Beyond Philology No. 18/1, 2021
ISSN 1732-1220, eISSN 2451-1498

https://doi.org/10.26881/bp.2021.1.03

The obstruentised rhotic of Polish: An acoustic study

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Received 27.03.2021,
accepted 9.06.2021.

Abstract

This paper reports the results of a study aimed at establishing the acoustic characteristics of the obstruentised rhotic of Polish, i.e. an r-sound that is neither adjacent to a vowel nor syllabic. The study has revealed that the physical realisation of the sound is dependent on the position it occupies within the syllable as well as on the manner of articulation of the following segment. In onset positions, the obstruentised rhotic is likely to be articulated as a trill when followed by a stop. In contrast, spirantised variants are common in those clusters where the rhotic precedes a fricative. In prosodically weak coda positions, the degree of phonetic reduction is greater than in the onset. The observed variants include voiceless trills, spirantised rhotics, affricated rhotics, taps and instances of deletion.

Keywords

rhotics, Polish, phonetic reduction

Analiza akustyczna polskiego /r/ w pozycjach nieprzylegających do samogłoski

Abstract

Artykuł przedstawia wyniki badania mającego na celu określenia cech akustycznych polskiego dźwięku /r/ w kontekstach, w których nie przylega on do samogłoski. W przeciwieństwie do niektórych języków słowiańskich, np. czeskiego czy chorwackiego, polski fonem /r/ nie jest zgłoskotwórczy w takim otoczeniu. Wyniki badania sugerują, że fizyczna realizacja fonemu /r/ zależy głównie od pozycji dźwięku /r/ w sylabie oraz od sposobu artykulacji następnej spółgłoski. W nagłosie sylaby, /r/ ma często realizację drżącą, jeśli następny dźwięk jest wybuchowy lub nosowy, np. w słowie *krnąbrny*, szczelinowy alofon jest natomiast częstym wariantem w zbitkach spółgłoskowych, w których /r/ znajduje się przed spółgłoską szczelinową, np. w słowie *drżenie*. W artykule opisano ponadto inne alofony dźwięku /r/: bezdźwięczny drżący, szczelinowy, zwarto wybuchowy i jednouderzeniowy. Zaobserwowano również nieliczne przypadki elizji. Zgromadzone dane wskazują ponadto, że stopień redukcji fonetycznej dźwięku jest wyższy w wygłosie niż w nagłosie.

Słowa kluczowe

dźwięki rotyczne, polski, redukcja fonetyczna

1. Introduction

There seems to be a general consensus in phonetic literature that the natural class of rhotics can hardly be defined on acoustic or articulatory grounds due to its being made up of segments that differ with respect to their place and manner of articulation (Ladefoged and Maddieson 1996, Lindau 1985, Wiese 2001). Despite the significant differences among r-sounds, all members of the natural class share an important distributional feature, i.e. they occupy vowel-adjacent positions within the syllable. However, in some languages, rhotics do not necessarily adjoin a vowel, e.g. in Czech *krk* 'neck', *krv* 'blood' or the words *herd* and *father*, pronounced [hɹ̩d] and [fɑːðɹ̩] in American English (Ladefoged and Maddieson 1996: 234). In these examples, the rhotic sounds constitute a peak of sonority within a cluster and, therefore, are regarded as syllabic consonants.

Due to the overwhelming preponderance of vowel-adjacent rhotics in the world's languages, most phonetic literature focuses on sounds that follow the pattern (Blecua 2001, Demolin 2001, Jaworski and Gillian 2011, Proctor 2009, Recasens and Espinosa 2007, Solé 2002, Żygis 2005). A fair amount of attention has also been devoted to syllabic rhotics (Browne 1993, Jaworski 2014, Priestly 1993, Sussex and Cubberley 2006), while very little has been written about obstruentised rhotics, i.e. r-sounds that are neither vowel-adjacent nor syllabic (Gussmann 2007). Sound combinations containing an obstruentised rhotic can be found in Polish as well as in the languages that make up the Eastern Slavonic group. Being cross-linguistically rare, such consonant clusters are definitely marked, which further implies that they should manifest a tendency towards phonetic reduction.

The paper attempts to fill the gap in the literature by providing a detailed description of the acoustic characteristics of the obstruentised rhotic of Polish. The sound's properties are examined with respect to: (i) its position within the syllable and (ii) the manner of articulation of the adjacent segment(s). The Polish rhotic phoneme /r/, classified as a post-alveolar trill, is normally reduced phonetically to a tap or, less frequently, to a fricative or approximant even in those contexts where its articulation should not pose a serious problem, as in the word-initial position (Gussmann 2007, Jaworski and Gillian 2011, Jaworski 2018, Łobacz 2000). Surprisingly, one often gets the impression that a strong, trilled allophone of /r/ is frequently produced in #rC and CrC clusters not only in careful speech, but also in conversational Polish.

The paper is structured as follows. Section 2 outlines the diachronic changes that affected r-sounds in the Slavic languages and brought obstruentised rhotics into existence. Section 3 is concerned with the distribution of the obstruentised rhotic of Polish. Section 4 describes at some length how the data analysed in the study were collected. This is followed by Section 5, where the obtained results are presented and interpreted. The final part of the paper includes several concluding remarks and suggestions for further research.

2. The rise of the obstruentised rhotic

During the Proto-Slavonic period (ca. 1,500 BC – the 10th century AD), one Slavic language is said to have been spoken throughout the Slavic area, although a certain amount of dialectal variation was definitely present (Klemensiewicz 1999, Moszyński 1984, Stieber 1979, Shevelov 1964). For practical purposes, Proto-Slavonic is further divided into Early Proto-Slavic (EPSl), also referred to as Common Slavic (CS), and Late Proto-Slavic (LPSl).

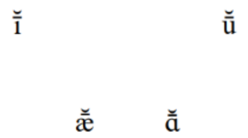
The phonology of EPSl was greatly affected by two phenomena referred to as the tendency for intrasyllabic harmony and the tendency for rising sonority (Carlton 1990, Moszyński 1984, Schenker1993: 67, Shevelov 1964, Stieber 1979, Townsend and Janda 1996). The former was primarily manifested by palatalisation of consonants before front vowels, whereas the latter consisted in arranging sounds within the syllable such that their sonority increased while moving from the first to the last segment. Since only open syllables could meet the requirement, all coda consonants were eliminated.[1]

As far as the rhotic segments of EPSl are concerned, some of the processes that affected them were intimately related to, or conditioned by, certain changes to the vowel inventory of EPSl. According to Carlton (1990: 98), the Early Proto-Slavic vowels were distinctive with respect to the following features:

[1] This phenomenon is also referred to as the law of open syllables (Carlton 1990, Schenker 1993).

