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Ukrainian rhotic consonants in comparison to Russian: An acoustic study

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ABSTRACT

This short paper maintains a discussion on the nature of rhotic consonants in two different but genetically related languages (Ukrainian and Russian). The main goal of the paper is carrying out a modern acoustic study about rhotic realizations in the two target languages, as well as putting forward some considerations about a possible sound change. Acoustic analysis is carried out using LPC and FFT measurements in order to capture the difference in rhotic realizations. The results allow for a description of the acoustic properties of the Ukrainian language, and suggest the existence of an ongoing simplification process of rhotic consonants in both languages.

1. Introduction

The behavior of rhotic consonants and their classification under a natural class has always been a contentious topic in academia. Rhotic segments are characterized by the phenomenal phonetic variability in connection to voice, place, and manner of articulation that is typical for the whole sound class, not even across the languages, but also within a single language system. This paper examines variation across two languages as well as the realization of rhotic segments within the systems of both. Ukrainian and Russian are reported to have two rhotic consonants: hard trill /r/ and its palatalized counterpart /rʲ/ (Kavitskaya et al., 2009; Pompino-Marschall et al., 2016; Yanushevskaya & Bunčič, 2015). The surface forms, however, differ in each language. For instance, Żygis (2004) reports that the palatalized trill is partially lost in Ukrainian, surfacing only at the onset, while the Russian palatalized trill occurs in all positions. However, Popov (2014) claims that /rʲ/ is considered to be a phoneme in the Russian language only “by convention”, and is realized as a fricative trill in most cases. This claim is supported by the articulatory study by Stoll (2017) who expressed the future possibility of Russian /rʲ/ to change into a fricative trill, as Czech and Polish ones did. On the other hand, this change is not reported in connection to Ukrainian trills. Both, in Ukrainian and Russian, /rʲ/ is also reported to surface as an alveolar tap [ɾʲ] (Pompino-Marschall et al., 2016; Yanushevskaya & Bunčič, 2015; Żygis, 2004). However, the conditions that cause this realization are not stated, nor is the acoustic evidence. Russian plain trill /r/ is hypothesized to surface either as an alveolar tap [ɾ] or as an alveolar trill [r] with only one closure (or resonant portion) (Kouznetsov & Pamies-Bertrán, 2008). Information about Ukrainian /r/ is scarce and obsolete. To conclude, the information is numerous but scattered and conflicted. This paper fulfills the need for an acoustic study of Ukrainian rhotics that will shed a light on their acoustic properties as well as account for the difference in phonetic realizations of rhotics in comparison to Russian.

Before the paper proceeds, it is important to define the acoustic and articulatory properties of trill and tap (since these sounds are expected to be the main allophones of /r/ in both languages). It is known that articulation of trill and tap involves different articulatory processes. The former involves socalled trill cycles. Trill cycle begins with the voluntary placement of the tongue against the upper articulatory organ, creating stricture, which then is broken down due to the high velocity of the airflow, releasing the air (Dhananjaya et al., 2012). Commonly, trill contains from two to three trill cycles, although one-cycle trills are possible as well (Kavitskaya et al., 2009; Kouznetsov & Pamies-Bertrán, 2008). Still, trills with one closure incorporate different lingual gestures than that of a tap. A study carried out by Recasens and Pallarès (1999) establishes that articulation of /r/ involves more tongue body constraint and more retracted apicoalveolar closure together with the backing of the tongue dorsum. The backing of the tongue dorsum causes the F2 of /r/ to be systematically lower in similar phonetic environments when compared with /ɾ/ (ibid.). Moreover, during vowel coarticulation, tap is more prone to adapt to adjacent segments, which indicates lesser tongue constraint (ibid.). This establishes that the trill cycle by no means consists of a sequence of taps since both involve different tongue gestures during their articulation.

The difference in tongue movement can be captured acoustically: when compared, an F2 of a trill is lower than that of a tap due to the retraction of the tongue dorsum (Kouznetsov & Pamies-Bertrán, 2008; Recasens, 1991; Recasens & Pallarès, 1999). Also, a trill yields a rapid increase and decrease in amplitude due to the Bernoulli effect (Kouznetsov & Pamies-Bertrán, 2008). This will help to compare the recordings where the analyzed rhotic appears to be either a trill with one closure or a tap.

