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**ON THE PHONETIC STRUCTURE OF THE
RHOtic TAP AND ITS PHONOLOGICAL
IMPLICATIONS**

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Introduction

The present dissertation focuses on the phonetic details of the composition of the rhotic tap [r], as spectrograms of words containing the sound show them. The goal is to elaborate on the structure of this sound, which is argued to be that of one constricted interval flanked by two vocalic elements, as maintained by Polish authors (Stolarski 2011, Dłuska 1983, among others, cited in Stolarski 2011), and to discuss some of the phonetic and phonological implications of said structure.

In Chapter 1, I review previous studies that look at the tap in several phonetic contexts, focusing on the interpretations given to the vocalic elements observed systematically next to the constricted interval associated with the sound. Since each study deals with one or two phonetic contexts, this chapter of the dissertation aims to get a complete picture of the structure of the sound by reviewing all the contexts. Crucial to the understanding of the role of the aforementioned vocoids are the data from Slavic languages, which are not discussed in the other studies. These data help complete the puzzle, since the tap occurs with no nuclear vowels in the vicinity (contexts #rC, CrC, Cr#). All contexts taken into consideration, the vocalic elements appear to be *part of* [r], and the sound always contains two vocoids, which is the conclusion I reach. This conclusion has implications for Lindau's (1985) parameters model for the "family" of rhotics, which I also discuss in this chapter. Also, the tap's vocalic character points to a similarity between this sound and liquids and nasals, which also appear vowel-like on a spectrogram.

Chapter 2 probes deeper into the structure of the rhotic tap with an experiment using Romanian words containing this sound in the phonetic environments that the language provides. The main goal of the experiment is to measure the quality of the vocalic elements of the tap in order to see how it varies function of the nuclear vowels near them and also if there are limits to this variation. The quality of the vocoids for each context is shown in detailed graphs, which suggest that there is indeed an area in which the vocalic elements of [r] tend to cluster. They are systematically mid-high, central-front.

To cover contexts where the tap is not close to any full vowel, Polish data are plotted on a graph for comparison with the Romanian data. With no vowels around, the vocoids of the tap exhibit even less variation and do not deviate as much to the front area of the vocalic space.

Another goal of the experiment is to test the hypothesis in Chapter 1 for context VrV, in which the vocalic elements of the tap would not be salient because of the full vowels right next to them, into which they “melt”. The formant changes in the VrV recorded nonsense sequences support the conclusion of the first chapter.

In Chapter 3, I touch on some phonological implications of the tap having the structure outlined in the previous two chapters. Specifically, the strong vocalic component of [ɾ] may be linked to its ability to exist and function as a syllabic consonant and behave phonologically as a vowel in some Slavic languages (which /l/ also does in Czech and Slovak). Also, the vocoids in the tap make us think of C(V)r(V)C sequences in different terms. The constriction and its place in a vocalic continuum, as well as the existence of these vocoids and their quality, provide insights into the perception of Slavic words by Romanians and phenomena like metathesis.

Chapter 1. Previous studies – putting together contexts to determine the structure of [r]

The tap, [r], is a sound belonging to the rich, heterogeneous, and difficult to describe class of rhotics. This chapter of my dissertation is dedicated to bringing together previous acoustic studies done on a variety of languages in which this sound is present in the inventory. These studies look at the rhotic tap in a multitude of phonetic contexts and I will show how each of these contexts provides an important piece of the puzzle that is the structure of [r]. I will then outline the conclusion that stems from this “bird’s eye” view on the tap and briefly elaborate on its (phonetic) implications. The structure that the spectrograms reveal has implications for the tap’s relationship to other rhotics, as well as to the other liquid consonant ([l]) and nasals.

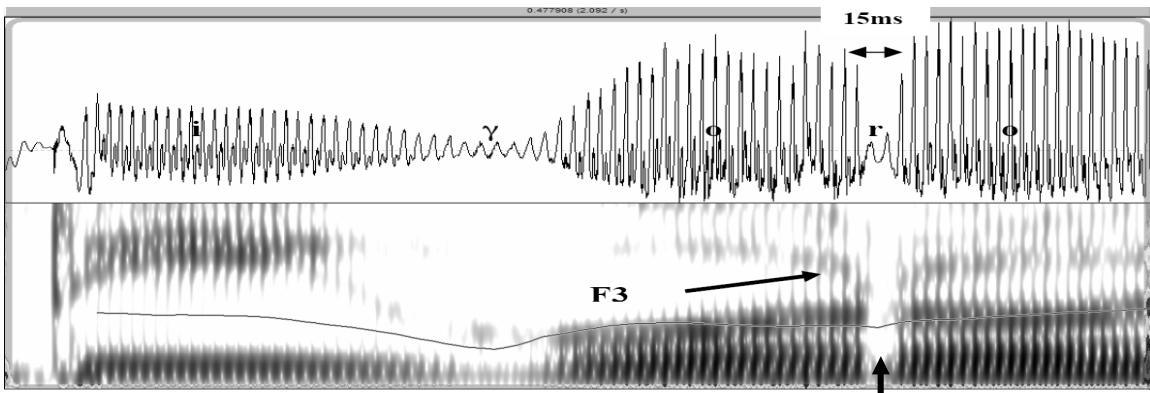
1.1 Evidence from languages where [r] is flanked by nuclear vowels

The tap involves, articulatorily speaking, “a fast, ballistic tongue tip raising movement and a single, short, apicoalveolar contact” (Recasens and Espinosa 2007: 1). They have, therefore, been characterized as very short alveolar stops, which would place the sound in the natural class of obstruents (Baltazani 2009).

1.1.1 Context VrV

Acoustically, the tap’s quick tongue gesture is characterized by a single closure with a mean duration of 20 ms (Ladefoged and Maddieson 1996, cited in Baltazani 2009). When the tap is in intervocalic position, this constriction is indeed conspicuous, constituting an interruption of acoustic energy in the vocalic “background”. In context VrV, therefore, the tap is seen on a spectrogram as a very brief constricted interval. An example is shown in Spectrogram 1 below:

A portion of the Greek word *yriyoro* ‘fast’, showing an intervocalic tap:



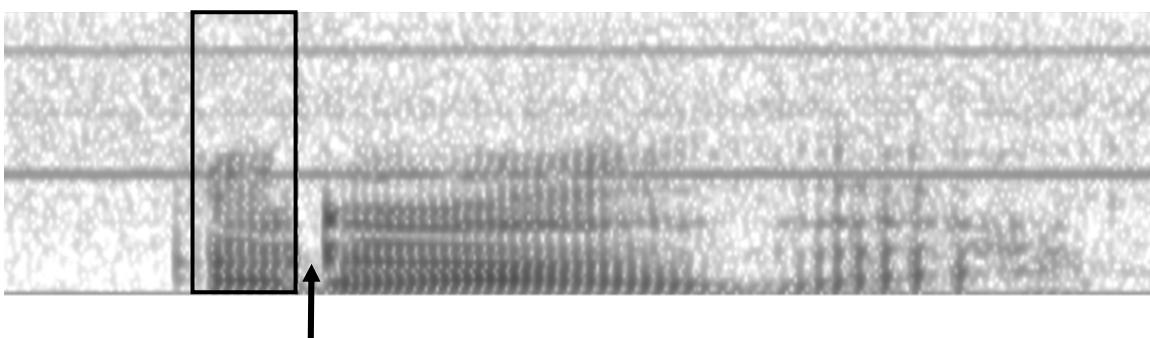
Spectrogram 1

(from Baltazani 2009)

1.1.2 Contexts #rV and Vr#

In context #rV the tap has a pause on its left side and a vowel on the right, while when the tap is in context Vr#, the vowel is on the left and the pause on the right. In these cases, studies report a brief vocalic element flanking the constriction on the side where it borders with a pause. This happens cross-linguistically (see Avram 1993 for Romanian; Vago and Gósy 2007 for Hungarian; Baltazani and Nicolaidis 2011a, b for Modern Greek). Examples are given in Spectrograms 2 and 3:

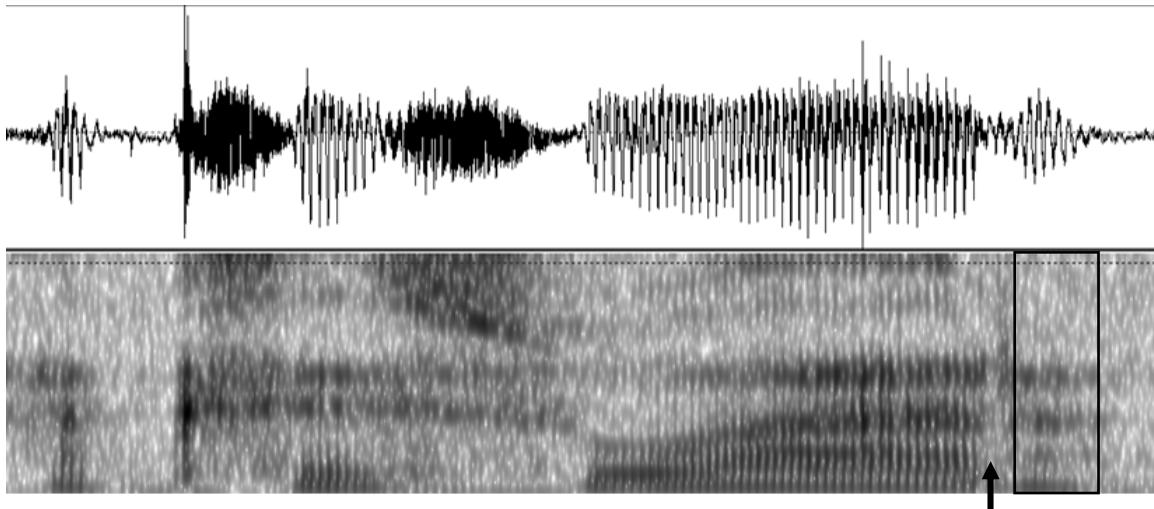
The Greek word *roða* ‘wheel’, showing a word-initial tap:



Spectrogram 2

(from Baltazani and Nicolaidis 2011a)

The Greek word *aksesouar* ‘accessory’, containing a word-final tap:



Spectrogram 3

(from Baltazani and Nicolaidis 2011b)

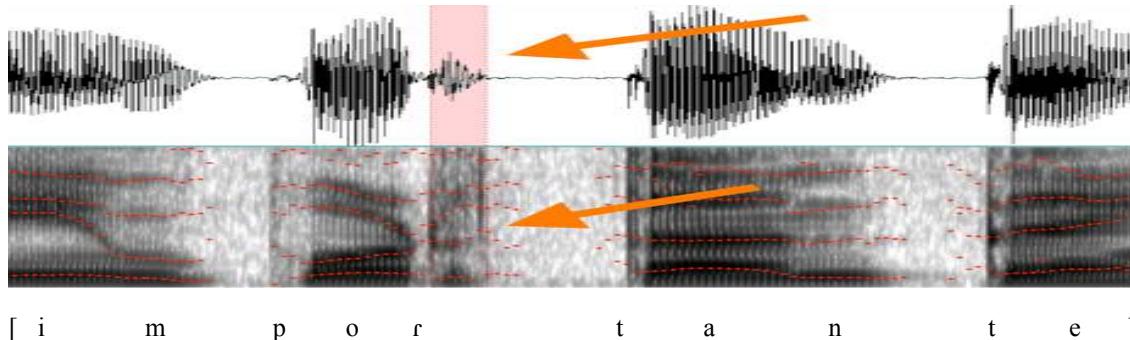
As may be observed from Spectrograms 2 and 3, the brief vocoid, and not a constriction, is what the word starts with if the context is #rV and what the word ends with for Vr#. When the phonetic realization of /r/ is a sound with one constricted interval, said constricted interval is not alone, but systematically accompanied by vocoids across languages.

1.1.3 Contexts (V)CrV and VrC(V)

When [r] occurs in consonant clusters like rC and Cr, where it has a consonant on one side and a vowel on the other, the same phenomenon described in 1.1.2 can be observed. Specifically, spectrograms show a vocoid intervening between the constricted interval of the rhotic and the other consonant in the cluster. Thus, cluster Cr displays the structure “consonant-vocoid-constriction-full vowel”, while rC has the reverse structure, meaning that the vocoid is on the right side of the constriction, where the other consonant in the cluster is (“full vowel-constriction-vocoid-consonant”). Again, this appears to hold across languages (see Baltazani 2009, Baltazani and Nicolaidis 2011b, Nicolaidis and Baltazani 2011 for Greek; Vago and Gósy 2007 for Hungarian; Ramírez 2006 among others for Spanish; Recasens and Espinosa 2007 for Catalan; Avram 1993 for Romanian).

The vocoid is easy to delimit if the C in the Cr cluster is a stop, as Spectrograms 5 and 6 show. The stop provides contrast with the vocoid, emphasizing it:

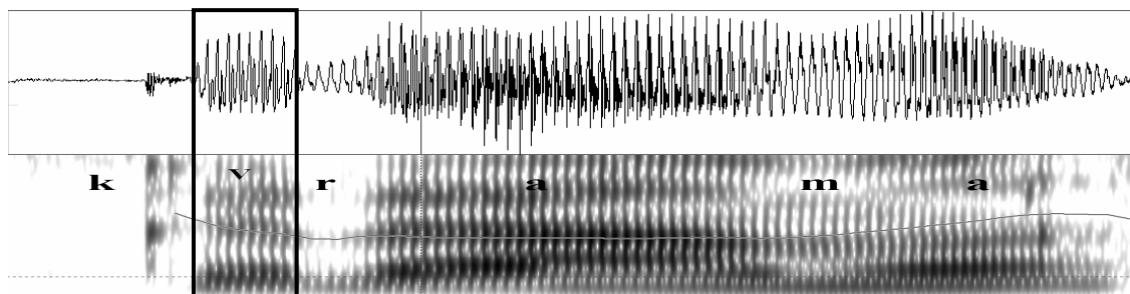
The Spanish word *importante* ‘important’ with a delimited vocoid in a rC cluster:



Spectrogram 4

(from Schmeiser 2009)

The Greek word *krama* ‘alloy’ – context Cr:



Spectrogram 5

(from Baltazani 2009)

1.1.4 Interpretation of the vocalic elements

The interpretation of the vocalic element observed in contexts #rV, Vr#, (V)CrV and VrC(V) has been extensively discussed in the literature. Traditionally, it is labeled epenthetic, (Ramírez 2006, among others), which would imply that it is not part of the tap and it should not appear. Other terms used in the literature to describe this vocoid are “*svarabhakti vowel*” and “*excrecent vowel*” (Schmeiser 2009, footnote 2).