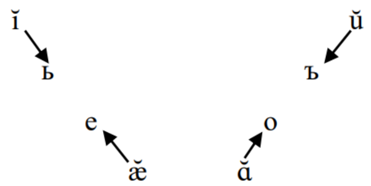
height (high vs. low), advancement (front vs. back) and duration (long vs. short),[2] as presented in (1). Apart from these vowels, EPSl also had vowel-sonant sequences, inherited from Proto-Indo-European, which are said to have been diphthongs (Carlton 1990, Moszyński 1984, Shevelov 1964, Stieber 1979).

(1)



During the Late Proto-Slavic period, the short vowels underwent a qualitative change, presented in (2), which brought into existence two mid-open and two mid-close vowels. It is the vowels [ь] and [ъ], referred to as *jers*, that played a crucial role in the development of both obstruentised and syllabic rhotics.

(2)



The jers /ь/ and /ъ/ had weak and strong variants. The strong jers subsequently developed into fully fledged vowels, while the weak jers fell out of the system. The fall of the weak jers /ь/ and /ъ/, which began in the 10th century and is said to have been completed by the end of the 12th century (Stieber 1979: 49, Townsend and Janda 1996: 73), not only reduced the number of vowels in the inventory, but it also signalled the end of phonotactic constraint on consonant clusters, i.e. the law of rising sonority. The immediate consequence of the change was the rise of many types of consonant clusters including ones containing

[2] In Slavic linguistics, the diacritics [˘] and [¯] represent phonologically short and long vowels, respectively.

inter-consonantal r-sounds which are still retained in several Slavic languages either as syllabic or obstruentised rhotics (Carlton 1990, Stieber 1979, Townsend and Janda 1996).

Obstruentised and syllabic rhotics arose as a result of changes that affected the **tъrt* and **trъt* sound patterns. By convention, the grapheme <t> stands for any consonant, <r> for any liquid and <ъ> for any jer (Carlton 1990, Stieber 1979, Townsend and Janda 1996). Importantly, the changes that affected **tъrt* and **trъt* were closely related although the two sound patterns were quite different in terms of phonology as the former was a diphthong, while the latter contained a common onset cluster followed by a vowel (Carlton 1990, Stieber 1979, Townsend and Janda 1996).

Proto-Slavic diphthongs were simplified, or monophthongised, by dropping the first element, which also affected the existing **tъrt* sound patterns. However, the changes were not uniform. In East Slavic, **tъrt* changed such that an imitative vowel was epenthesised after the liquid. This phenomenon, referred to as *pleophony* or *polnoglasie* (Shevelov 1993, Timberlake 1993), transformed **tărt* into **torot*. In the South and West Slavonic languages, the strong /ъ/ and /ь/ of **tъrt* developed into full vowels (Carlton 1990, Moszyński 1984, Stieber 1979), whereas weak jers were lost. The loss of weak jers resulted in the emergence of **tr̩t* sound patterns, where the front vs. back contrast had been neutralised, with some exceptions.

As regards **trъt*, in East Slavic, reflexes of **trъt* not only keep the order of the jer and liquid, but they also distinguish between the front and back jer in the case of /r/ (Townsend and Janda 1996: 65). In other areas, three reflexes of **trъt* occurred, depending on whether the jer was strong or weak (Carlton 1990: 153). The deletion of the front jer /ь/ yielded the syllabic palatalised sonant /r̩ʲ/, whereas the elision of the back jer /ъ/ gave rise to the plain syllabic rhotic /r̩/. In LPSl, the two syllabic rhotics remained distinctive in South Slavic and Central Slavic, but in the course of time, they merged into /r̩/.[3] The next important development involved a merger of the syllabic rhotics arising from **trъt* with those arising from **tьrt* (Carlton 1990: 153).

Sound sequences of the **tr̩t* type, irrespective of their origin, underwent further changes in the different Slavic languages. In most South Slavic languages, the rhotic still has the phonological status of a syllabic consonant. As for West Slavic, Czech and Slovak are the only languages in which the rhotic sound retained its syllabicity.[4] In Polish and the two Sorbian languages, the **tr̩t* syllable remained unchanged, but it was later restructured in various ways. Importantly, in none of the three languages are interconsonantal rhotics considered to be syllabic. Finally, in Bulgarian and Kashubian, **tr̩t* was replaced with syllables containing a vowel whose quality differed from what might be expected from strong [ъ] or [ь]. This replacement was typically, **tr̩t* > **trVt,* but changes of the **tr̩t* > **tVrt* type were also attested (Carlton 1990, Moszyński 1984, Schenker 1993, Stieber 1979, Townsend and Janda 1996).

[3] During the Old Church Slavonic period (OCS), which extended from the mid 9th century till the end of the 11th, the plain and palatalised syllabic sonorants were not distinguished from sequences of sonorants followed by a reduced vowel. It is assumed that, prehistorically, there were front and back syllabic sonorants, always followed by a front or back vocalic element respectively, as suggested by the two spellings *črьvь* and *črьvь* 'worm' (nom. sg.) (Huntley 1993: 127). The difference was no longer marked in the ortho-graphy of OCS as the two sounds had merged. Huntley (1993) further argues that the sonorant pairs /l/ – /lʲ/ and /n/ – /ɲ/ were still distinct after /r/ and /rʲ/ had merged. Neutralisation of the phonological contrast between the two trills may be attributed to their being hardly distinguishable, which was due to the very short linear distance between their places of articulation.

[4] The phonotactics of the Czech language allows for sound sequences in which the fricativised trill /r̝/ occurs in interconsonantal position or in postconsonantal, word-final position, e.g. *pohřbu* 'funeral' (gen. sg.) or *vnitř* 'interior' (archaic). In spite of this, the sound does not have the status of a syllabic rhotic (Bičan 2013).

3. Distribution of obstruentised rhotics in Modern Polish

The phonotactics of Modern Polish is rather complex as it allows for heavy onset clusters, e.g. *pstrąg* [pstrɔ̃ŋk] 'trout', and even heavier coda clusters, e.g. *przestępstw* [pʃɛstɛ̃mpstf] 'crime' (gen. pl.). In addition to that, Polish also allows for cross-linguistically rare sound patterns that include obstruentised rhotics in onset and coda positions. Obstruentised rhotics occur in the four contexts presented in (3).