It is important to mention that if a rhotic sound produced with closure comes after a pause or consonant, it must have a vocalic component before the closure (Kouznetsov & Pamies-Bertrán, 2008). Since tap is considered to be a short closure period (an interruption of the airflow) the vocal segment is needed before the closure to interrupt the airflow and produce a tap. If the vocalic segment is taken out of the utterance, only silence remains. In the case of trill, the vocalic element before the pause is treated as an initiation of a trill cycle. In addition, a recent study carried out by Cicres and Llach (2021) showed that during trill articulation there is a much higher presence of vocalic components in word-medial position. Therefore, it is expected to see trill occurring more often in the medial position, mostly with two or more trill cycles. It was also observed that the fricative component was one of the most frequent ones in the final position (Cicres & Llach, 2021). Thus, if a trill occurs in a final position, it is expected to be fricaticized.

Howson (2016) also establishes that there is a great delay in the achievement of F2 during the articulation of palatalized rhotics. He explains that the delay is based on the conflicting constraints of palatalization and trill-like articulation. Recasens and Pallarès (1999) provide a useful analysis of trill and tap behaviour in the /iCi/ context, concluding that “the lingual gesture for /r/ is highly constrained and antagonistic with respect to that for /i/”. Based on this, it is anticipated to see /rʲ/ being reduced to /ɾʲ/ in most of the cases. Żygis (2004) concludes that due to these constraints on the tongue dorsum, languages tend to drop either trillization or palatalization gestures or change the manner of articulation at all.

The main aim of the paper is to provide a comparative acoustic analysis of rhotic consonants in Ukrainian and Russian languages. It is hypothesized that due to the great tongue constraint during the articulation of a trill, speakers of both Ukrainian and Russian will reduce the number of trill cycles, or change the manner of articulation to tap or fricative. Another claim is that within a phonemic system if trill and tap are not distinctive, speakers will favor tap due to easier articulatory gestures.

2. Methodology

The methodology was based on the contrastive phonetic analysis that heavily revolve around the acoustic examination. Acoustic data was collected from five native speakers per language (three females, and two males for each language). The cognate words *ряд* /rʲad/ “row”, *пар* /par/ “steam”, *таро* /taro/ “tarot”, *морю* /ˈmorʲu/ “sea (DAT.)”, and one word with the same phonetic environment *рад* /rad/ “glad” in Russian, and “council (GEN. pl.)” in Ukrainian were recorded. The choice of words allows for the investigation of rhotic consonants in two languages in the same phonetic environments: in initial, intervocalic, and final positions. Since Ukrainian palatalized /rʲ/ does not occur in codas, the final position was not analyzed.

The analysis aimed at extracting careful speech from participants since the articulation needed to be as close as possible to the standard. This way an articulation rate could be controlled which would allow making generalizations about phonemic properties of the rhotics. Each speaker was instructed about the lexical and grammatical meanings of the words.[1] Then, the participants were asked to read the mentioned words in isolation two times. Two repetitions were collected from each participant, yielding 100 tokens (50 per Russian and 50 per Ukrainian). The data was opened with version 6.2.01 *Praat* software (Boersma & Weenink, 2021) for acoustic analysis. Each recording was presented through a wide-band spectrogram. The spectrograms with the same words uttered in Ukrainian and Russian were put together for comparison on the basis of speaker numbers (thus, spectrograms of S1 in Ukrainian were put together with the spectrograms of S1 in Russian). The first three speakers were females, while S4 and S5 were males. The table was compiled in this way to avoid sex variables confusing the data since the main approach to the data was a comparative analysis of frequency values of rhotic segments.

Language exposure was controlled as well. All native Ukrainian speakers claimed to have little exposure to the Russian language, using Ukrainian on an everyday basis as well as at home. Russian native speakers claimed to have no exposure to Ukrainian whatsoever, using Russian in their households.

The rhotic segments were located in each recording and the number of resonant portions was counted and compared. The LPC analysis of each rhotic segment was carried out in order to get more precise frequency peaks. Before the analysis, the recordings were resampled to 11025 Hz and pre-emphasized.[2]

The number of coefficients for the spectral analysis varied from 14 to 18 to ensure maximum precision. In some cases, the FFT technique was used to aid the data provided by the LPC. In the case of trill, the spectral slices were captured during the first resonant portion and the closure. If there were two resonant portions, the spectra of the second one were also taken into consideration. Then, the frequencies were measured manually. In the case of tap, the spectral slices during the closure were extracted and calculated manually.