Other authors (Avram 1993; Baltazani 2009) consider that the vocoid is part of another realization of the rhotic phoneme, which is different from the intervocalic tap.

Schmeiser (2009) prefers to use the label “vowel intrusion” for the phenomenon, based on the argument that while an epenthetic vowel is part of the syllabic make-up of the word, an intrusive vowel is not. Indeed, the vocalic element does not add another syllable to the word by breaking consonant clusters in (V)CrV or VrC(V).

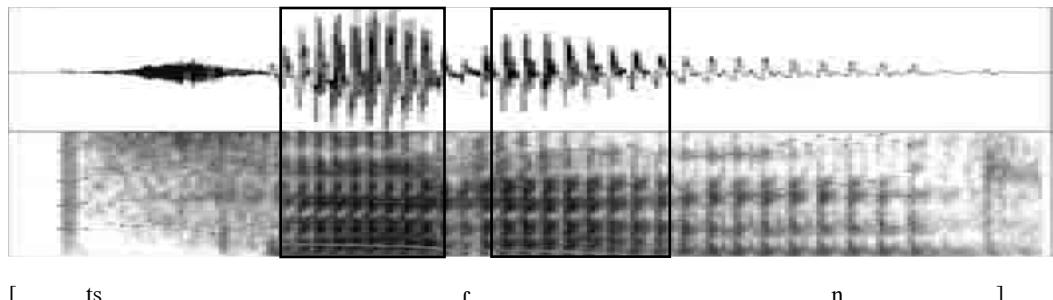
Bradley and Schmeiser (2003) offer a different interpretation of what they call the intrusive vowel. Adjacent articulatory gestures may exhibit various degrees of overlap and, within a syllable, consonantal gestures are superimposed on the vowel gesture. The vocalic element between the constriction of the tap and an adjacent consonant is simply the result of less than maximal overlap between the two consonantal gestures. This explanation is offered for Cr clusters, and could work for rC as well, but the vocoids would not be expected in #rV or Vr#, since in these cases we cannot speak of two adjacent consonants that would overlap to different degrees.

1.2 Evidence from Slavic: [r] with no nuclear vowels in its vicinity

The interpretations described above are based on studies done on rhotics in languages like Greek and Spanish, where /r/ is always flanked by at least one nuclear vowel. However, important information about the structure of the tap can be obtained from the Slavic languages, which have the rarer contexts #rC, CrC, Cr#. In these contexts, there are no full vowels flanking /r/, but only consonants and pauses.

Studies done on Serbo-Croatian, Slovak and Polish (Gudurić and Petrović 2005; Pavlik 2008; Stolarski 2011) report that /r/ is frequently realized as a tap in these languages. These studies also show that when [r] has no nuclear vowels in its vicinity, two vocalic elements appear flanking the constricted interval. The two vocoids appear regardless of whether /r/ is syllabic (Serbo-Croatian and Slovak) or non-syllabic (Polish). Examples of taps in each of the aforementioned context can be found in the Spectrograms 6-10 below:

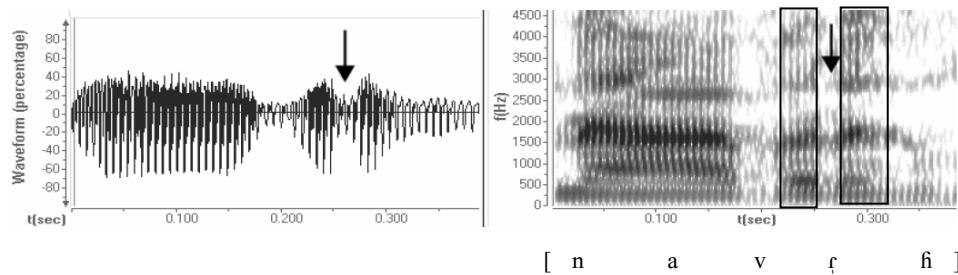
The Serbo-Croatian word *crn* ‘black’ – syllabic tap in CrC:



Spectrogram 6

(from Gudurić and Petrović 2005)

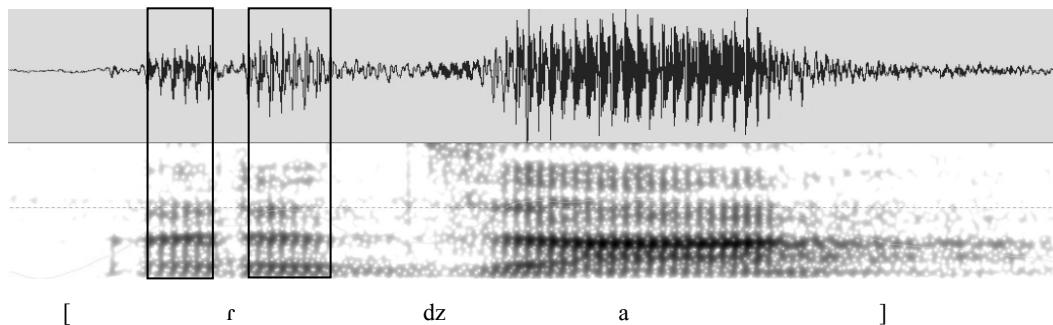
The Slovak word *navrh* ‘proposal’ – syllabic tap in CrC:



Spectrogram 7

(from Pavlik 2008)

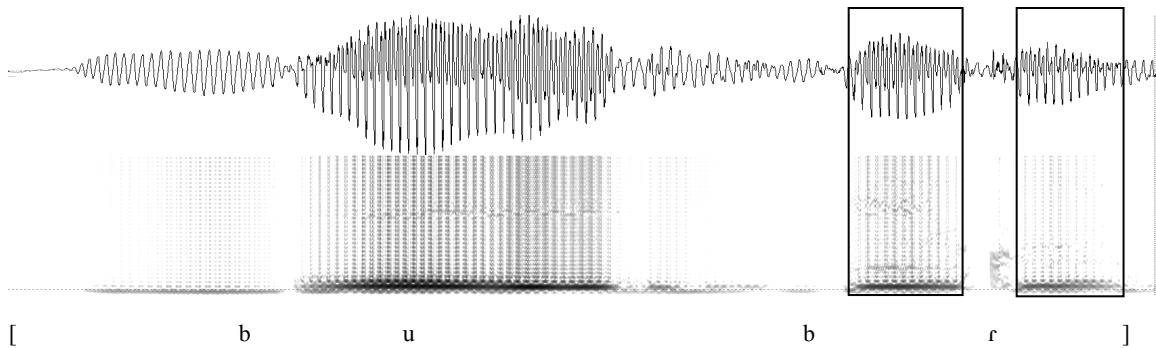
The Polish word *rdza* ‘rust’ – non-syllabic tap in #rC:



Spectrogram 8

(from Stolarski 2011)

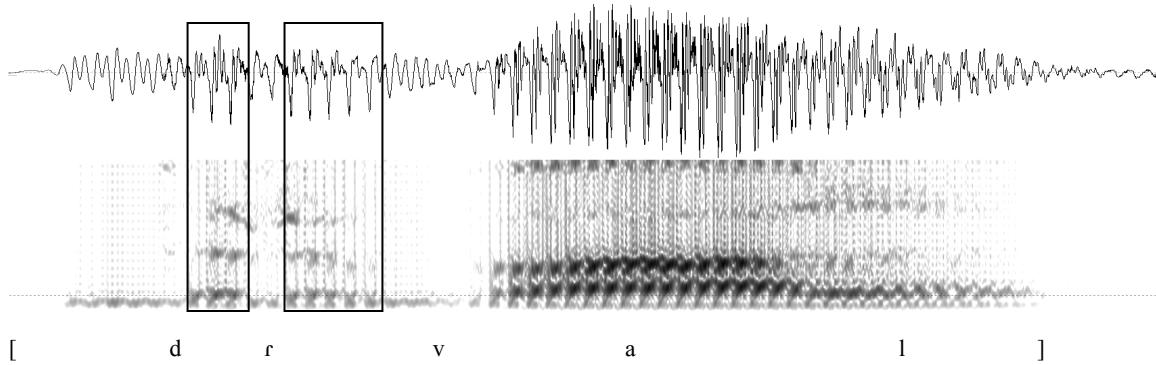
The Polish word *bóbr* ‘beaver’ – non-syllabic tap in Cr#



Spectrogram 9

(from recordings made by Ł. Stolarski)

The Polish word *drwal* ‘lumberjack’ – non-syllabic tap in CrC



Spectrogram 10

(from recordings made by Stolarski)

1.3 The overall picture: the structure of [r]

Summarizing all the contexts, we get the following “puzzle pieces”:

- context VrV: the only conspicuous element on spectrograms is a brief constriction;
- context #rV: one vocoid appears at the very beginning of the word, on the left side of the constricted interval, between it and the pause;
- context Vr#: one vocalic element is present at the end of the word, on the right side of the constriction, just before the pause;

- context (V)CrV: one vocoid appears on the left on the constricted interval, separating it from the adjacent consonant;
- context VrC(V): a vowel-like part is present on the right of the constriction, before the onset of the second consonant in the cluster;
- contexts #rC, CrC, Cr#: two vocoids flank the constricted interval, one on each side.

The generalization emerging from having considered all the contexts is that a salient vocalic element appears whenever, and on the side on which, the tap does not border with a full vowel. Thus, we see two vocoids in contexts where it borders only with pauses and/or consonants, one when it has a full vowel on one side and a consonant or pause on the other. No such vocoid is observable in the only context in which [r] is flanked on both sides by full vowels.

It may, therefore, be argued that the structure of the tap is the same in all contexts, and it is the one we observe in #rC, CrC and Cr#, namely “vocalic element – constricted interval – vocalic element” (in agreement with Stolarski 2011 and others cited therein). These three contexts render both vocoids salient on a spectrogram, since the adjacent consonant or pause provides the necessary contrast. When there is one vowel bordering the tap, the rhotic segment’s own vocoid on that side is not salient because it “melts” into the nuclear vowels and is overshadowed by it. Thus, #rV, Vr, CrV and VrC only show part of the picture, meaning one vocoid. In VrV there is no clearly delimited, salient vocoid observed on the spectrogram because, since there are full vowels on both sides of the tap, both vocoids of [r] are immediately continued by the adjacent full vowels. In section 2.2.3 I will attempt to provide evidence that the tap’s vocalic elements are detectable in context VrV as well.

The Figures 1 and 2 below show the structure of the tap and the way it becomes apparent in the various phonetic contexts:

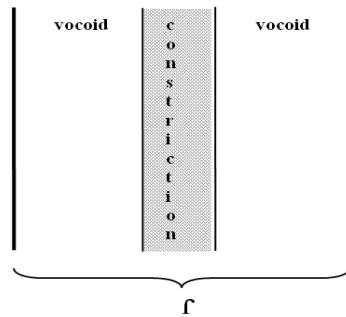
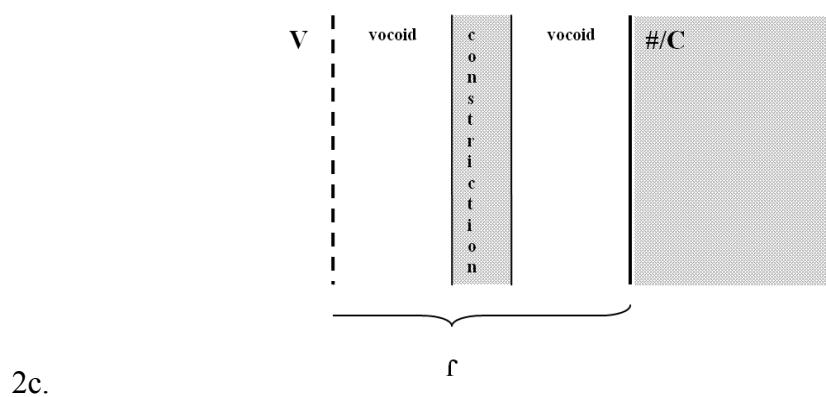
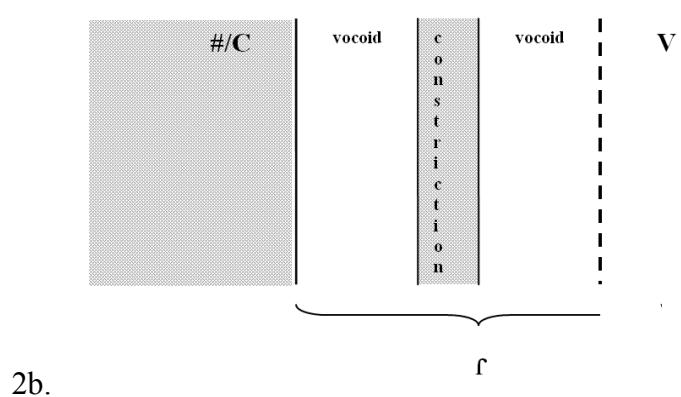
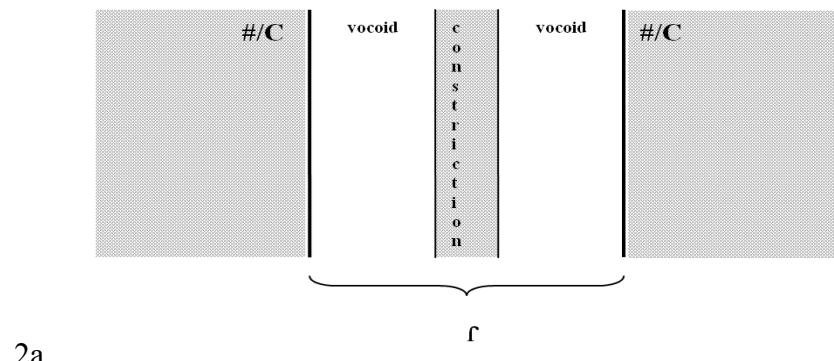