(3a) #_C – word-initial, preconsonantal position, e.g. *rdza* [rd͡za] 'rust'
(3b) C_C – inter-consonantal, onset position e.g. *drwal* [drval] 'woodcutter'
(3c) C_.C – inter-consonantal, coda position, e.g. *Piotr.ka* [pjɔtrka] 'Peter' (gen. sg.)
(3d) C_# - word-final, postconsonantal position, e.g. *wiatr* [vjatr] 'wind'

It must be emphasised at this point that the Polish lexicon does not contain very many words meeting the phonotactic criteria in (3). For instance, the sound combination in (3a) is found only in the following eight words: *rdest* 'knot grass', *rdza* 'rust', *rdzeń* 'core', *rtęć* 'mercury', *rwać* 'to tear', *rwetes* 'turmoil', *rżeć* 'to neigh', *rżnąć* 'to cut' and their derivatives. Equally infrequent are clusters of the C_C type in (3b). Excluding proper nouns, which definitely extend the list, there are only ten lexical items that follow this sound pattern: *brnąć* 'wade', *drgać* 'vibrate', *drwal* 'woodcutter', *drwić* 'sneer', *grdyka* 'Adam's apple', *krnąbrny* 'recalcitrant', *krtań* 'larynx', *trwać* 'to last', *trwonić* 'squander', *trwoga* 'fear'. In addition to these words, interconsonantal coda rhotics are also found in several derivatives of *krew* 'blood' and *brew* 'eyebrow', where the vowel of the root is deleted, e.g. *krwisty* 'bloody', *brwi* 'eyebrows'.

With regard to coda positions, inter-consonantal r-sounds (3c) only occur in word-medial clusters, e.g. in several inflected forms of the name *Piotrek* such as *Piotrka* (gen. sg.), and in several inflected and derived forms of the noun *mędrzec* 'sage', e.g. *mędrca* (gen. sg.). Clusters of this type are also found in a handful of words to which the prefix *kontr-* 'counter' can be attached, e.g. *kontrkandydat* 'opponent'. Word-final, post-consonantal rhotics (3d) occur in a relatively large number of words, many of which are of foreign origin, e.g. *metr* 'meter', *litr* 'liter', *teatr* 'theater', *filtr* 'filter' (see the Appendix).

The clusters in (3) constitute an articulatory difficulty not only by virtue of being rather infrequent. It has been established that infrequent words are not reduced phonetically to the same extent as high-frequency words (Bybee 2001, Shockey 2003). Francis and Kučera (1982) define high frequency words as ones that occur more than 35 times per one million words. According to the National Corpus of the Polish Language (nkjp.pl), the vast majority of the target words used in this study are regarded as low-frequency items. The proper name *Piotr* as well as the gen. sg. form of *krew* 'blood' constitute exceptions to the general rule.

4. The study

The primary objective of the study is to provide a detailed description of the acoustic and temporal characteristics of the obstruentised rhotic of Polish. The former specifies the F1 and F2 values of the vocalic elements occurring between constriction phases of trills, while the latter includes the duration of the constituents of rhotics. An attempt is also made to determine whether or not the position within the syllable exerts an influence on the pronunciation of the rhotic phoneme. Finally, the collected data are also expected to provide conclusive evidence as to how the neighbouring segment(s) affect the physical realisation of the obstruentised rhotic of Polish.

To achieve the goals of the study, ten native speakers of Polish, aged 21–22, were asked to take part in the recording session. At that time, they were students at Szczecin University in its Department of English. None of the participants were reported or observed to have a speech impediment or hearing impairment. The participants were asked to read a list of words embedded in the carrier phrase *Powiedziała X, not Y* 'She said X, not Y'. The rationale behind choosing this carrier phrase is that the items in slots X and Y are contrasted, which increases the likelihood of trilling. The target words contained obstruentised rhotics in the four contexts presented in (3). The wordlist was designed such that, in each group, half of the rhotics were immediately followed/preceded by a stop and the other half by a fricative (see the Appendix). In addition, 75 words with the vowels /i a u/ in stressed position were used as distractors. The vowels were later used as a frame of reference for describing the quality of intrusive vocalic elements of obstruentised trills.

The recording sessions took place in the phonetics lab at Szczecin University in November 2011. The data were recorded at a 44,100 Hz sampling rate directly into a laptop computer (Sony Vaio SVF1532U1EW) using an M-Audio Uber Microphone. The Praat Software (version 4.2.21) was used to digitise the data, carry out the acoustic analyses and produce spectrograms and oscillograms.

5. Allophones of the obstruentised /r/ of Polish

An acoustic analysis of the data revealed that the obstruentised rhotic of Polish is highly susceptible to phonetic change in the four contexts investigated in the study. Given their articulatory and acoustic properties, the allophones encountered in the recordings were divided into five groups, according to their manner of articulation. These include: voiced trills [r], fricated trills [r̥], spirantised rhotics [ɹ̝], affricated rhotics [ɾʒ] and taps [ɾ].[5] In addition to these variants, instances of deletion were included, although they were rather infrequent. Table 1 provides

[5] Since the IPA alphabet does not provide a symbol for affricated rhotics, [ɾʒ] will be used throughout the paper to represent variants of this type as it involves a closure followed by a period of friction.

information as to the frequency of the occurrence of the six articulatory variants of the obstruentised /r/ distinguished in the study.

With regard to voiced trills, the vast majority of rhotics that fall into this category (89 %) include two full cycles of vibration, while in the remaining 11 % three cycles were made. If three constriction phases occur, the degree of phonetic reduction increases with each consecutive occlusion. This phenomenon is illustrated in Figure 1, which depicts a trill in the word *brnąć* [brnɔ̃t͡ɕ] 'to wade'. Typically, the first cycle includes a complete closure, while in the second and third cycle the constrictions are usually incomplete and may even have an indistinct formant structure (see also Jaworski 2018).

Fricated trills tend to occur in clusters in which they are flanked by voiceless consonants, e.g. in the words *krtań* [kr̥taɲ] 'larynx' and *trwoga* [tr̥fɔga] 'fear'. Allophones of this type were also encountered in post-consonantal, word-final position (see Table 1). Fricated trills exhibit marked differences with respect to the number of occlusions, which is very likely to be correlated with the amount of articulatory effort. The trill in Figure 2, which presents the word *krtań* 'larynx' pronounced by S3, is made up of five cycles of vibration (marked A-E); however, the 40 instances of fricated trills found in the data typically include three closures, with durations ranging between 12.4 and 15.7 ms. The short duration of the closure phase results from the considerable amount of friction that is due to its being preceded by a voiceless plosive[6] (see Jaworski 2018).