The arithmetic means of the first three frequency peaks of rhotic segments for each speaker were calculated, put in the table, and compared cross-linguistically. Finally, the number of all captured allophonic realizations for each language was counted and presented in a table.

3. Results and comments

Figure 1 shows the example of a cross-language spectrogram comparison of the cognate word /taro/. The main difference is nested within the rhotic segment. It can be observed that the utterance of the Russian word contains a trill due to the two distinct resonant portions. It is not, however, clear right away whether the Ukrainian pronunciation contains a tap or a trill with one closure since the initiation process of a trill may be nested within the preceding vowel.

This is why the LPC and FFT techniques were used to measure the frequency peaks of rhotic segments. The main difference that the paper is concerned about is that F2 of trills is systematically lower than F2 of taps, as noted by Recasens (1991), and Kouznetsov and Pamies-Bertrán (2008).

Tables 1-3 show the formant peaks of rhotic segments in each cognate word of Russian and Ukrainian. It was expected to see [ɾ] in an intervocalic position in both Russian and Ukrainian. Table 1 shows the frequency peaks of plain and palatalized rhotic segments in intervocalic positions. Altogether, Ukrainian speakers managed to produce seven taps. S1, S2, and S3 of Ukrainian used tap in both, palatalized and non-palatalized environments, with F2 reaching up to 1515 Hz, 1713 Hz, and 1668 Hz, respectively. S4 kept trill articulation in a non-palatalized environment reaching, 1250 Hz but adhered to tap when exposed to palatalization, with 1397 Hz. Data of S5 shows the articulation of a trill in both cases (1140 Hz for /r/, and 1187 Hz for /rʲ/).

In contrast, Russian speakers produced five trills and five taps. The frequency peaks are similar to the data in Russian and Spanish provided by Kouznetsov and

[1] It was important to avoid ambiguity created by stress since in both languages /ˈmorʲu/ and /moˈrʲu/ are two different words.

[2] Each recording was pre-emphasized to increase the amplitudes of high frequency components in order to flatten the spectral slice. The pre-emphasis value varied from 100 Hz to 125 Hz depending on the number of coefficients.

Pamies-Bertrán (2008). In a non-palatalized environment, trill articulation was dominant in the VCV context. S1, S4, and S5 frequency values reached 1146 Hz, 1276 Hz, and 1227 Hz. In contrast with other speakers of Russian, the F2 of these speakers are lower by 400-500 Hz, which indicates retracted tongue dorsum during trill articulation. Furthermore, F2 values are in the same range as F2 values of Ukrainian speakers during trill articulation.

In a palatalized environment, S1 and S5 maintained trill articulation with second formant peaks reaching 1083 Hz and 1185 Hz. Data of other speakers showed a greater F2 value in relation to mentioned speakers. What is more, frequency values are in the same range as frequency values during the articulation of tap in Ukrainian.

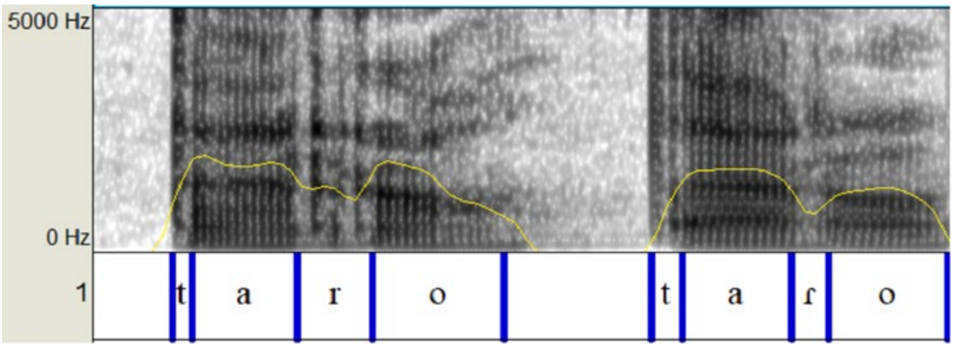

Figure 1. Comparison of acoustic data of Russian S1 /taro/ (left) and Ukrainian S1 /taro/ (right).