Figure 1: The structure of the tap



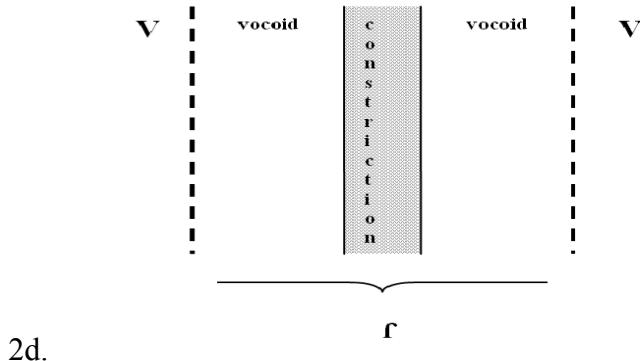
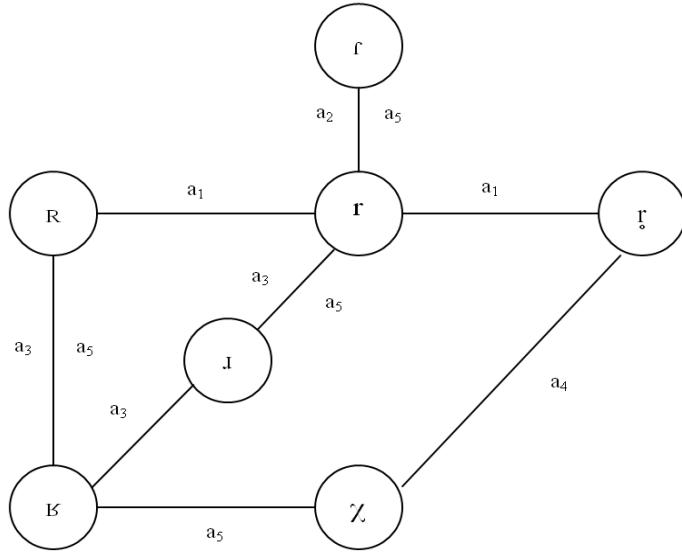


Figure 2: The tap in different phonetic contexts

Figure 2a shows a tap flanked only by pauses or other consonants, with the two salient vocalic elements. The vocoids are salient especially when any consonants flanking the tap are stops or fricatives, since their spectral characteristics are different from that of a vowel, thus providing the necessary contrast. Figure 2b is a representation of [r] in a context that contains one full vowel on the right side. The tap's first vocoid is delimited, while the second vocoid, the one on the right, is continued by the full vowel, so one cannot tell where the second vocalic element of the tap ends and the full vowel begins. Figure 2c shows the reverse of 2b: the full vowel is on the left, rendering the second vocoid of the tap salient. Finally, 2d represents context VrV. Since there are full vowels on both sides, neither vocoid of the tap is delimited.

1.4 Implications for Lindau's “family of resemblances” model

Lindau (1985) mentions that the lowered third formant that had been thought to be a common phonetic characteristic of the class of rhotics is actually not a property of all the members of the class. Lindau(1985: 166) claims that “there is no physical property that constitutes the essence of all rhotics”. Instead, the relation between members of the class of rhotics is more like that of resemblance within a family. Each member resembles one or several other members with regard to one or several properties, but there is no characteristic that all rhotics share. This idea is illustrated in Figure 3 below:



Parameter relations among r-sounds: a_1 = pulse pattern (trill); a_2 = closure duration; a_3 = presence of formants (sonorant); a_4 = presence of noise; a_5 = distribution of spectral energy (place of articulation)

Figure 3

(from Lindau 1985: 167)

According to Figure 3, trills and taps are similar in that they both contain closure(s) (parameter a_2) and place of articulation (parameter a_5). Parameter a_5 is common to approximants as well. Trills are like approximants with respect to parameter a_3 , the presence of formants, since trills are formed by alternating brief vowel-like parts and constrictions.

As a consequence of the claim that the tap includes vocalic elements, the figure above would have to be slightly adjusted. [r̄]'s vocoids give it the property denoted by parameter a_3 , which makes it similar to the other rhotics that have this property, including trills and approximants. This would “strengthen the relations” within the family of rhotics, as more links are added between family members. These additional links are represented by the dashed lines in Figure 4. In addition to resemblances that are not present in Figure 3, the tap and the trill will be linked by three parameters, counting a_3 .

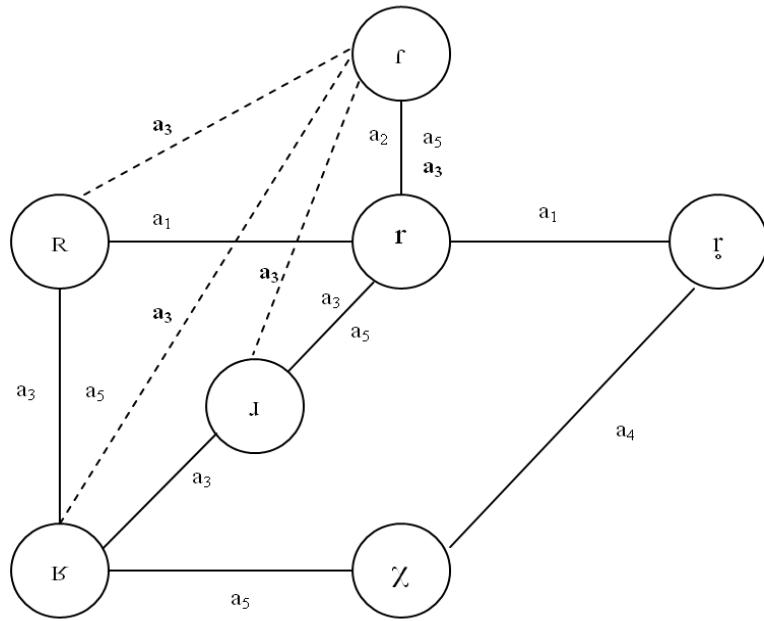
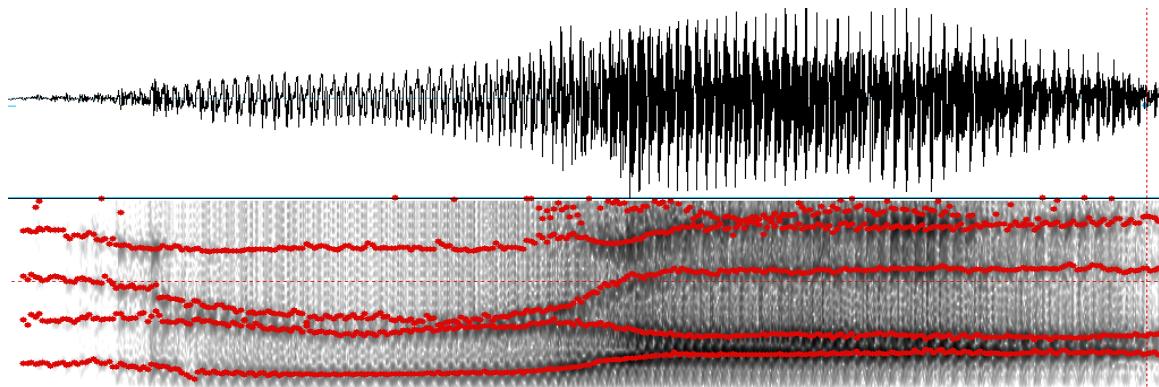


Figure 4

The rhotic for which a lowered F3 is indeed a defining characteristic is the (English) approximant, [ɹ]. Otherwise, the approximant has spectral characteristics that resemble that of a vowel. The tap's own vocalic elements concur with the articulatory similarity between the tap and the approximant. The difference between them is the degree of constriction in the vocal tract, which is full in [r], but partial in [ɹ].

Spectrogram of [ɹə]:



Spectrogram 11

(sound file from http://en.wikipedia.org/wiki/Alveolar_approximant)

Spectrogram 11 shows an approximant in context #rV. As can be observed, F3 starts somewhat high, then lowers and has a plateau stage, after which it rises again, drawing a curved shape. Spectrogram 1, of an intervocalic tap, shows a falling F3 towards the constriction of the tap. After the constriction the third formant rises again. Thus, a parallel might be drawn between the tap and the approximant, for which the falling F3 in Spectrogram 1 provides an indication.

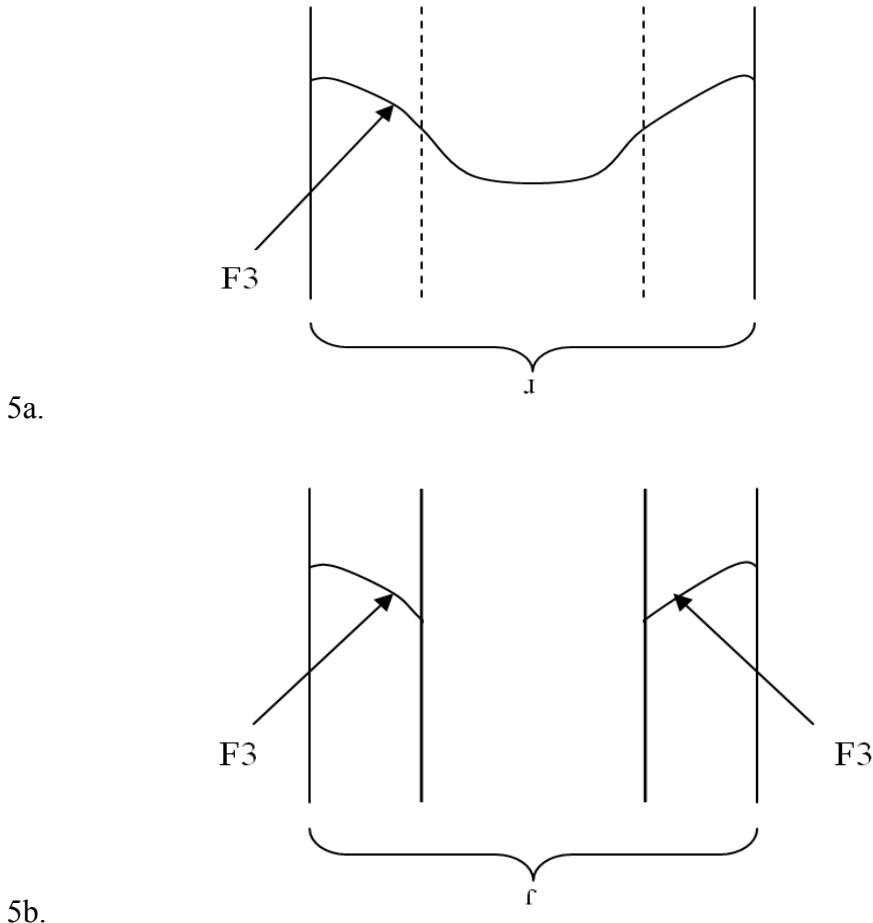


Figure 5: Possible parallel between taps and approximants

The F3 contour in Spectrogram 11 suggests that the approximant may have what would be the counterparts of the tap's vocoids. However, there is no complete constriction like in the case of the tap, so F3 continues into its low plateau phase, after which it rises again, for the counterpart of the second vocoid of the tap. The complete closure of the tap do not allow us to see an F3 in its center, but the parallel is suggested by F3 “falling into” the constriction in Spectrogram 1. Figure 5 illustrates this idea. Since

the tap has clearly delimited vocalic elements flanking a full closure, we can observe the boundaries of each of its components. The approximant has no total constriction to provide this contrast, so the “parts” of an approximant are not separate from each other.

This possible parallel between taps and approximants described above remains a topic for further research. It would have to be seen, for example, if the pattern F3 exhibits in Spectrogram 1 is systematic.

Another similarity is that between the tap and the trill, which is noticed by Lindau in her study (1985: 166), who suggests that “a trill can be regarded as a series of taps” and that “taps look very much like the closure phase of a trill”. The implication is that a trill is a series of taps separated by vocoids. However, if taps have vocalic elements, they share with trills both the vowel-like components and the constrictions. Stolarski (2011) mentions that, in a trill, each constricted interval is preceded and followed by a vocoid. A trill may indeed be regarded as a series of taps and the main difference between them is the number of constrictions, as shown in Figure 6.