[6] Although Polish voiceless plosives are weakly aspirated even in stressed syllables, in C_C onset clusters they tend to be pronounced with a considerable amount of friction due to a greater-than-usual articulatory effort exerted by speakers.

Table 1

Number of articulatory variants produced
in the four contexts examined in the study

Context \ Variant		r	r̥	ɹ̝	ɾˢ	ɾ	ø
#_C	(195)	160	-	-	35	-	-
C_C	(197)	127	23	34	8	5	-
C_.C	(193)	-	-	121	65	-	7
C_#	(198)	-	17	140	24	11	6
Total	(783)	287	40	295	132	16	13

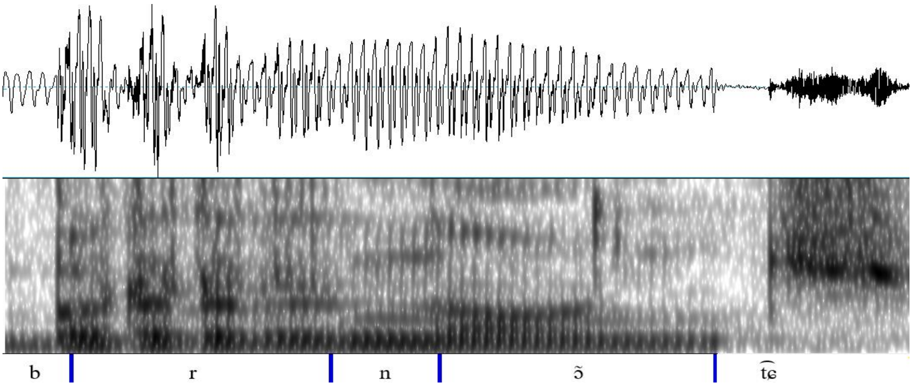


Figure 1

Spectrogram of *brnąć* ‘to wade’ with a trill with three constrictions

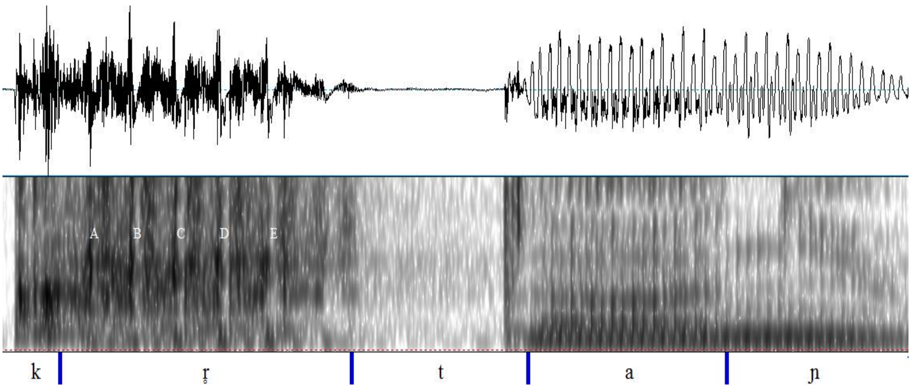


Figure 2

Fricated trill in the word *krtań* ‘larynx’ produced by S3

Spirantised rhotics constitute the most frequent allophone of the obstruentised /r/ of Polish. A token of this type, produced in the word *trwonić* [tɹ̥fɔɲit͡ɕ] 'squander', is presented in Figure 3. Spirantised rhotics represent a greater degree of phonetic reduction than fricated trills due to the fact that the former lack a complete constriction. In other words, they are realised phonetically as a period of friction. On the other hand, the changing amplitude of friction in the oscillogram and the changing intensity of the spectrum indicate that the articulating part of the tongue was not totally motionless throughout the rhotic segment. This also suggests that the speaker tried to produce a trill. Trills require a considerable amount of articulatory effort as well as a high degree of articulatory precision. Therefore, they are not always attainable, especially in connected speech. As a consequence, they are usually sacrificed and the less demanding allophones of /r/ are produced.

Somewhat surprisingly, as many as 132 of the tokens were classified as affricated rhotics. Allophones of this type consist of a tap followed by a strong burst of noise similar to that of an unaspirated plosive. The duration of the burst release was used as a criterion for distinguishing between tapped variants and affricated ones. It was arbitrarily assumed that an affricated rhotic is made up of a closure followed by a period of friction that is at least 1.5 times longer than the closure phase.[7]

Figure 4 depicts a word-final, affricated rhotic produced in the word *bóbr* 'beaver'. The rhotic sound is separated from the preceding plosive by a 35-millisecond intrusive vocalic element. The rhotic itself consists of an 18-milisecond complete closure phase followed by a period of relatively strong friction whose duration is 15 miliseconds longer. The duration of the closure phase is thus comparable with that of the taps produced in numerous languages (see Baltazani 2009 for Greek, Blecua 2001,

[7] Affricated rhotics do not seem to have been mentioned in phonetic literature, yet realisations that meet the articulatory criteria described above are presented in Celata et al. (2016). The authors use the symbol [ɾɹ̥̝] to represent affricated allophones of rhotics occurring in Sicilian Italian.

Jaworski and Gillian 2011 for Polish, Jaworski 2018, Recasens and Pollarès 1999 for Spanish). As for the period of friction, it may be even twice as long as the constriction phase. Interestingly, neither the spectrogram nor the oscillogram show signs of vocal fold activity throughout the rhotic sound. This finding is somewhat surprising given that the preceding plosive is fully voiced.