/taro/	Russian			Ukrainian		
	F1	F2	F3	F1	F2	F3
S1	458	1146	1723	655	1515	2048
S2	719	1684	1957	580	1713	2406
S3	583	1689	2296	678	1668	2542
S4	522	1276	1998	609	1250	1765
S5	487	1227	1834	480	1140	1770

/morʲu/	Russian			Ukrainian		
	F1	F2	F3	F1	F2	F3
S1	366	1083	1978	331	1385	2308
S2	458	1661	2192	505	1447	2412
S3	315	1370	2186	643	1483	2285
S4	314	1406	2215	568	1397	2125
S5	614	1185	1921	463	1187	1995

Table 1. Frequency peaks of rhotic segments in Ukrainian and Russian /taro/ and /morʲu/.

The average frequencies of recordings containing palatalized rhotic segments are lower in contrast to the formants of plain segments because the preceding vowel /o/ is produced in lower frequencies than /a/. The data shows that in the palatalized environments, in both Russian and Ukrainian, trills are more subjected to reduction than in non-palatalized environments.

Table 2 features the formants of a plain rhotic segment in the initial position. As it was mentioned before, it is expected to see a vocalic element present before the closure of a rhotic segment. Figures 2 and 3 show that vocalic elements are present both in Russian and Ukrainian articulations.

/rad/	Russian			Ukrainian		
	F1	F2	F3	F1	F2	F3
S1	471	1193	2025	614	1556	2256
S2	525	1634	2291	678	1679	2626
S3	581	1749	2410	684	1765	2723
S4	522	1435	2320	568	1429	2480
S5	473	1268	2125	518	1426	2337

/rʲad/	Russian			Ukrainian		
	F1	F2	F3	F1	F2	F3
S1	476	1493	2377	464	1850	2631
S2	426	1669	2643	405	1836	2723
S3	402	1315	2293	528	2001	2867
S4	603	1639	2634	551	1730	2520
S5	468	1803	2473	473	1754	2385

Table 2. Frequency peaks of rhotic segments in Ukrainian and Russian /rad/ and /rʲad/.

Table 2 shows frequency peaks of rhotic segments in /rad/ and /rʲad/. In the initial position, Ukrainian speakers produced ten taps since in comparison to some Russian speakers the F2 frequency of

Ukrainian participants is systematically 300-550 Hz higher.

Russian speakers produced seven taps (S1, S2, S3, S4, S5) and three trills (S1, S3, S5). Each speaker that produced a trill in a non-palatalized environment changed the articulation to tap in a palatalized environment with the exception of S3. Interestingly enough, S3 kept tap in /rad/, with F2 reaching 1749 Hz but changed the manner of articulation to trill in /rʲad/, F2 being 1315 Hz. This is unusual since the rest of the data as well as the mentioned works showed a common pattern of trill changing to tap when exposed to palatalization, not vice versa.

The frequency range between F1 and F2 is vast during the articulation of palatalized rhotics, as compared to non-palatalized articulation. This corresponds with the data from Howson (2016), who observed a delayed increase in F2 during the production of palatalized rhotics.

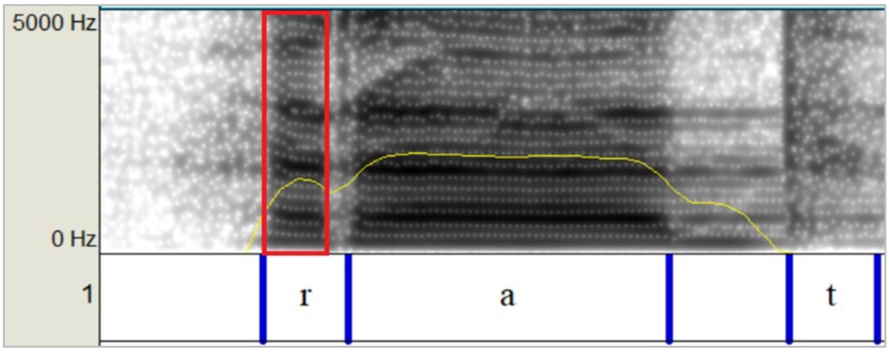

Figure 2. Ukrainian /rad/ (vocalic element is indicated by the red line).