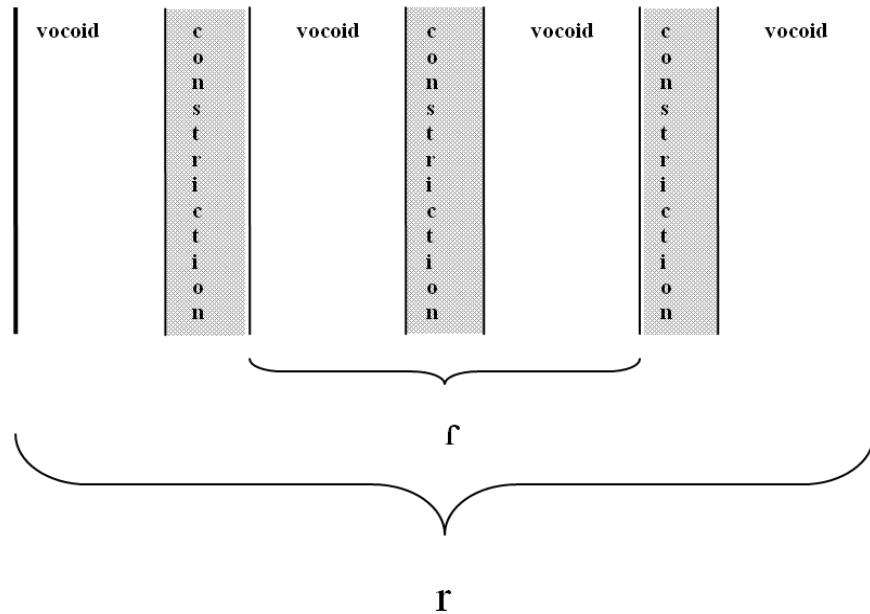
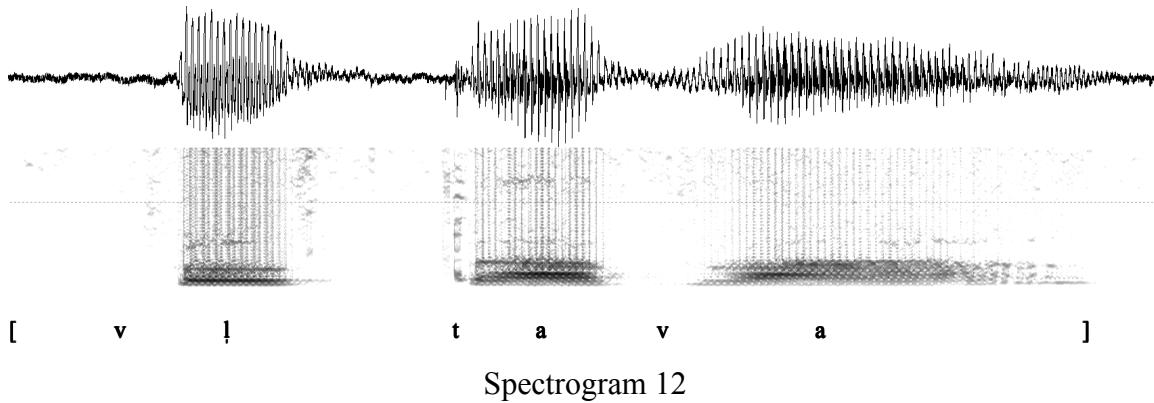


Figure 6: A trill is a series of taps

1.5 Comparison to laterals and nasals

The spectral characteristics of laterals are similar to that of vowels, with fainter higher formants (Ladefoged and Johnson 2010). Nasals are also not unlike vowels, with wider formant bands.

The Czech word Vltava (river name), showing a vowel-like syllabic lateral:



The tap's vocalic elements make it partly vocalic in nature as well, making it similar to the other sonorant consonants. The full constriction still makes it unlike laterals and nasals, but it is more similar to them than a simple constriction would be. How the tap's vocalic nature might shed light on its sonorant-like phonological behavior is discussed in Chapter 3.

Chapter 2. The current study on Romanian [r]

The first chapter of this paper looked at the general structure of the tap. There appear to be strong indications that its phonetic structure is “vocoid – constriction – vocoid”. This chapter focuses on other aspects of the phonetics of [r]. Specifically, the quality of the sound’s vocoids will be subject to investigation, after which the (relative) durations of the vocalic elements and the constricted intervals are briefly discussed. Finally, formant transitions are argued to indicate that the same structure of the tap is detectable in intervocalic context, despite the difficulty to separate the vocalic components of the tap from the full vowels in such cases.

2.1 Experiment purposes and setup

The Romanian language has one rhotic phoneme, which has been subject to acoustic analysis in Avram (1993). This analysis revealed that, in most cases, /r/ is realized as a tap, with the vocoids described in Chapter 1 appearing saliently where [r] does not border with a full vowel.

The current experiment investigates aspects of [r] in three phonetic contexts found in Romanian. The main purpose of the study is to thoroughly measure the quality of the vocalic elements, in order to get an accurate view of how much this quality may vary. Another key aim is to study the formant changes in context VrV, since, as will be argued, they provide insights into the structure [r] has in this context. A third purpose is to briefly elaborate on the duration of the constricted intervals and the vocoids.

For the purposes of the analysis, recordings of Romanian words in isolation were made. These words contain /r/ in phonetic contexts #rV, (V₁)CrV₁, V₁rC(V₁) and V₁rV₁. C is a stop consonant (/p, t, k, b, d, g/), and V is one of the seven monophthongal vowels of Romanian (/i, e, a, o, u, ə, ɨ/). As can be observed, in Romanian /r/ is always flanked by

at least one nuclear vowel, which means that each word offered at most one saliently delimited vocoid.

Clusters Cr and rC were flanked either by the same vowel, or by one vowel and one word-boundary (pause). This strategy was chosen in order to have the tap's vocoid in the immediate vicinity of only one vowel, so as not to have it influenced by two vowels of different qualities at the same time. If the vocoid is under the influence of vowels of only one quality, the vocalic part has the opportunity to maximally approach the quality of the nuclear vowel that *is* in its vicinity. For instance, in order to find out how much the vocoid can approach [u], preference was given to the inclusion of words containing the sequence /#Cru/, rather than /aCru/, where a word with /uCru/ could not be found. Table 1 below shows examples of words used in the experiment.

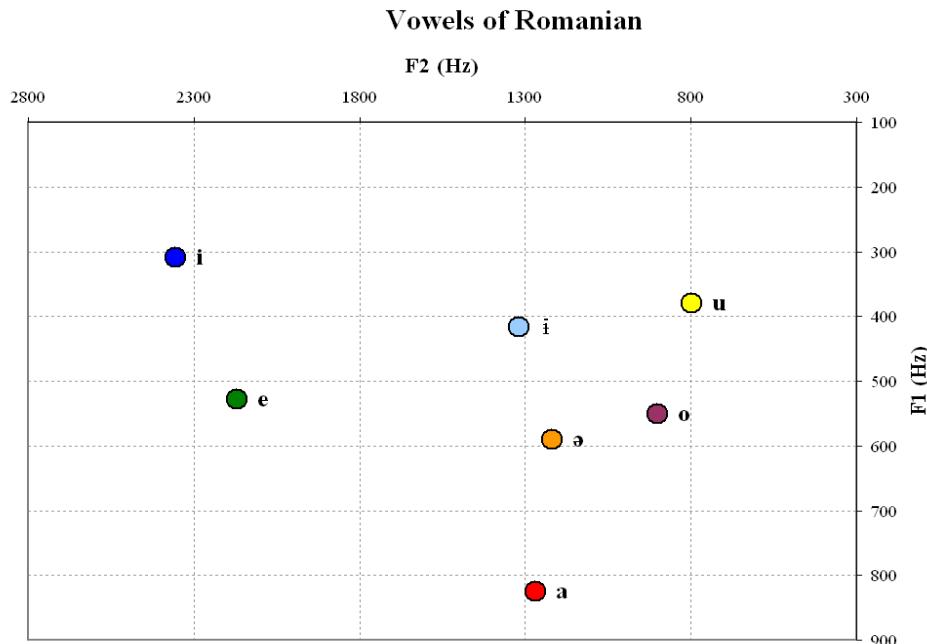
CONTEXT	EXAMPLE	GLOSS
#rV	/'radu/	proper name
	/re'dutʃere/	'reduction'
Cr	/abra'ziv/	'bracelet'
	/de'kret/	'decree'
	/bra'tsarə/	'bracelet'
	/grə'dinə/	'garden'
rC	/kor'don/	'belt'
	/porto'kalə/	'orange'
	/a'lerg/	'I run'
	/tirg/	'bazaar'
VrV	/pe'rete/	'wall'
	/'fərə/	'without'

Table 1: Examples of words used in the experiment

In total, a number of 112 words ($14 (\#rV) + 14 (VrV) + 14 \times 3 (Cr) + 14 \times 3 (rC)$) were used in the experiment. Five participants (four female, one male) read the words off PowerPoint slides appearing every four seconds and the recording session was repeated

three times for each speaker. This resulted in a corpus of 1680 words that were subject to acoustic analysis with the software PRAAT (Boersma and Weenink 2011).

In addition to the words described above, speakers were asked to utter sustained tokens of the seven vowels of Romanian, as well as nonsense V₁rV₁ sequences. The vowel tokens were elicited in order to plot the vowel space using the average formant values of vowels uttered by the same five speakers (shown in Graph 1 below). The nonsense sequences were recorded for the study of the formant transitions towards the constricted interval.

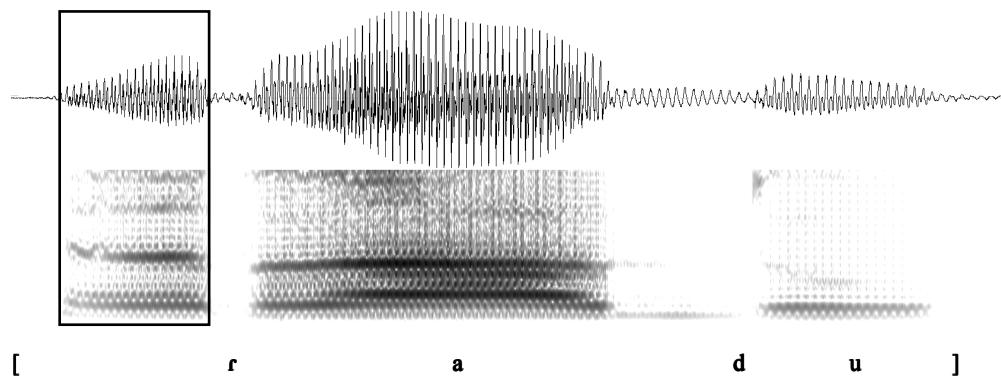


Graph 1

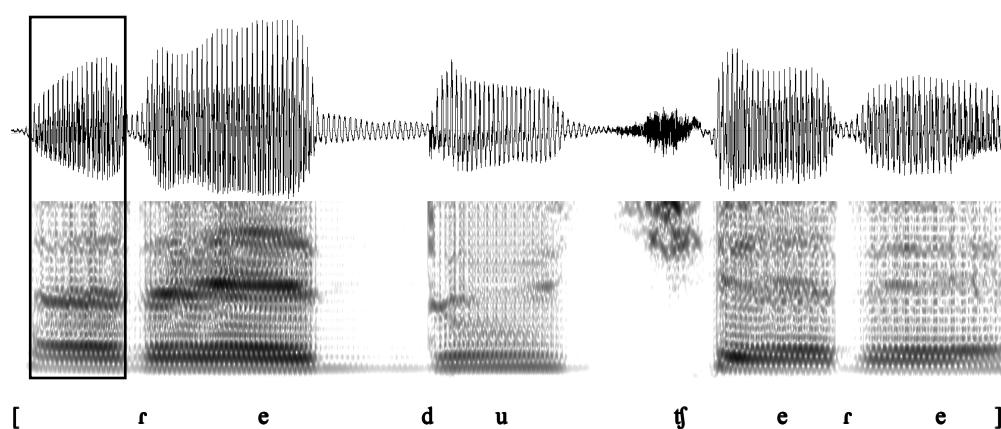
2.2 Results

The acoustic analysis showed that the realization of the rhotic phoneme was [r] (i.e. a constriction with the salient vocalic element) in 87,4% of all tokens (1469 out of 1680). /r/ was a tap in 86,6% of tokens for contexts #rV, Cr and Cr considered together (1274 out of 1470), which means that a total 1274 vocalic elements were taken into account when measuring the quality of the vocoids. Other realizations of /r/ included trills

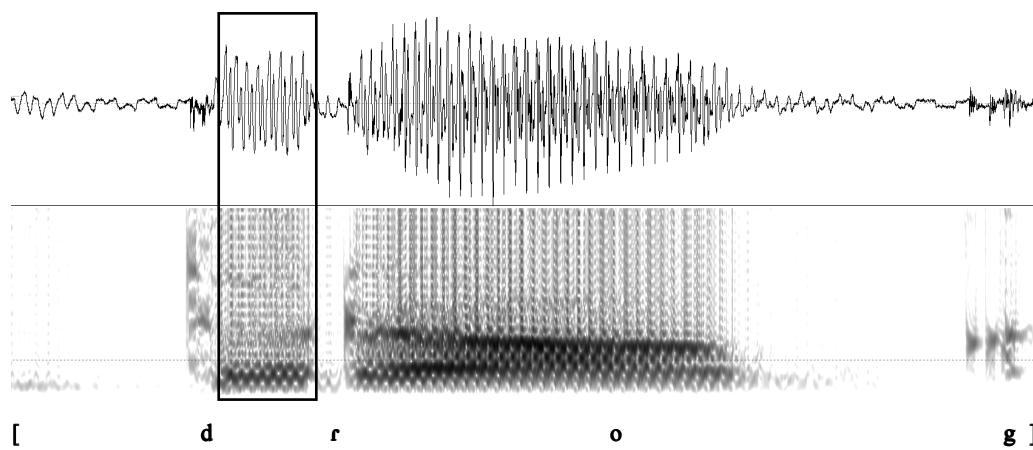
and approximants, but these were not included in the analysis. Spectrograms 13-18 below show samples of (vocalic elements of) taps, as they appeared in #rV, Cr and rC.