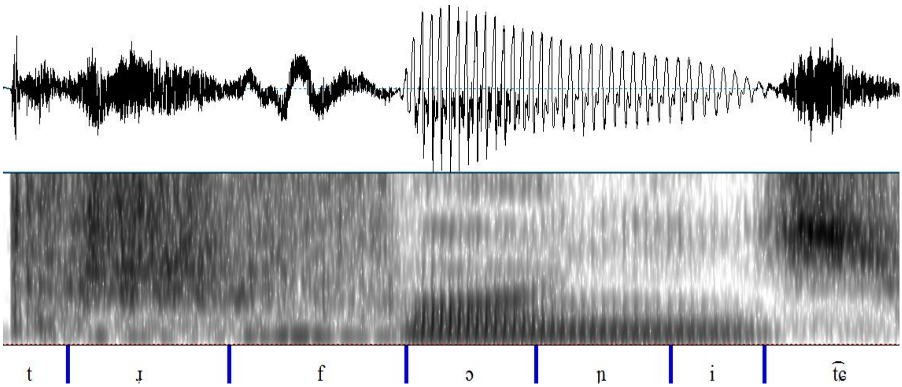


Figure 3
Spirantised rhotic in the word *trwonić* 'squander'

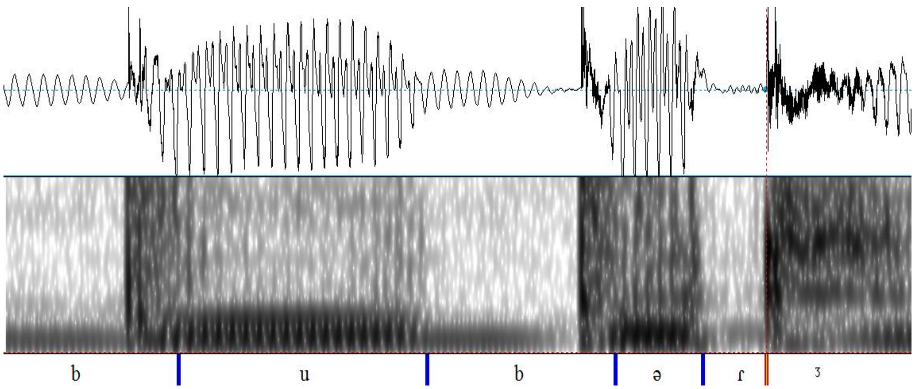


Figure 4
Affricated rhotic in the word *bóbr* 'beaver'

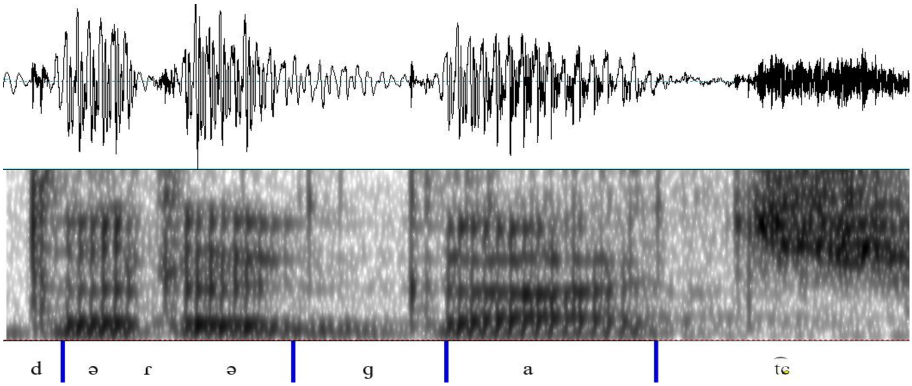


Figure 5
A tapped variant of obstruentised /r/
occurring in the word *drgać* 'to vibrate'

Obstruentised rhotics may also be realised phonetically as taps. In the recordings analysed for the purposes of the study, tapped variants constituted a tiny minority, as only 16 instances of tapping were encountered. These findings are rather surprising given that the taps constitute the most frequent allophones of vowel-adjacent r-sounds, not only in Polish, but also in the other Slavic languages (Jaworski 2018). Figure 5 presents a variant of this type, produced in the interconsonantal position in the word *drgać* [drgat͡ɕ] 'to vibrate'. Since this token occurs between two plosives, the tap is separated from the flanking plosives by two intrusive vocalic elements. In this case, the preceding element is shorter than the following one, 24 ms and 32 ms respectively, but by no means should it be regarded as the norm (see Jaworski 2018). As for the acoustic properties of the vocalic elements, they happen to correspond with those of the neutral vowel schwa. The preceding and following intrusive elements are almost identical with F1 at the level of 511 Hz and 514 Hz, and F2 values of 1490 Hz and 1497 Hz respectively. The closure phase of 17 ms falls within the range described the in works of other authors investigating rhotics, e.g. Blecua (2001), Solé (2002), Ladefoged and Maddieson (1996), Recasens and Pallarès (1999), Jaworski (2018).

5.1. Initial, pre-consonantal position

In the initial, pre-consonantal position, only two variants of /r/ occur, namely a voiced trill and an affricated rhotic. The former is considerably more frequent (82 %) than the latter (18 %). The results strongly suggest that the two allophones of /r/ are, to some extent, dependent on the manner of articulation of the following consonant as trilling appears to be the norm in those target words where rhotics are immediately followed by stops, as in *rdest* [rdɛst] 'knot grass', while affrication is common in rhotic-fricative sequences, e.g. *rżeć* [rʒɛt͡ɕ] 'to neigh'.

As regards the acoustic properties of trills occurring in this context, Table 2 presents the mean duration of the first two constriction phases as well as those of the vocalic interval between the closures (V1) and between the second closure and the following consonant (V2) produced by the ten participants. In the case of the male participants, the average duration of the first closure phase is 18.13 ms (± 4.17), while that of the second occlusion is 17.25 ms (± 4.63). The vocalic intervals, however, follow the reverse pattern in which V1 is slightly longer than V2 (20.4 ms vs. 22.3 ms respectively). The results yielded by a one-way ANOVA test indicate that there is a certain amount of inter-speaker variation, yet the differences did not turn out to be statistically significant ($p > .05$).[8] As regards the duration of C1, the amount of inter-speaker variation is relatively close to the 5 % significance threshold (df = 9, F = 1.72; p = 0.0889). A similar level of variation was obtained for the duration of C2 (df = 9; F = 1.76, p = 0.0806). The differences are slightly greater as far as intrusive vocalic segments are concerned, as they reached the significance level with p = 0.0471 (df = 9; F = 1.97) and p = 0.0339 (df = 9; F = 2.09) for V1 and V2 respectively.

[8] A one-way ANOVA test is a standard statistical tool when several groups of scores are compared with respect to a single variable (Howitt and Cramer 2005: 187).