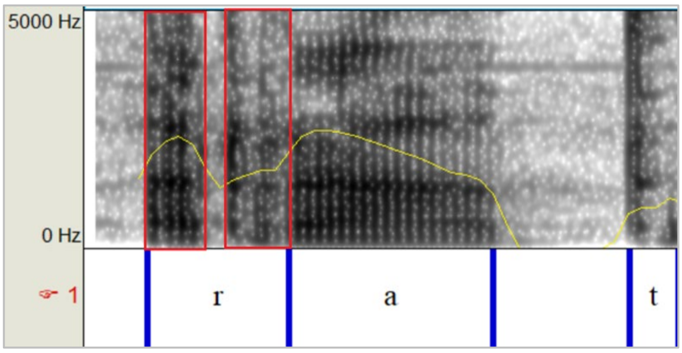

Figure 3. Russian /rad/ (vocalic elements are indicated by the red line).

Finally, Table 3 shows the F1-F3 values of rhotic segments in the final position. Each Ukrainian speaker except one (S5) managed to produce a tap reaching 1672 Hz, 1655 Hz, 1620 Hz, and 1597 Hz as opposed to Russian F2 values 1221 Hz, 1256 Hz, 1095 Hz, 1265 Hz indicating a trill articulation. Russian data mirrors the Ukrainian one, with four trill articulations and one tap (S2, 1568 Hz). Moreover, the spectrogram in Figure 4 shows that in the final position Russian speakers tend to break the trill cycle resulting in a fricative trill. This realization was common in each case where trill occurred as well as in S5 in Ukrainian.

/par/	Russian			Ukrainian		
	F1	F2	F3	F1	F2	F3
S1	516	1221	2453	568	1672	2499
S2	734	1568	2429	528	1655	2562
S3	678	1256	1974	661	1620	2235
S4	447	1095	2211	685	1597	2545
S5	533	1265	2346	495	1323	1999

Table 3. Frequency peaks of rhotic segments in Ukrainian and Russian /par/.

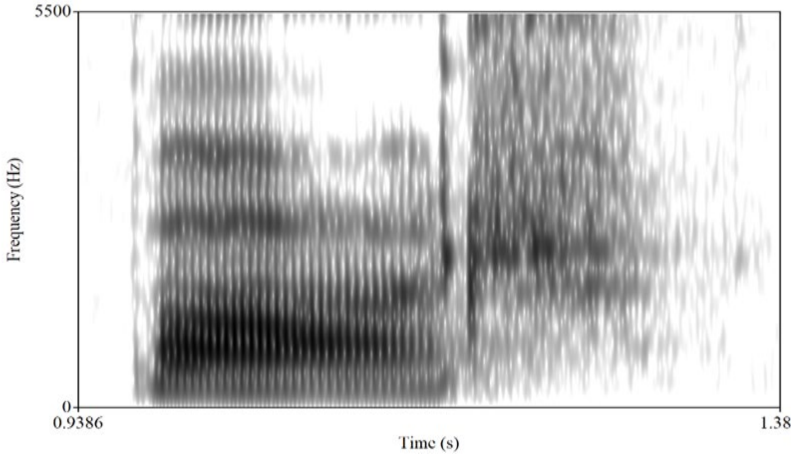

Figure 4 Russian /par/ with a fricative trill.

The number of all possible realizations of rhotic segments based on the measurements of the first three frequency peaks in Ukrainian is shown below in Table 4. Altogether, out of 50 tokens (two repetitions counted) tap had an occurrence of 84%, trill — 12%, and fricative — 4%.

It is important to mention that six out of eight trill occurrences were articulated by the same speaker (S5). Participant S5 produced trills in intervocalic and final positions, keeping a tap in the initial position. The other two trills were articulated by S4 in /taro/.

Overall, the two-cycle trill was captured only two times in S5 in the final position. All other trills had one trill cycle. Kouznetsov and Pamies-Bertrán (2009) provide the same information in Russian, claiming that 90% of trills occur with one closure.