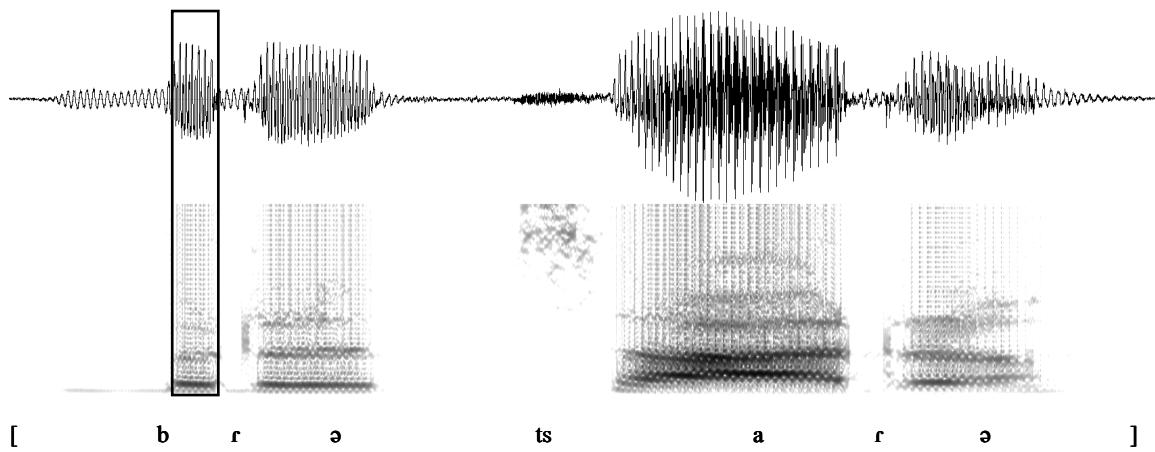
Spectrogram 13: The word /'radu/ (proper name) – context #rV



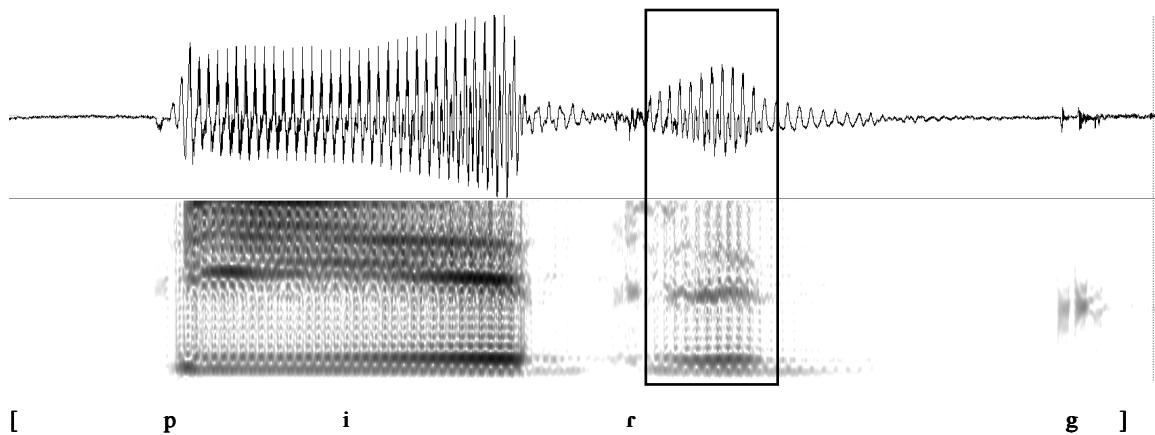
Spectrogram 14: The word /re'dutſere/ 'reduction' – context #rV



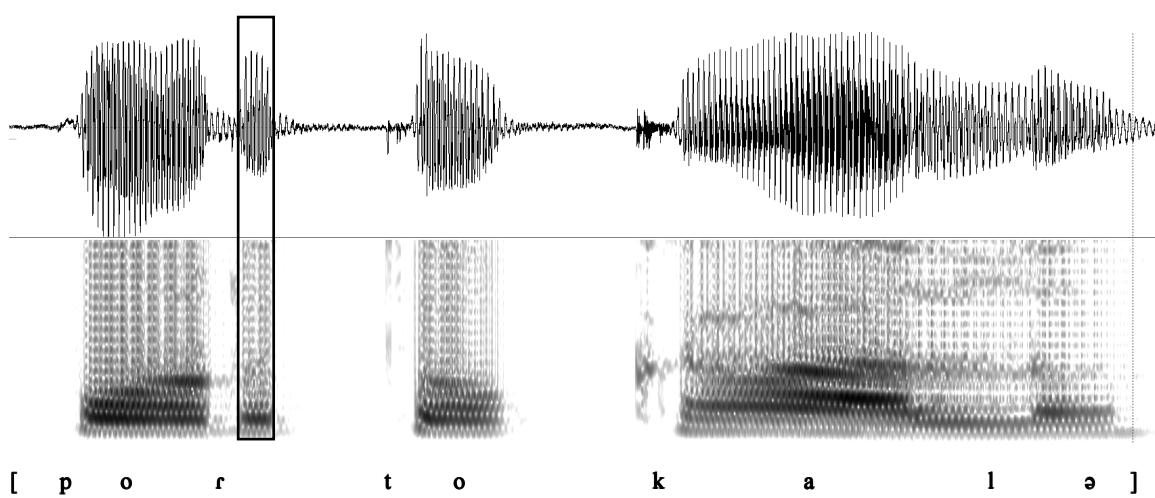
Spectrogram 15: The word /drog/ 'drug' – context Cr



Spectrogram 16: The word /brə'tsarə/ 'bracelet' – context Cr



Spectrogram 17: The word /pirg/ 'defense tower' – context rC



Spectrogram 18: The word /porto'kalə/ 'orange' – context rC

2.2.1 Quality of the vocalic elements

2.2.1.1 Previous findings

The vocalic elements of the tap have been reported to have qualities similar to that of the vowels [ə] and [i] (Avram 1993; Ramírez 2006; Vago and Gósy 2007; Stolarski 2011), placing them in the central area of the vowel space. However, studies also show the vocoids to be similar to the nuclear vowels in their vicinity, albeit more central (Quilis 1993 cited in Schmeiser 2009; Baltazani 2009, among others).

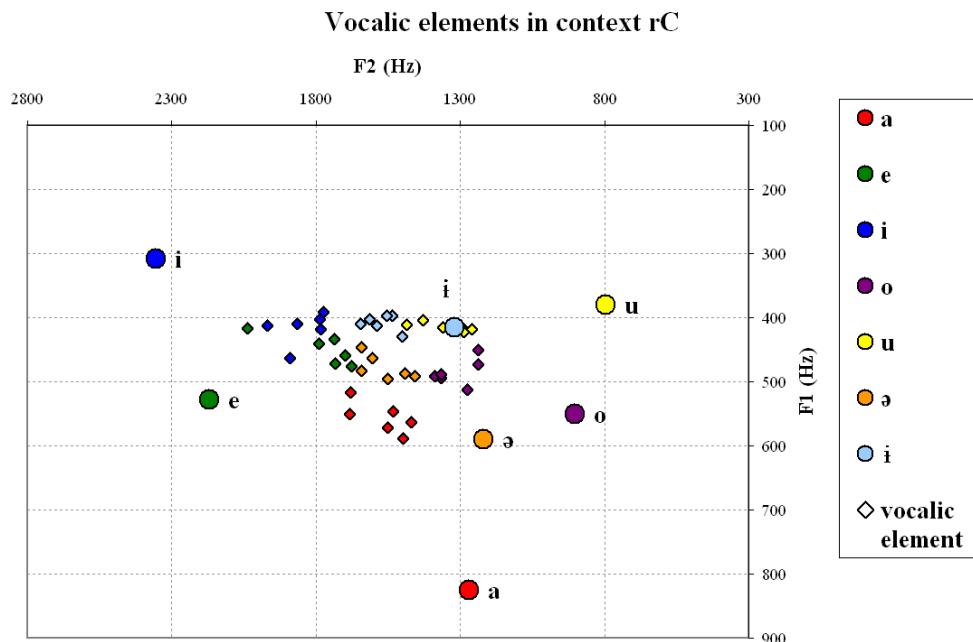
Schmeiser (2009) finds the vocoids in rC to be less affected by the full vowel than Quilis (1993) reports for Cr, while Baltazani (2009) found that rC is the context in which the vocalic elements are similar to the full vowel flanking the cluster, while the vocoids in Cr are more central. According to the description in Baltazani (2009) for rC, the vocoids corresponding to the full vowel [i] are lower and more back, those for [e] are more back than [e], with [o] and [u] they are more front and when around [a] they are higher than the full vowel. Baltazani and Nicolaïdis (2011b) mention that in #rV vocoids are centralized. The overall picture presents vocoids that are inside the space delimited by the nuclear vowels. They may be similar to the full vowels or more central, according to their phonetic context.

2.2.1.2 Current findings: narrowing down the possible space of variation

The studies mentioned above mention describe the vocalic elements in languages like Modern Greek or Spanish, which do not include mid or high central vowels in their inventories, but only /i, e, a, o, u/. It would, therefore, be interesting to see what happens to the quality of the tap's vocoids when the full vowels flanking the rhotic are themselves central. Perhaps the data from Romanian, a language which has the central vowels /ɨ/ and /ə/, might help narrow down the possible space of variation of the vocalic elements of the tap. It is, thus, the main aim of the current study to provide a detailed description of the quality of these vowel-like parts in each of the contexts Cr, rC and #rV. The following

subsections present the average quality of the vocoids in each word, as compared to the average quality of the Romanian vowels, uttered by the same participants. These are plotted on graphs, in which the color of the vocalic elements (small size) matches the color of the full vowel in its vicinity (large size). For example, green squares show the vocalic elements in context #re, green triangles correspond to words containing the sequences /eCre/ or /#Cre/, while green diamonds represent the vocalic parts in /erCe/ and /erC#/ words.

2.2.1.2.1 Context rC

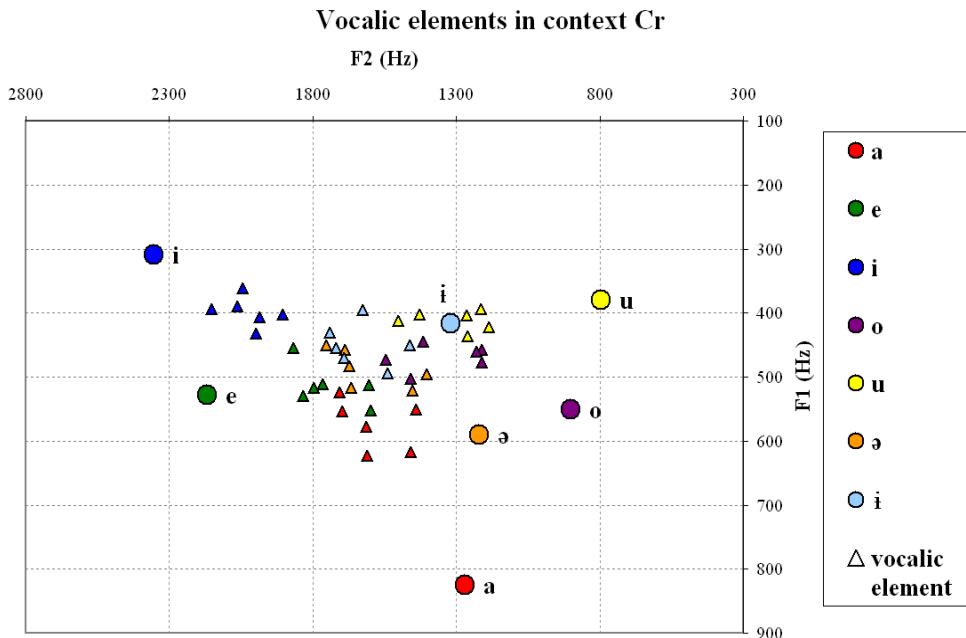


Graph 2

Graph 2 above shows the vocoid average quality for all words containing context $V_1rC(V_1)$. As can be seen, the vocalic elements in /arC(a)/ are more front and considerably higher than [a], reaching the mid area. Those in /irC(i)/ are more back and slightly lower, while when the vowel in the vicinity of the cluster is [e], they are as back as those for [i], but slightly higher. The full vowels [o] and [u] surrounding the tap make the vocoids considerably more front than [o] and [u] themselves. In this case, the vocalic elements are similar to [i], while words containing [ə] have vocoids that are a little more

front than the high-central vowel. [ə] keeps the vocoids equally front, and somewhat higher than [ə] itself. All in all, even though the vocoids show a certain amount of variability, they exhibit a strong tendency to cluster in the mid-high, central-to-front area of the vowel space. There are clear limits to how much the vocoids can vary, which is easy to deduce from Graph 2. The difference in height between [a] and its corresponding vocoids is greater than that between [e] and its vocalic elements. Likewise, the vocoids for [o], [u], [ə] and [i] are quite similar with respect to backness. The fact that the tap's vocalic elements for [ə] and [i] are only slightly more front than those for [o] and [u] is a strong indication that there is a limit beyond which the vocoid cannot be more back.