Table 2

Mean duration of the closure phases (C1 and C2)
and vocalic intervals (V1 and V2) of word initial trills

	Male participants				
	S1	S2	S3	S4	S5
C1	17.1 ± 3.1	16.8 ± 3.2	18.5 ± 2.8	18.7 ± 2.6	18.5 ± 3.0
C2	16.3 ± 2.7	16.1 ± 2.5	16.1 ± 2.8	16.8 ± 4.3	17.1 ± 2.5
V1	19.8. ± 3.2	21.5 ± 3.0	19.7 ± 3.2	20.2 ± 3.8	20.8 ± 3.2
V2	22.5 ± 2.5	22.7 ± 3.4	20.1 ± 3.2	23.0 ± 3.5	22.4 ± 3.8
	Female participants				
	S6	S7	S8	S9	S10
C1	18.6 ± 2.5	16.8 ± 2.8	18.9 ± 3.0	20.0 ± 3.2	19.5 ± 2.4
C2	17.4 ± 2.3	18.0 ± 3.0	17.6 ± 2.4	17.7 ± 2.7	19.3 ± 2.1
V1	19.9 ± 3.0	21.6 ± 3.5	20.5 ± 3.6	18.3 ± 2.5	19.4 ± 2.2
V2	20.7 ± 3.5	21.7 ± 3.5	22.1 ± 3.2	20.8 ± 4.1	20.3 ± 3.3

These findings differ, to a certain extent, from the data reported by other authors, e.g. Blecua (2001), Lindau (1985), Ladefoged and Maddieson (1996), Recasens and Pollarès (1999), with respect to the duration of constrictions and vocalic elements. According to the above-mentioned sources, in the case of vowel-adjacent apical trills, the duration of both the closure phases and the vocalic intervals is on the order of 25 ms. The considerably shorter closure phases obtained in this study may be atributed to the fact that the examined trills are either adjacent to a consonant or flanked by two consonants. Needless to say, the differences may also be attributed to speaker-specific factors.

5.2. Inter-consonantal, onset position

Polish phonotactics allows for three-segment onset clusters involving an interconsonantal rhotic, in which the first slot is occupied by one of the plosives /b t d k g/, whereas the third slot can be filled by: (i) /t/, /d/ or /g/, (ii) /f/, /v/ or /ʒ/ or (iii) the nasal /n/. The collected data includes 197 tokens of the phoneme /r/ in this environment, 64.5 % of which were clas-sified as voiced trills, 11.7 % as voiceless trills, 17.2 % as fricatives and 4 % as affricated taps. Only five of the tokens (2.5 %) met the articulatory criteria of a tap sound (see Table 1). As in the case of word-initial, pre-consonantal sequences, the physical realisation of a rhotic segment appears to be dependent on the following segment. More specifically, trilled variants tend to occur between stops, while fricated allophones are usually produced when immediately followed by fricatives, especially the voiceless /f/.

With regard to voiced trills, their physical properties do not seem to differ considerably from those of their word-initial counterparts. However, the duration of the constriction phases (typically two, less frequently three) is slightly shorter and falls within the range of 12.8 to 22.6 ms (see Table 3 for details). As in the case of pre-consonantal onset trills, a series of one-way ANOVA tests were conducted to determine whether the acoustic parameters of trills vary from speaker to speaker. In fact, the level of statistical significance was reached with respect to the duration of C1 (df = 9, F = 2.0, p = 0.0454), but not with regard to C2 (df = 9, F = 1.92, p = 0.0552). As in the previous context, the first constriction tends to be longer than the following one(s). The same tendency is also visible in the data regarding intrusive vocalic elements. V1 and V2 exhibit a fair amount of interspeaker variation as, in both cases, the statistical tests yielded significant results, with (df = 9, F = 2.06, p = 0.0386) and (df = 9, F = 2.28, p = 0.0213) for V1 and V2 respectively.

As noted above, 33 of the tokens in CrC onset clusters underwent spirantisation. This type of phonetic reduction is definitely facilitated by a following fricative. In the group of target words meeting this requirement, 29 of the r-sounds (29 %) were articulated as fricatives. This percentage is considerably higher than in the case of initial, pre-consonantal rhotics (section 5.1). The difference may be accounted for by referring to the segmental make-up of the clusters in question. Unlike initial, pre-consonantal rhotics, the ones in the CrC context can be followed by the sound /f/, the only voiceless fricative allowed in this position. In inter-consonantal onset clusters, 55 % of the r-sounds adjacent to the labio-dental /f/ underwent spirant-isation, compared with only 11.7 % of those followed by a voiced spirant, either /v/ or /ʒ/.

Table 3

Mean duration of closures (C1; C2) and vocalic intervals (V1; V2) of inter-consonantal onset trills

	Male participants				
	S1	S2	S3	S4	S5
C1	16.5 ± 3.4	15.8 ± 3.7	16.6 ± 4.0	17.1 ± 3.5	16.8 ± 3.6
C2	16.3 ± 3.7	16.1 ± 2.5	16.0 ± 3.9	17.2 ± 4.0	16.4 ± 3.4
V1	22.3 ± 4.6	20.5 ± 4.4	20.3 ± 5.1	20.8 ± 4.7	19.7 ± 4.3
V2	23.2 ± 4.9	21.7 ± 4.8	20.3 ± 4.9	21.4 ± 4.2	20.4 ± 4.3
	Female participants				
	S6	S7	S8	S9	S10
C1	17.3 ± 3.8	16.9 ± 3.5	17.1 ± 4.0	16.4 ± 4.2	17.6 ± 3.3
C2	16.7 ± 3.8	16.1 ± 3.3	16.8 ± 4.0	16.8 ± 3.7	17.4 ± 4.4
V1	20.9 ± 4.4	19.9 ± 5.1	20.5 ± 4.9	20.3 ± 4.3	21.1 ± 5.2
V2	20.7 ± 4.5	20.1 ± 4.7	21.0 ± 4.6	20.5 ± 5.0	22.9 ± 4.9

5.3. Heterosyllabic Cr.C clusters

In the Polish language, inter-consonantal coda rhotics can only be encountered in word medial clusters where the r-sound and the following consonant are heterosyllabic. Since coda positions are prosodically weak, constituents of such clusters should be more susceptible to phonetic reduction than onset segments. This prediction has been confirmed by the results as trilled realisations are not attested in this environment and instances of deletion occur occasionally. The 193 tokens fall into one of the following categories: (i) fricatives (62.6 %), (ii) affricated rhotics (33.6 %) and (iii) instances of deletion (3.6 %).

The large number of spirantised rhotics in this context is hardly surprising, given that the rhotic is placed between two voiceless stops in three quarters of the target words. The most frequent variant, produced in *kontrkandydat* [kɔntɹ̝̊kandɨdat] 'opponent', is presented in Figure 6. The section of the spectrogram showing the sequence of the dental plosive /t/ and the post-alveolar rhotic resembles that of an affricate, in that the burst of the former sound blends with the friction of the rhotic.