Table 5 below shows the number of all possible rhotic realizations in Russian. Tap occurred in 52% of utterances, trill in 32%, and fricative in 16%. In contrast to Ukrainian, Russian speakers maintain trill articulations more frequently. In general, out of 24 occurrences (fricative trill included), eight trills (33.3%) with two trill cycles occurred. The rest of the utterances occurred with one trill cycle.

As to the fricative component, the data is in agreement with the results of the study by Cicres & Llach (2021) — the most frequent position of the fricative component is the final position.

	Russian			Ukrainian		
	Initial position	**Intervocalic position**	**Final position**	**Initial position**	**Intervocalic position**	**Final position**
Tap	14	10	2	20	14	8
Trill	6	10	0	0	6	0
Fricative	0	0	8	0	0	2

Table 4. Rhotic realizations in Russian and Ukrainian.

Figure 5 shows the mean number of trill cycles in /r/ and /rʲ/ across analyzed environments in Russian. The most frequent position where trill with two-cycle occurred was the initial position, with the mean number of trill cycles reaching 1.6 in non-palatalized environment. Other values are 1.2 in medial, and 1.25 in final positions. In palatalized environment, each trill occured with one trill cycle. This opposes the result of the study by Cicres and Llach (2021) where the number of components was systematically higher in the medial position. It is, however, should be mentioned that in both, Russian and Ukrainian trill occurred most frequently precisely in the medial position. Based on this, it can be stated that trill is more likely to occur in the medial position as opposed to initial and final ones.

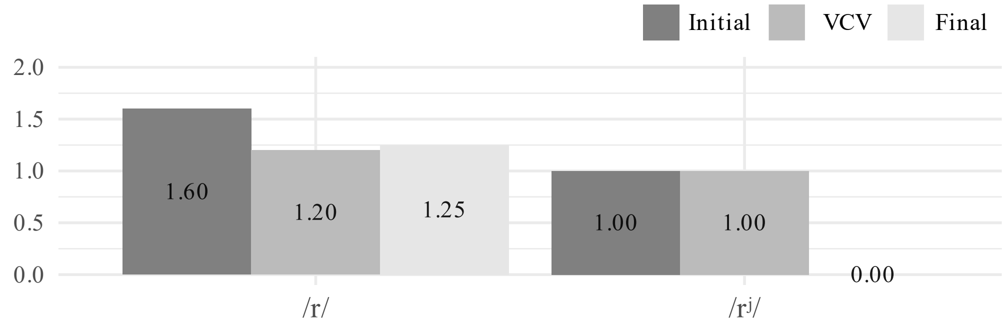

Figure 5. Mean numbers of trill cycles in Russian

4. Conclusion

Taking into consideration works by Żygis (2004), Kavitskaya et al. (2009), Stoll (2017), Popov (2014), and Kouznetsov and Pamies-Bertrán (2008), the data of this paper provides yet another example of trill simplification in Slavic languages.

The paper dealt with the acoustic description of rhotic consonants in Ukrainian compared to Russian. In Ukrainian, the LPC and FFT measurements, as well as visual analysis of spectrograms, showed that tap /ɾ/ articulation, both in palatalized and non-palatalized variations, is more common than any other variant in initial, intervocalic, and final positions. Unexpectedly, in Russian, /ɾ/ was the most prominent realization as well, dominating 52% of overall utterances.

Two hypotheses were analyzed in this paper. First claimed that both Ukrainian and Russian speakers will either reduce the number of trill cycles in rhotic segments or change the manner of articulation. The second hypothesis claimed that on the condition of two rhotics not being distinctive within a single phonemic system, the speakers tend to choose tap over trill.

The data extracted from Ukrainian participants shows that the majority of speakers prefer tap over trill in all environments, with 84% of occurrence, therefore proving both hypotheses. In Russian, data shows that the speakers use trill as long as the palatalization does not interfere with the tongue gestures needed to produce a trill cycle, proving the second hypothesis. Also, it is, indeed, true that speakers tend to reduce the number of trill cycles to one since the two-trill cycle occurred only in 30% of overall trill occurrences.

More research is needed in connection to the Ukrainian rhotic sounds, but based solely on the acoustic study, the paper implies the sound change and concludes that Ukrainian /r/ is treated as a trill by convention, and in the majority of cases is realized as a tap /ɾ/.

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