2.2.1.2.2 Context Cr



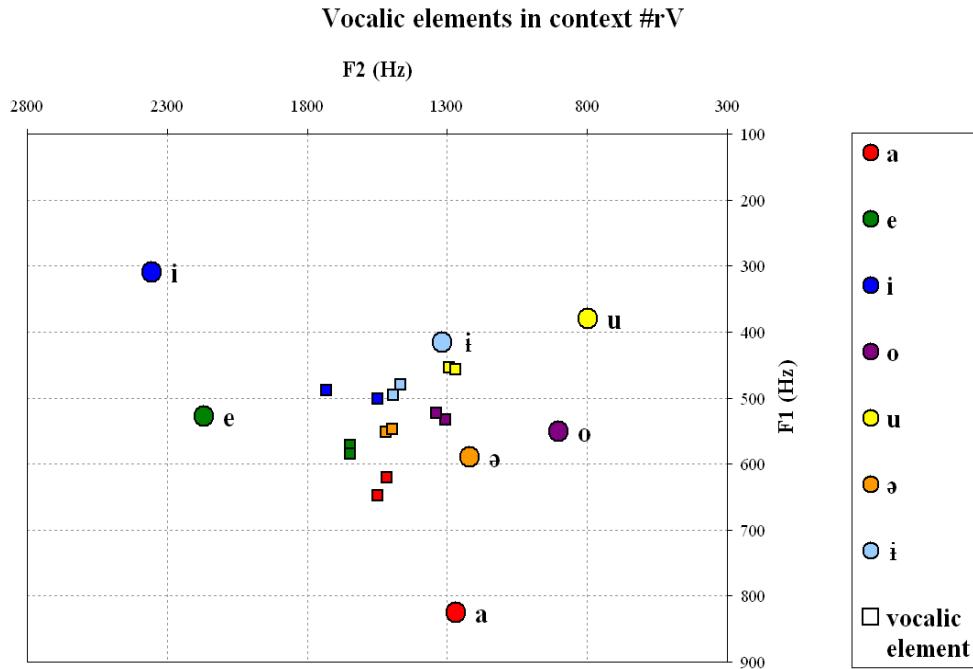
Graph 3

In Graph 3 the vocoids of the words containing (V₁)CrV₁ sequences are plotted. As in rC, the vocoids tend to approach the quality of the nuclear vowel(s) surrounding the tap. The vocoids are mid when the full vowel surrounding [r] is [a], though they are considerably higher than [a], and slightly more front, just like in context rC. In the [o] and

[u] words the vocalic elements are more front, overlapping with [i]. It appears that, all in all, contexts rC and Cr give relatively similar vocoids, which are mid-high and central-to-front. A difference worth mentioning concerns the [i] vocoids. They are higher and considerably more front than in rC, exhibiting a high degree of similarity to the vowel [i]. The vocoids surrounded by [e] are also more front than in context rC.

All in all, context Cr allows the vocoids to vary more than rC, an observation which is in agreement with Schmeiser (2009). They cover a slightly broader area of the vowel space, but still remain mid-high and central-to-front.

2.2.1.2.3 Context #rV



Graph 4

Unlike Cr, context #rV appears to force the vocoids to cluster together in the mid-central area of the vowel space. The vocalic elements in the [i] words are much lower and more back than in Cr and even rC. Those for [e] are also more back, while in the [o] and [u] words the expected difference in backness is maintained. #rV is the context that

allows the [a] vocoids to approach [a] the most, though an F1 around 600-650 Hz ensures that the vocalic elements remains mid rather than low.

Considering all three contexts described above, a general conclusion is that the vocalic elements tend to approach the quality of the vowels they are surrounded by, but this variation appears to have certain limits. They remain **mid-high, central-to-front**, and consistently stay away from [a], [o], and [u]. Words with /r/ surrounded by central full vowels help identify the space of the vocoids. The graphs show that having these vowels around pushes the vocalic elements of the tap to be slightly more front than [ə] and [i] themselves, indicating that the limit where the vocoids cannot increase in backness anymore is near. Indeed, though the vocalic parts in the [o] and [u] words surpass the full vowels [ə] and [i] in backness, the distance in backness between [o] and [u] and the corresponding vocoids is greater than that between [ə] and [i] and their own vocoids.

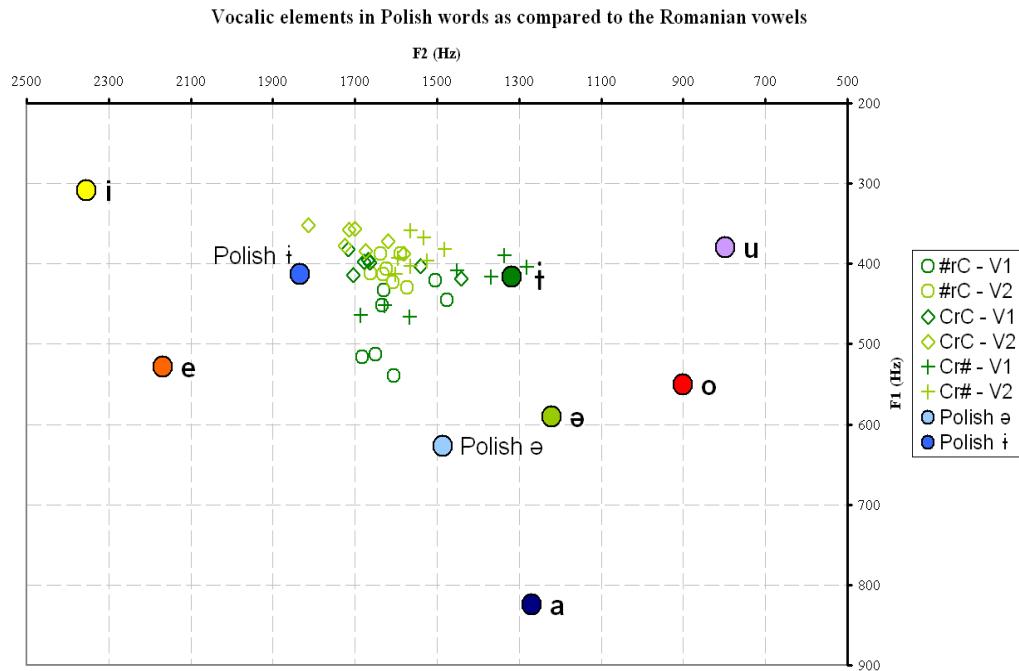
An interesting point is that the vocoids tend to cluster in the area of the Romanian [i], and in many cases there is even overlap. It appears to be the case that the vocoids of the tap are, on average, very similar to the high-central vowel. Another vowel very close to the vocoids of [r] is [ə], though the Romanian [ə] is more back than the classical 500-1500 Hz [ə]. Were this vowel slightly more front, it would overlap with the tap's vocalic elements.

There is also a certain degree of variation according to context: Cr allows the vocoids to vary the most, while #rV seems to be the context that keeps them together in a tight area. However, despite the slight context-dependent variation, the generalization made above holds, in that the vocalic elements have their own area of the vowel space and their quality seems to never surpass certain thresholds.

2.2.1.2.4 Contexts #rC, CrC and Cr#: comparison with Polish data

Unfortunately, the Romanian language only has contexts in which /r/ is flanked by at least one full vowel. It does not have the contexts #rC, CrC, Cr#, available in Slavic languages and mentioned in Chapter 1.

In order to draw a picture as complete and detailed as possible of the quality of the tap's vocoids, contexts #rC, CrC, Cr# should be taken into account, which is what this subsection aims to do. Graph 5 plots the vocalic elements in the aforementioned contexts in Polish words (data from the tables in Stolarski 2011: 18-20¹). They are compared to the vowels of Romanian from the current experiment, as well as the Polish [i] and [ə] (data from Stolarski 2011).



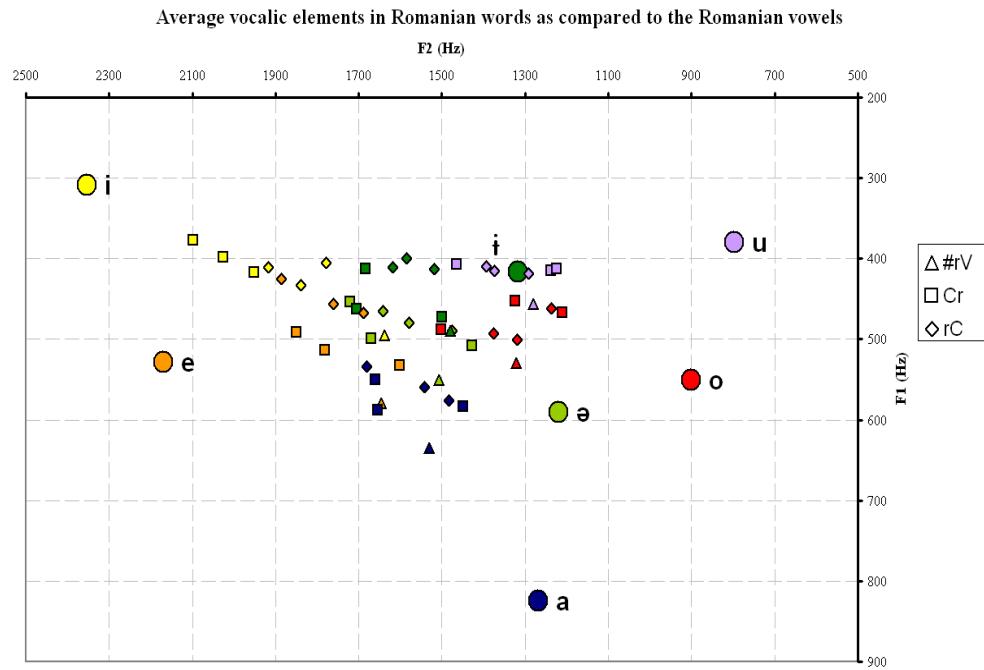
Graph 5

As mentioned above, Polish #rC, CrC and Cr# words are plotted in Graph 5. Since there is no nuclear vowel in the vicinity of the rhotic phoneme, both vocalic elements are salient, which means two vocoids per word. The first vocoid in each word is represented by dark green, while the vocalic elements on the right of constricted intervals have the light green color. Dark green and light green are also used to represent the Romanian [i] and [ə] respectively, while dark blue and light blue are used for the Polish equivalents.

¹ The averages given in these tables for the vocalic elements in /r/ in Polish words took into account cases of trilling, in which case the values for the first and second vocoids were given; however, this is not expected to significantly influence the averages.

The graph shows that the Polish vowels are similar in height to the Romanian counterparts, but they are considerably more front, and the Polish vocoids seem to fit in the space between the Romanian and Polish central vowels from the point of view of backness. The vocoids show similarity to the Romanian [i], and exhibit a strong tendency to cluster in the mid-high, central area.

It would be interesting to compare the vocoids in taps flanked by full vowels to those in taps that are not affected by nuclear vowels. For this purpose, Graph 6 shows the average quality of the vocoids in Romanian words in all three contexts, which are taken separately in Graphs 2-4. For clusters Cr and rC, vocalic elements from words with C at the same place of articulation (e.g. /k/ and /g/) were averaged together. As for context #rV, the vocoids of the two words recorded for each of the Romanian vowels are shown as one (triangle). Again, the vocoids represented by each square, triangle and diamond are of the same color as the full vowel flanking the tap they are part of.



Graph 6

If we compare the Polish vocoids to those in Graph 6, it would appear that not having any nuclear vowels around (the case of the Polish #rC, CrC, Cr# vocoids) keeps

the vocalic parts of [r] clustered together in a tighter area. The Romanian vocalic elements are under the influence of the full vowels flanking /r/, so the tendency of the vocoids to vary and approach the quality of said full vowel is stronger. For example, the Romanian vocoids can be considerably front, while the inter-consonantal contexts (Polish) keep them central. The Polish vocoids also tend to be, on average, higher than the vocalic elements with nuclear vowels in their immediate vicinity.

Overall, the tap's vocoids (both in Romanian and Polish words) cluster in a specific area of the vowel space. They are **mid-high and central** (similar to [i]), with a tendency to be front if next to a front vowel.

2.2.2 Remarks on the duration of the vocalic elements and the constricted intervals

Taking the average durations of the constrictions and the vocalic elements into account, current measurements are in agreement with previous studies, in that the average duration of the constricted interval is smaller than the duration of the vocalic element.

Average duration (ms)	#rV	rC	Cr	VrV
Vocalic element	49,0	31,0	30,3	
Constriction	27,3	26,9	24,0	28,8

Table 2: Average durations of constriction and vocalic elements in Romanian words

As Table 2 shows, the longest average vocoid is found in word-initial position and it is considerably longer (about 20 ms) than the vocoids in other contexts, which is in agreement with what is reported by Baltazani and Nicolaïdis (2011a, b). The vocoids in Cr and rC have about the same duration, while the shortest constricted interval is in context Cr. The average duration of the constricted interval is similar across contexts.

However, the constrictions are not always shorter than the vocoids. The measurements show variation, in that sometimes the constriction is long and the vocoid is

short, while other times the constricted interval is short and the vocoid long. Table 3 gives detailed measurements of the average durations for the vocoids and constrictions, as well as the difference between them for all contexts. The table contains these data for three speakers, taking into account words in which the consonant in Cr and rC clusters is either /t/ or /d/. Table 4 shows the range within which the constrictions, the vocoids, and the difference between constriction and vocoid in the same word may vary. The speakers and the words considered are the same in Tables 3 and 4.

Speaker	Context	Average (ms)			
		V	C	Difference when	
				V>C	V<C
SR	rC	31	28	12	8
	Cr	28	27	8	8
	#rV	32	29	12	10
	VrV		28		
SP	rC	25	26	6	8
	Cr	26	23	11	11
	#rV	31	29	14	9
	VrV		32		
AG	rC	35	25	15	6
	Cr	30	22	10	8
	#rV	55	24	39	9
	VrV		27		

Table 3: Average durations of the vocoids and the constrictions and the average difference between them

Table 3 shows that there is inter-speaker variation. For example, AG stands out for very long vocoids in context #rV, as well as for the big difference between vocoid and constricted interval in the same context when the vocalic element is longer than the constriction.