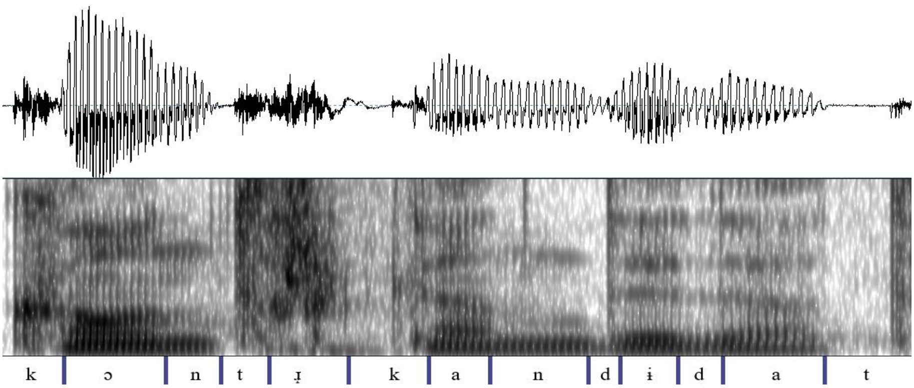


Figure 6
A spirantised /r/ in *kontrkandydat* 'opponent'

Although it needs to be verified by other studies, fricated variants may result from retroflexion of the rhotic segment. After the release of the plosive, rather than moving the apex away from the teeth, speakers probably produce a retroflex gesture by raising the tip of the tongue and moving it towards the alveolar ridge, main-taining a certain degree of contact with the teeth as well as the ridge.

5.4. Word final, post-consonantal position

Word final, post-consonantal rhotics appear to be particularly difficult to pronounce as the phoneme /r/ exhibits the greatest amount of variation in this context. Allophones attested in this position include: (i) voiceless trills (8.6 %), (ii) spirantised rhotics (70.7 %), (iii) taps (12.1 %) and (iv) instances of deletion (3 %). Additionally, in this environment, Speaker 4 produced five tokens (2.5 %) of an idiosyncratic r-sound, whose characteristics bear a striking resemblance to those of an alveolar plosive /t/.[9] The percentages definitely change in casual spontaneous speech where the percentage of deleted segments is rather likely to be higher.

The preponderance of spirantised rhotics in the Cr# position seems to be, at least partially, due to /r/ being preceded either by a voiceless plosive or by a fricative. In this prosodically weak position, even a small amount of aspiration of the stop results in frication of /r/. The likelihood of frication is additionally enhanced by the segmental make-up of such clusters where the post-alveolar rhotic is preceded by one of the dental plosives /t d/. This means that the same part of the tongue articulates both the plosive and rhotic gestures, which further facilitates phonetic reduction.

Tapped word-final rhotics are rather infrequent and, judging from the data, their distribution appears to be limited to those contexts where the phoneme /r/ is preceded by a voiced

[9] These tokens were excluded from the analysis.

consonant, as in *bóbr* [bubɾ] 'beaver' or kadr [kadɾ] 'frame'. Tapped variants consist of three elements, i.e. a closure phase flanked by two epenthetic vocoids. The duration of the vocalic element preceding the closure is, on average, 23.1 ms (± 4.14 ms) long, whereas that of the other voicoid ranges between 20.8 ms 28.6 ms, with the average duration of 25.1 ms (± 3.67 ms). In Cr# clusters, the intrusive vocalic element preceding the closure tends to be longer between the dental /d/ and the rhotic than in sequences involving the bilabial /b/ followed by /r/, yet the few tokens present are insufficient for making valid generalisations.

The average duration of the closure phase of a word-final tapped variant lasts 16.3 ms (± 3.1ms), thus the value is comparable with the length of closures produced in trills (section 5.2) and those of taps articulated in the other contexts (Jaworski and Gillian 2011, Jaworski 2014, 2018). However, the data includes five unusual taps produced by S4 in clusters made up of a dental plosive followed by a rhotic. What distinguishes these from typical taps is the duration of the closure phase being approximately three times longer than that of a typical tap and comparable with the hold phase of the dental plosive /t/, with the average value 55.8 ms (± 5.4 ms). They are also followed by a burst of noise rather than a vocalic segment (Figure 9). It can be argued that the burst is a consequence of the prolonged closure which appears to be sufficiently long to increase the air pressure behind the occlusion to such a degree that an abrupt release produces a certain amount of noise. However, given that only one of the participants produced this particular variant, it should probably be regarded as a speaker-specific feature.

As few as 8 % of the word-final r-sounds were pronounced as voiceless trills. The low token frequency of this particular variant implies that the participants had considerable difficulty articulating the [r̥] sound as, in the vast majority of cases, they failed to create and maintain the aerodynamic conditions for trilling. Somewhat surprisingly, none of the trills in the data is voiced, even those preceded by voiced consonants.

Finally, the data also contains six instances of elision, which typically occur in those items where the phoneme /r/ is preceded by a fricative. Word-final rhotics were judged to have been deleted if the friction in the section of the spectrogram that corresponded with the fricative-rhotic sequence did not show any signs of change with respect to intensity or range, nor did it include any of the other allophones described above.

5.5. Intrusive vocalic elements

The acoustic data presented in this section include the mean values of the first two formants of the intrusive vocalic elements that occur between the constrictions of the 287 trilled variants of /e/ encountered in the examined recordings (see Table 4). In order to show how the vocalic elements are distributed in the vowel space in relation to other Polish vowels, the first two formants of 25 tokens of stressed /i a u/ sounds were also measured to provide a frame of reference for the intrusive vocalic elements. All the measurements were made manually at the midpoint of each vowel.

The data presented in Table 4 indicates that the vocalic elements occurring in trilled variants ought to be classified as mid-central vowels as their acoustic characteristics do not differ significantly from those of the schwa sound. The schwa vowel, also referred to as a vowel of undetermined quality, has one resonance at 500 Hz, another one at 1500 (Ladefoged 1996: 121). In the case of the male speakers, however, one might argue that they should rather be described as mid-high and central on account of their F1 being slightly lower than that of /u/. This claim is further supported by the evidence in Figure 7 that shows the distribution of the vocalic elements, marked [ə], in relation to the peripheral vowels /i a u/ produced by S1. In his speech, the mean F1 value of the vocalic elements is 442 Hz (± 37 Hz), while that of the second formant is 1612 Hz (± 71 Hz).

