatory difficulty for the speaker. As a result, speakers resolve the difficulty by applying phonological processes that replace difficult sounds with ones that are easier to produce, but share some crucial articulatory features with the underlying speech sound. Interestingly, in the case of Welsh and Czech, it is the secondary articulatory features that are retained, while the primary feature (trilling) is eliminated. This finding calls into question the traditional division of articulatory features into primary and secondary as trilled variants that are supposed to be the articulatory target either do not occur in the recordings (in Czech), or their frequency of occurrence is unexpectedly low (in the case of Russian and Ukrainian).

Table 1. Distribution of allophones of complex rhotics

| Language | Tokens | Trill | One-tap trill/Tap | Fricative | Approximant |
|---|---|---|---|---|---|
| Welsh | 729 | 92 | 31 | 606 | 0 |
| Czech | 100 | 0 | 24 | 76 | 0 |
| Russian | 100 | 4 | 18 | 63 | 15 |
| Ukrainian | 100 | 8 | 11 | 69 | 12 |

The data in Table 1 are rather surprising as the three trills differ significantly in terms of articulation, yet they all show a strong tendency towards fricativisation. In the case of the Welsh and Czech sounds, fricativisation can probably be thought of as preservation of the secondary articulatory feature. On the other hand, the /rʲ/ sound, which used to be a phoneme of all Slavic languages[29], was replaced with the fricative /ʒ/ in Polish, whereas in Czech it changed into a fricated trill[30]. Thus, the palatalised rhotic also manifests a tendency towards fricativisation as evidenced by both its pho-

28 In this work, the terms *fricated trill* and *fricativised trill* are introduced to distinguish two sounds of Czech. The former is used in the phonetic literature to refer to the Czech rhotic phoneme /r̝/ that consists of trilling and friction produced simultaneously (see Dankovičová, "Czech", 70–74). However, as shown in this study, the /r̝/ phoneme may have an allophone pronounced as a period of friction without a single closure phase. Such allophones are referred to fricativised trills, which seems to be a convenient phonetic label for the resultant allophone. The same term is used to refer to those allophones of the spirantised /r̝ʰ/ of Welsh and the palatalised /rʲ/ of Russian and Ukrainian that are realised phonetically as a period of friction.

29 Żygis, *(Un)markedness of trills*, 383–407.

30 Stieber, *Zarys gramatyki porównawczej języków słowiańskich*, 1979.

nological history and synchronic variation. In Russian, and probably in Ukrainian, the rhotic tends to be uninterrupted, i.e. pronounced either as a fricative or approximant[31].

## Conclusions

The results of the experiment conducted for the purposes of the study point to the conclusion that the marked trills of Welsh, Czech, Russian and Ukrainian manifest a very strong tendency towards phonetic reduction. The most convincing piece of evidence that was presented in this paper is that, in each of the investigated languages, trilled variants constitute a minority and in the Czech language not a single a fully articulated trill, i.e. one consisting of at least two constrictions, was produced. In speech, these complex segments undergo radical reduction, most frequently they are rendered as fricatives. Thus, it may be stated that they become less marked.

The finding that merits particular attention is the type of phonetic reduction that affects the spirantised rhotic of Welsh and the fricated rhotic of Czech. The majority of the examined tokens were realised physically as fricatives. This probably means that the articulatory cost of preserving the primary feature, i.e. trilling, is too high for speakers and, therefore, they opt for other possible choices. Of these, the fricativised allophones appear to be the best solution as they still preserve a crucial articulatory feature of both /r̥ʰ/ and /r̝/. As for the fricativisation of the palatalised /rʲ/, the phenomenon been attested in the phonological history of the Slavic languages. For instance, in Polish, the palatalised trill first underwent fricativisation and later merged with the phoneme /ʒ/ and so did the sound of Kashubian. The fricated trill of Czech was brought into existence by the same process.

With respect to the concept of markedness, the processes applied by the informants definitely represent a change towards an unmarked segment in terms of articulation. As a result, sounds of high articulatory complexity become relatively simple. The observed substitutions do not have any influence on the phonotactic properties of the sounds in question. However, as mentioned in the previous paragraph, diachronically such changes may affect the phonotactic properties of the sounds by eliminating them from certain positions within the syllable or even modify the sound inventory of a language by merging with other phonemes.

## Bibliography

Blecua, Beatriz. *Las vibrantes del Español: manifestaciones acústicas y procesos fonéticos*, Doctoral dissertation, Barcelona, 2001.

31 Leonid Kasatkin, *Sovriemiennij ruskijizik: fonietika*, 40 (Moscow: Academia, 2006).

Ball, Martin. "How many rhotic phonemes does Modern Welsh have". In: *Representations and Interpretations in Celtic Studies*, eds. Czerniak, Tomasz, Maciej Czerniakowski, Krzysztof Jaskuła, 49−61. Lublin: Wydawnictwo KUL, 2015.