Speaker	Context	Range (ms)			
		V	C	Difference when	
				V>C	V<C
SR	rC	14~57	16~54	1~30	1~17
	Cr	15~43	17~57	1~24	1~32
	#rV	16~60	17~58	1~40	1~20
	VrV		19~46		
SP	rC	17~39	16~56	1~16	1~24
	Cr	15~49	13~43	1~31	3~21
	#rV	19~66	16~56	3~32	2~29
	VrV		23~45		
AG	rC	22~76	21~39	2~47	1~17
	Cr	19~54	17~43	1~32	4~24
	#rV	28~85	17~37	9~62	9
	VrV		18~46		

Table 4: The range of durations for vocoids, constrictions, and the difference between them

As Table 4 shows, there is intra-speaker variation as well. Indeed, the duration of the constrictions and the vocoids show vary even between token to token of the same word, uttered by the same speaker, since the recording session was repeated three times for each of the participants. Both constricted intervals and vocoids may be short (less than 20 ms), as well as relatively long (more than 40 ms). Within the same word, the vocoid and the constriction may have equal duration or the difference between their durations may be very small. The difference between them may also be considerable (even over 40 ms).

The current experiment did not control for factors like speech rate and stress placement, which could influence these durations. Therefore, more investigation is needed in order to elaborate further on this topic. Another issue for further research is the following: how long can the vocoids be before speakers perceive them as full vowels? And then, what vowel would they perceive them as? Would there be differences among native speakers of different languages?

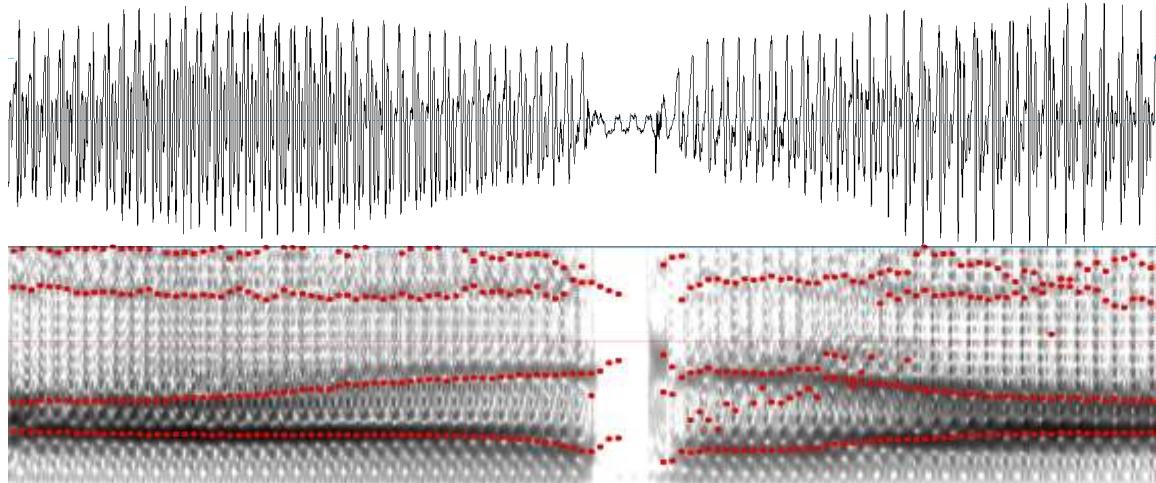
2.2.3 The same structure in VrV?

This subsection looks at the formant changes in the recorded nonsense VrV² sequences, in order to determine if the “vocalic element – constriction – vocalic element” structure of [r] is detectable in context VrV.

When the tap is in context VrV, abrupt formant changes have been reported in the first vowel, towards the constriction (Baltazani and Nicolaidis 2011a, b). If [r] has vocoids of its own, these changes would be expected to be systematic. Specifically, the formants should change, in the immediate vicinity of the constriction, towards the configuration of a vowel in the mid-high, central area of the vowel space. As seen in the previous subsections, this is the area where the vocoids of the tap cluster.

Do formants systematically aim, when nearing the constriction, towards a structure similar to that of the salient vocoids in other contexts? This would indeed appear to be the case, as the following spectrograms of nonsense V₁rV₁ show.

The nonsense sequence [ara]:

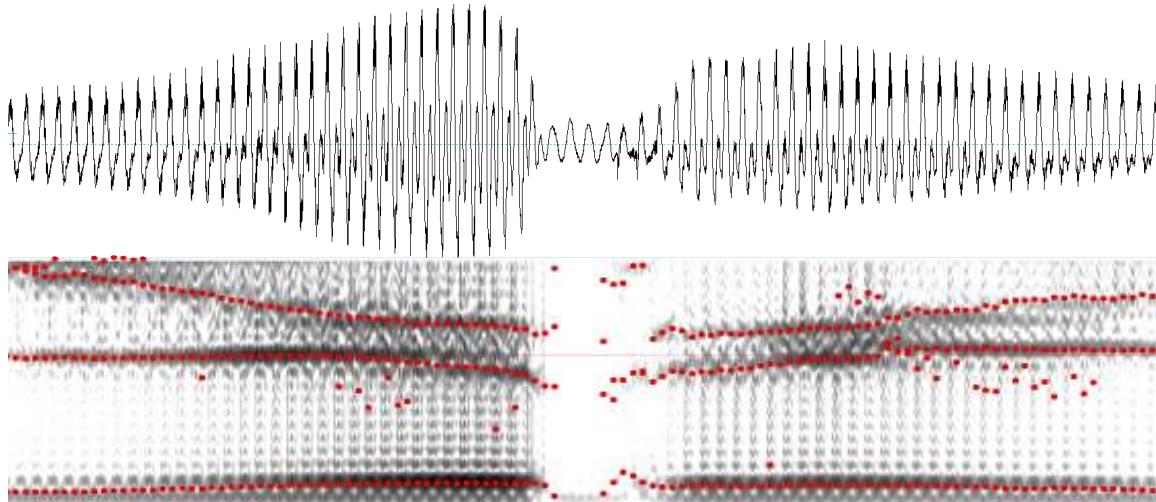


Spectrogram 19

² The words /a'ra/ and /'ere/ are words of Romanian, meaning ‘to plough’ (imperf.) and ‘eras’ respectively. In the current experiment [ara] and [ere] were presented to the speakers as nonsense sequences, on par with the others. The participants were not told to stress one or the other of the syllables.

[a] is a vowel that has a high F1 and a low F2. As can be seen in Spectrogram 19, in the sequence [ara], F1 decreases and F2 increases near the constriction. This makes the target configuration higher and more front than [a].

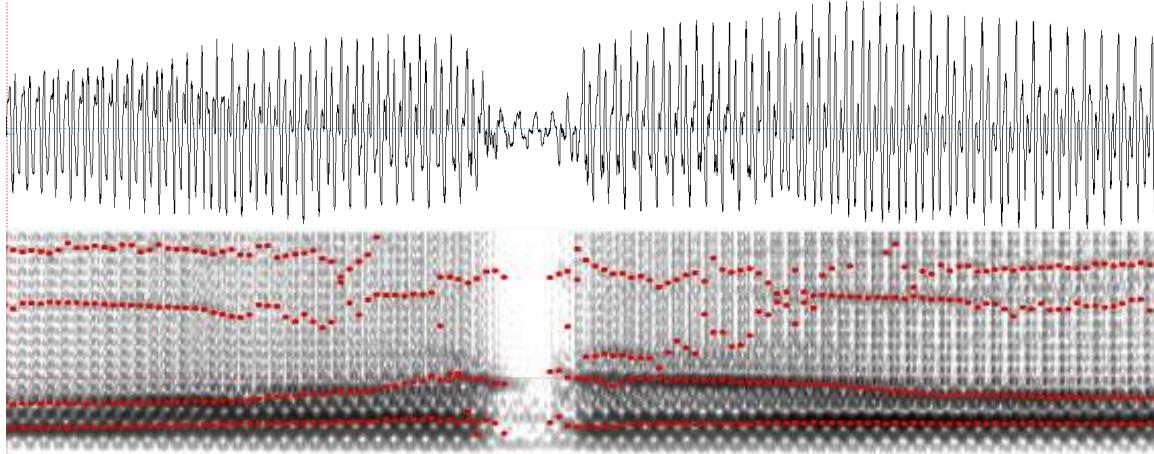
The nonsense sequence [iri]:



Spectrogram 20

The vowel [i] has the reverse structure, a low F1 and high F2. In Spectrogram 20 of the nonsense sequence [iri], there is a slight increase in F1 and a decrease in F2 towards the constricted interval. This means that, when nearing the constriction, formants aim for a vowel that is a little lower and more back than [i]. It is to be expected that formants would not change as much in [iri] as they do in [ara]. As the graphs showed, the vocoids of the tap approach [i] more than they approach [a].

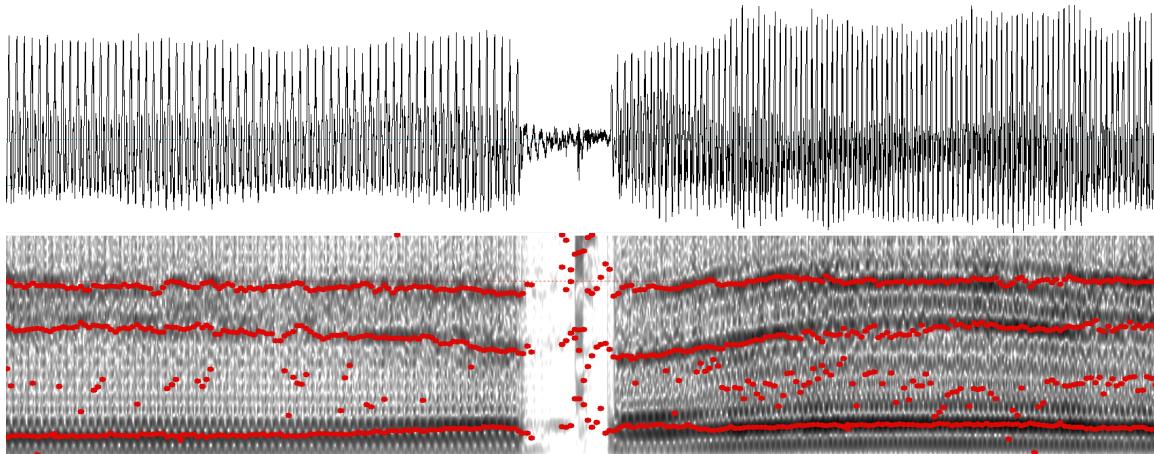
The nonsense sequence [oro]:



Spectrogram 21

The vowel [o] has a relatively low F1 and a relatively low F2. Spectrogram 21 shows a rising F2 towards the constriction, which is to be expected, since the vocoids of the tap are on the same level of height as [o] (F1 does not change), but more central than the back [o] (the increase in F2).

The nonsense sequence [ere]:

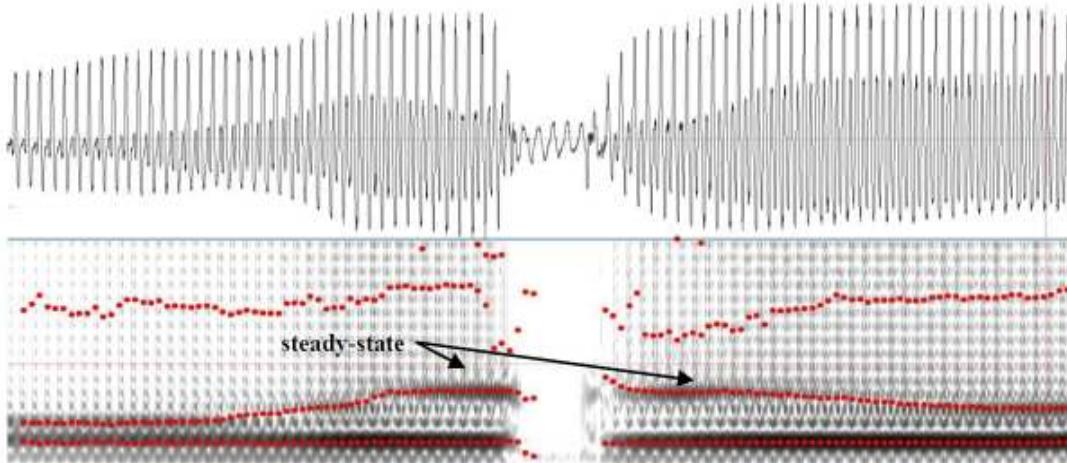


Spectrogram 22

The vowel [e] is characterized by a relatively low F1 and a relatively high F2. A slight increase in F1 and a decrease in F2 can be noticed near the constriction in the sequence [ere] in Spectrogram 22. This means that immediately before and after the

constricted interval, the vowel is a little lower and more back than [e], indicating the central area of the vowel space.

The nonsense sequence [uru]:



Spectrogram 23

The vowel [u] has a low F1 and a low F2, visible at the edges of spectrogram 23. Near the constriction, F2 increases, suggesting a vowel more front than [u]. F1 does not change, but the tap's vocoids are similar to [u] in height, so a change in F1 would not be expected.

In some nonsense VrV tokens, such as the one in Spectrogram 23, formants exhibit a steady-state portion near the constriction. This supports the claim that there are vocoids belonging to the tap, detectable even in VrV. It might be said that the parts before and after the constricted interval in which F2 is in a steady-state configuration represent the vocoids of the tap. However, as explained in Chapter 1, one cannot know where the tap's vocalic elements end and the full vowels begin when [r] is in context VrV.

Taking into account Spectrograms 19-23 together, the formant changes suggest that, immediately before and after the constricted interval, formants tend to approach a configuration that would place the vowel in the area where the salient vocoids from other

contexts have been shown to cluster (see Graphs 2-5). This target vowel is higher and more front than [a], lower and more back than [i] and [e], and more front [u] and [o].

Chapters 1 and 2 have presented the following structure for [r]: the sound is composed of a constricted interval flanked by two mid-high central (to front) vocalic elements. The data from Romanian, corroborated with the data from other languages, appear to support this hypothesis. In Chapter 3, I discuss some phonological implications of the tap having the phonetic structure described so far.