Table 4
The mean F1 and F2 values of vocalic elements produced in voiced trills

	Male participants				
	S1	S2	S3	S4	S5
No	24	26	33	18	39
F1	442 Hz (± 37 Hz)	461 Hz (± 44 Hz)	437 Hz (± 51 Hz)	483 Hz (± 47 Hz)	454 Hz (± 41 Hz)
F2	1612 Hz (± 71 Hz)	1621 Hz (± 73 Hz)	1582 Hz (± 68 Hz)	1499 Hz (± 76 Hz)	1567 Hz (± 67 Hz)
	Female participants				
	S6	S7	S8	S9	S10
No	31	27	36	38	15
F1	573 Hz (± 43 Hz)	549 Hz (± 51 Hz)	538 Hz (± 39 Hz)	498 Hz (± 46 Hz)	486 Hz (± 54 Hz)
F2	1622 Hz (± 83 Hz)	1617 Hz (± 73 Hz)	1589 Hz (± 58 Hz)	1454 Hz (± 71 Hz)	1654 Hz (± 67 Hz)

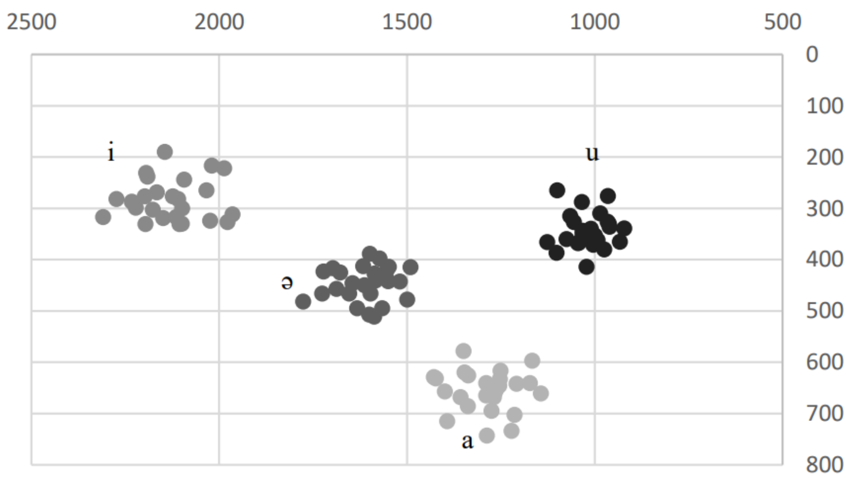


Figure 7
Distribution of vocalic elements in the vowel space (S1)

6. Conclusion

The acoustic analysis examined the susceptibility of the Polish obstruentised rhotic to phonetic change with respect two factors: (i) the position within the syllable and (ii) the manner of articulation of the adjacent segment(s). With regard to (i), the general conclusion that can be drawn from the data is that trilled variants predominate in prosodically strong onset positions (#_C and C_C), while in the two coda positions (C_# and C_.C) the sound is very likely to be reduced to a fricative. The results also indicate that the physical realisation of the rhotic segment, irrespective of the context, depends on the amount of muscular effort and articulatory precision, as evidenced by the different variants of /r/ produced in clusters that have the same phonological make-up, e.g. *rdza* [rd͡za] 'rust' and *rdzeń* [rd͡zɛɲ] 'core'. The significant number of trilled realisations of /r/ definitely has to do with the research methodology that facilitated accurate, or hypercorrect, pronunciation. As far as factor (ii) is concerned, the production of a trilled variant appears to be facilitated by an adjacent stop, plosive, affricate or nasal. In sound combinations involving fricatives, especially in coda clusters, the rhotic regularly undergoes frication.

The temporal characteristics of trilled allophones, i.e. the duration of their closure phases and vocalic intervals, differ substantially from the data presented by other authors, e.g. Ladefoged and Maddieson (1996), Recasens and Pallarès (1999), Blecua (2001), Solé (2002), yet none of the above-mentioned works is concerned with non-vowel-adjacent rhotics, so the discrepancies may have resulted from the consonantal environments in which the obstruentised rhotic was found.[10]

The results presented in the paper raise a number of questions that should be addressed in follow-up studies. For

[10] The comprehensive analysis of Slavic rhotics presented in Jaworski (2018) does not provide an answer to the question. Surprisingly enough, the Polish subjects whose speech was analysed in that study did not produce a sufficient number of vowel-adjacent trills to draw conclusions.

instance, it would be interesting to analyse samples of spontaneous speech to determine the extent to which the obstruentised rhotic of Polish is susceptible to phonetic change. An experiment could also be designed to establish whether or not the acoustic properties of the intrusive vocalic elements in obstruentised trills are dependent on the quality of the nearest phonological vowel. Finally, similar investigations of obstruentised rhotics in other languages that have them (Russian, Ukrainian), would undoubtedly provide more insight about the characteristics of these unusual sounds.

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APPENDIX

Target words used in the study

#_C	C_C	C_.C	C_#
rtęć	*drgać*	*Piotrka*	*Piotr*
rdest	*Brda*	*mędrca*	*wiatr*
rdza	*krtań*	*kontrwywiad*	*litr*
rtęciowy	*grdyka*	*kontrkandydat*	*metr*
rdzeń	*drganie*	*kontrdesant*	*kilometr*
rdzawy	*brnąć*	*mędrka*	*bóbr*
rdzenny	*krnąbrny*	*Jędrka*	*dóbr*
rdzewieć	*drgawki*	*Piotrkiem*	*tembr*
rtęciówka	*drgnąć*	*mędrcem*	*żubr*
rdestnica	*Brno*	*Pietrka*	*kadr*
rżenie	*trwonić*	*kontrkultura*	*manewr*
rwa	*drwal*	*kontrmanifestacja*	*cyfr*
rżysko	*drwić*	*kontrmarsz*	*Luwr*
rwetes	*krwisty*	*Piotrkowi*	*szyfr*
rżnąć	*brwi*	*mędrcowi*	*gofr*
rwać	*drżenie*	*mędrkowi*	*cyfr*
rwący	*drwina*	*Pietrkowi*	*Luwr*
rwany	*drwoga*	*kontrpropozycja*	*szyfr*
rwowy	*krwotok*	*kontrprojekt*	*manewr*
rwanie	*Drwęca*	*kontrrewolucja*	*gofr*

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