Colantoni, Laura. "Increasing periodicity to reduce similarity: An acoustic account of deassibilation in rhotics". In: *Selected Proceedings of the 2nd Conference on Laboratory Approaches to Spanish Phonetics and Phonology*, ed. Manuel Diaz-Campos 22−34. Somerville, MA: Cascadilla Proceedings Project, 2005.

Dankovičová, Jana. "Czech". In: *Handbook of the International Phonetic Association: A guide to the use of the International Phonetic Alphabet*. Cambridge: Cambridge University Press, 1999, 70−74.

Jaworski, Sylwester. Gillian, Edward. "On the phonetic instability of the Polish rhotic /r/". *Poznań Studies in Contemporary Linguistics* 47 (2011), 2: 380−398.

Jaworski, Sylwester. *Rhotic Sounds in the Slavic Languages*. Hamburg: Verlag Dr. Kovač, 2018.

Kasatkin, Leonid. *Sovriemiennij ruskij izik: fonietika.* Moscow: Academia, 2005.

Kavitskaya, Daria, Khali Iskarous, Aude Noiray, Michael Proctor. "Trills and palatalisation: Consequences for sound change". In: *Proceedings of the Formal Approaches to Slavic Linguistics* 17, eds. Justin Reich, Maria Babyonyshev, Daria Kavitskaya, 97–110. Ann Arbor: Michigan Slavic Publications, 2009.

Klemensiewicz, Zenon. *Historia języka polskiego.* Warszawa: Państwowe Wydawnictwo Naukowe, 1999.

Ladefoged, Peter, Ian Maddieson. *The Sounds of the World's Languages*. Chichester, West Sussex: Blackwell Publishers, 1996.

Recasens, Daniel, Aina Espinosa. "Phonetic typology and positional allophones for alveolar rhotics in Catalan". *Phonetica* 63 (2007), 1–28.

Shosted, Ryan. "An aerodynamic explanation for the uvularization of trills". In: *Proceedings of the 8th International Seminar on Speech Production*, eds. Rudolph Sock, Susanne Fuchs and Yves Laprie, 421−424. Strasbourg, INRIA, 2008.

Solé, Maria-Josep. "Aerodynamic characteristics of trills and phonological patterning". *Journal of Phonetics* 30 (2002), 655−688.

Stieber, Zdzisław. *Zarys gramatyki porównawczej języków słowiańskich*. Warszawa: Wydawnictwo Naukowe PWN, 1979.

Šimáčková, Šarka, Václav Podlipský, Kateřina Chládková. "Czech spoken in Bohemia and Moravia". *Journal of the International Phonetic Association* 42 (2012): 225–232.

Topolińska, Zofia. *A Phonological History of the Kashubian Language*. The Hague: Mouton & Co. N.V., Publishers, 1974.

Wierzchowska, Bożena. *Fonetyka i fonologia języka polskiego.* Wrocław: Ossolineum, 1980.

Wiese, Richard. "The unity and variation of (German) /r/". In: *R-atics: Sociolinguistic, phonetic and phonological characteristics of /r/*, eds. Hans Van de Velde, Roeland van Hout, 11–26. Brussels, Universite Libre de Brussels, 2001.

Żygis, Marzena. "(Un)markedness of trills: the case of Slavic r-palatalisation". *Zeitschrift fur Slawistik* 50 (2005): 383–407.

Abstract

This paper reports the results of an acoustic study concerned with the amount of allophonic variation shown by three unique trills: the spirantised /r̝ʰ/ of Welsh, the palatalised /rʲ/ of Russian and Ukrainian as well as the fricated /r̝/ of Czech. These trills are unusual by virtue of having a secondary articulatory feature, which poses an additional challenge to the speaker. To make the sound pronounceable, speakers apply phonological processes that reduce the amount of articulatory complexity. The results of the analysis point to the conclusion that, although the acoustic properties of the three trills differ to a great extent, they frequently undergo reduction to a fricative sound, which appears to be the most common articulatory variant encountered in the examined speech samples.

**Keywords:** rhotics, trills, reduction processes, phonetics

## ANALIZA AKUSTYCZNA TRZECH NACECHOWANYCH GŁOSEK DRŻĄCYCH: WALIJSKIEGO R̝ʰ, *SŁOWIAŃSKIEGO* Rʲ *ORAZ CZESKIEGO* R̝

Abstrakt

W artykule tym przedstawiono wyniki analizy akustycznej trzech nacechowanych głosek drżących: walijskiego spirantyzowanego /r̝ʰ/, palatalizowanego /rʲ/ występującego, między innymi, w językach rosyjskim i ukraińskim oraz czeskiego /r̝/. Wyjątkowość tych dźwięków jest wynikiem występowania drugorzędowych cech artykulacyjnych, które sprawiają, że są one niezwykle trudne do wypowiedzenia w mowie łączonej. Analiza akustyczna nagrań w pełni potwierdziła, że dźwięki te stanowią trudności dla mówiących, którzy najczęściej redukowali te trzy dźwięki do głosek szczelinowych bez drżenia.

**Słowa kluczowe:** głoski drżące, redukcja fonetyczna, fonetyka