Chapter 3. Phonological implications

Phonetically, as mentioned in Chapter 1, the tap has been assumed to be a simple, short constricted interval. Baltazani (2009) considers that, since [r] has stop characteristics, the sound is an obstruent. After all, the tap does include a complete constriction in the vocal tract, which is typical of stop consonants.

Chapters 1 and 2 of this paper have examined, in some detail, the phonetic structure of [r]. The conclusion reached is that this sound is a complex, heterogeneous mix of vocalic and consonantal parts. The present chapter argues that the sonorant-like phonological behavior of the tap is in agreement with, and explainable by, its phonetic composition (which includes vocalic elements).

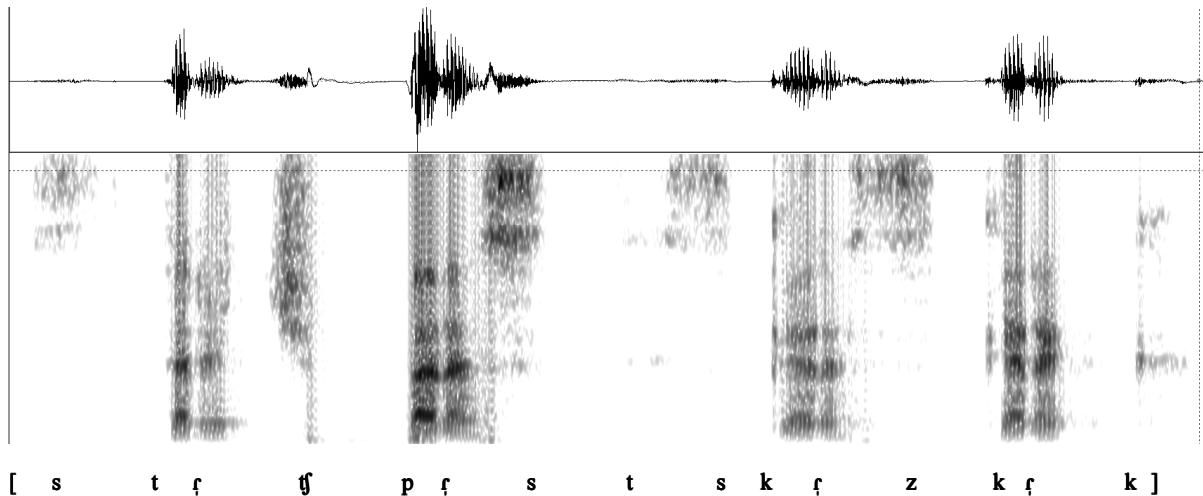
3.1 Syllabic and vocalic [r]

In Slavic languages, like Czech, Slovak, Serbo-Croatian, Macedonian and (possibly) Slovenian, /r/ can act as a syllable nucleus³ (which is typically the function of a vowel), in addition to its possibility to appear in onsets and codas (Sussex and Cubberley 2006). Acoustic studies report that /r/ is often pronounced as [r] (see Gudurić and Petrović 2005 for Serbian; Pavlík 2008 for Slovak).

It is to be expected that [r] should be able to do the job of a vowel, since this sound is itself partly vocalic in character. In Czech, for example, one can find entire sentences composed only of consonants. Spectrogram 24 below shows an example of

³ None of these languages have syllabic nasals, and Czech and Slovak include syllabic /l/ as well (see the example in Spectrogram 12). It is not surprising that consonants like laterals and nasals can act as syllabic nuclei, given that their spectral characteristics resemble those of vowels. There is a complete constriction in the vocal tract in their case, but this constriction is bypassed: the air escapes through the sides of the mouth (laterals) or through the nasal cavity (nasals).

such a sentence, in which all the syllabic nuclei are /r/, realized as [r]. The two vocalic elements that are expected to appear when [r] is between consonants are salient.



Spectrogram 24: The Czech sentence *Strč prst skrz krk* ‘Put your finger through your throat’

(sound file from: http://upload.wikimedia.org/wikipedia/commons/1/12/Prst_a_krk.ogg)

In Serbo-Croatian and Slovak, aside from being a possible nucleus, /r/ patterns with vowels in other interesting ways as well. In Slovak, /r/ can be the bearer of length distinctions and participate in the same alternations (lengthening and shortening) as vowels (Pouplier and Beňuš 2011). Examples are given below.

Lengthening through suffixation (acute accent means length):

- | | | | |
|--------|-----------------------|----------|----------------|
| (1) a. | <i>hrad</i> | ‘castle’ | (vowel) |
| | <i>hrád-ok</i> (dim.) | | |
| (2) a. | <i>vrch</i> | ‘hill’ | (syllabic /r/) |
| | <i>vŕš-ok</i> (dim.) | | |

Shortening through suffixation:

- | | | | |
|--------|--------------------|---------|---------|
| (3) a. | <i>zváž-i-t’</i> | ‘think’ | (vowel) |
| | <i>zvaž-ova-t’</i> | | |

- (4) a. *vykrm-i-t'* ‘feed’ (syllabic /r/)
vykrm-ova-t'
(Slovak; examples from Pouplier and Beňuš 2011)

In Serbo-Croatian, /r/ can bear both length and pitch distinctions (Sussex and Cubberley 2006: 187). This produces minimal pairs distinguished on the basis of the length and/or tone on /r/, such as those in the following examples:

- | | | | |
|---------|-------------------------------|--|--------------------------|
| (5) a. | <i>grǎd</i> (short falling) | ‘hail’ | |
| | b. | <i>grād</i> (long falling) | ‘town’ (vowel) |
| (6) a. | <i>vǎljati</i> (short rising) | ‘to be good’ | |
| | b. | <i>váljati</i> (long rising) | ‘to roll’ vowel |
| (7) a. | <i>Tǐst</i> (short falling) | ‘Trieste’ | syllabic |
| | b. | <i>tǐst</i> (long falling) | ‘cane’ /r/ |
| (8) a. | <i>tr̄nuti</i> (long rising) | ‘to become numb’ | syllabic |
| | b. | <i>tr̄nuti</i> (short falling) | ‘to extinguish’ /r/ |
| (9) a. | <i>grǎdu</i> (long falling) | ‘city’ – DAT.SG. | |
| | b. | <i>grádu</i> (long rising) | ‘city’ – LOC.SG. vowel |
| (10) a. | <i>sǐca</i> (short falling) | ‘heart’ – GEN.SG.; NOM., VOC., ACC., PL. | syllabic |
| | b. | <i>sǐcā</i> (long falling) | ‘heart’ – GEN.PL. /r/ |
| (11) a. | <i>bǐzo</i> (long rising) | ‘quick’ – (adjective) NEUT. SG. | syllabic |
| | b. | <i>bǐzo</i> (long falling) | ‘quickly’ – (adverb) /r/ |

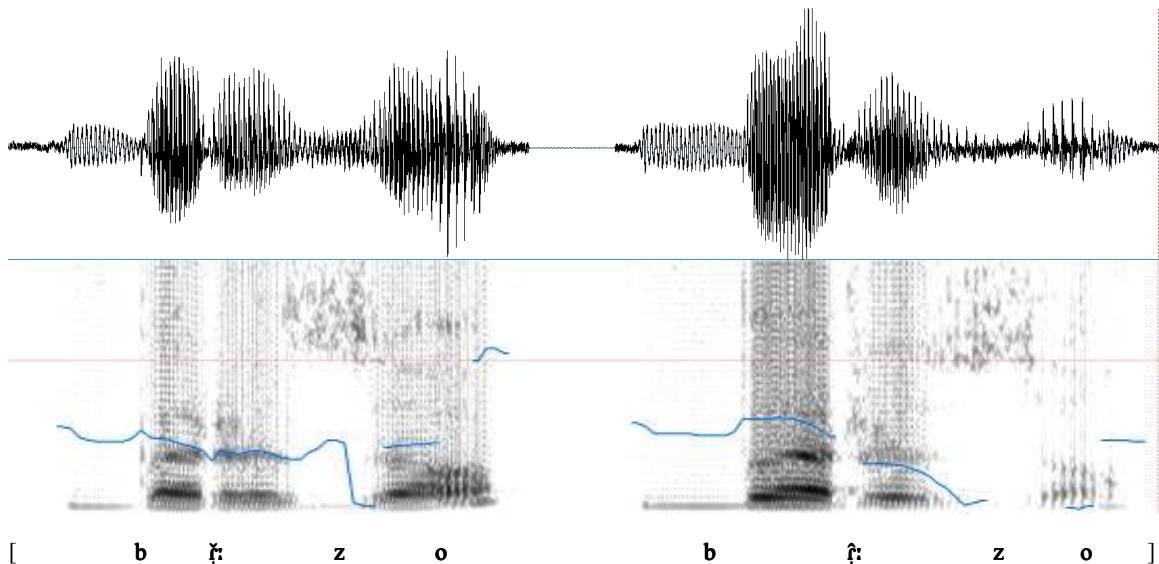
(Serbo-Croatian; examples from Sussex and Cubberley 2006: 187; Filipi and Ionilă 2001: 427; Browne 1993: 319, 321)

As mentioned above, acoustic studies suggest that, in Serbo-Croatian and Slovak, /r/ is typically pronounced as a tap. With tap realizations of the rhotic, the words in examples (1) – (11) that contain syllabic /r/ would be pronounced as in Table 5.

<i>vrch</i> (1b)	[<i>vɾx</i>]	Slovak (length distinction)
<i>vŕšok</i> (2b)	[<i>vɾ̩ʃok</i>]	
<i>vykŕmit'</i> (3b)	[<i>'vikɾ̩mit'</i>]	
<i>vykrmovat'</i> (4b)	[<i>'vikɾ̩movat'</i>]	
<i>Tŕst</i> (7a)	[<i>t̪ɾst</i>]	Serbo-Croatian (length and pitch (tone) distinction)
<i>tr̩st</i> (7b)	[<i>t̪̩st</i>]	
<i>tŕnuti</i> (8a)	[<i>t̪̩nuti</i>]	
<i>tr̩nuti</i> (8b)	[<i>t̪̩nuti</i>]	
<i>sŕca</i> (10a)	[<i>s̪̩tsa</i>]	
<i>s̪̩cā</i> (10b)	[<i>s̪̩tsa:</i>]	
<i>bŕzo</i> (11a)	[<i>b̪̩zo</i>]	
<i>b̪̩zo</i> (11b)	[<i>b̪̩zo</i>]	

Table 5: Pronunciations of the Slovak and Serbo-Croatian words with /r/ realized as a tap

Spectrogram 25 below shows the *bŕzo-b̪̩zo* minimal pair uttered by a native speaker. /r/ is realized as a tap (one constriction), the two vocoids are also easily distinguishable. Also, the falling pitch on the vocoids of [b̪̩zo] is observable.



Spectrogram 25: *Bŕzo* and *b̪̩zo* uttered by a female native speaker of Serbian.

The data above suggest a connection between the tap's having vocalic elements in its internal phonetic structure and its ability to behave like a vowel. Indeed, it would be reasonable to assume that the tap's vocoids are the bearers of the length and pitch distinctions. This idea is supported by Spectrogram 25.

Since [r] itself is largely vocalic in nature, placing it between two consonants may be what enables it to be treated as a vowel of the language. The vocalic elements would become "perceptually salient" when there are no full vowels in the vicinity of [r], since the consonantal environment would provide the necessary contrast. As a consequence, speakers can control the vocalic elements of the tap for linguistic purposes, just like they would any other vowel, despite there being a short constriction separating the two vocoids. If [r] borders with a full vowel, the tap will not be a syllabic nucleus, since its own vocalic parts are overshadowed by the full vowels and hence not salient to speakers, just like they are not salient on a spectrogram in context VrV. This concurs with Dłuska's (1983, cited in Stolarski 2011) mention that speakers are usually unaware of the existence of the vocoids in [r]. They are indeed unaware, unless the tap happens to be flanked by consonants or pauses on both sides and is the nucleus of the syllable. Note that in this case, the tap does contribute to the syllabic make-up of the word, which is an argument against the vocoids being considered "intrusive" (see Schmeiser 2009).

According to the argument about perceptual salience of the tap's vocoids outlined above, it would be expected that the tap should be in nucleus position whenever it is flanked by consonants. A counterargument may be found in Polish. In this language, /r/ is never in nucleus position, even in contexts where it has no full vowels in its vicinity, such as CrC. The rhotic is instead part of a consonant cluster. This opens up an interesting question for further research: are there systematic phonetic differences between syllabic taps and interconsonantal taps that are part of clusters?

Another aspect for further research concerns the tap in context VrV. In this case, in which [r] is flanked by full vowels on both sides, the only "conspicuous" part of the tap is the constriction, the obstruent-like part of the tap. The sound should, therefore, exhibit obstruent behavior in VrV, and it would be interesting to find out if this is indeed the case.

3.2 Perception and parsing

Chapters 1 and 2 present [r] as being comprised of two vocoids similar to [i] and [ə] flanking a brief constricted interval. The following subsections will consider the implications this structure has for the perception and parsing of this sound and those around it.

3.2.1 /r/ versus /ər/

Sussex and Cubberley (2006: 156-7) mention that an analysis of /ər/ instead of /r/ has been proposed for Slovenian and Macedonian, though /ə/ is absent from the Macedonian vowel inventory, as is /i/. Actually, it appears that Slavic languages with syllabic /r/ do not distinguish mid or high central vowels (according to the inventories in Sussex and Cubberley 2006: 154). An exception might be Slovenian, but the existence of /r/ in this language is debatable, and probably not the best analysis, as will be argued below. Bulgarian, on the other hand, clearly has /ə/ as part of its vowel inventory and no syllabic /r/.

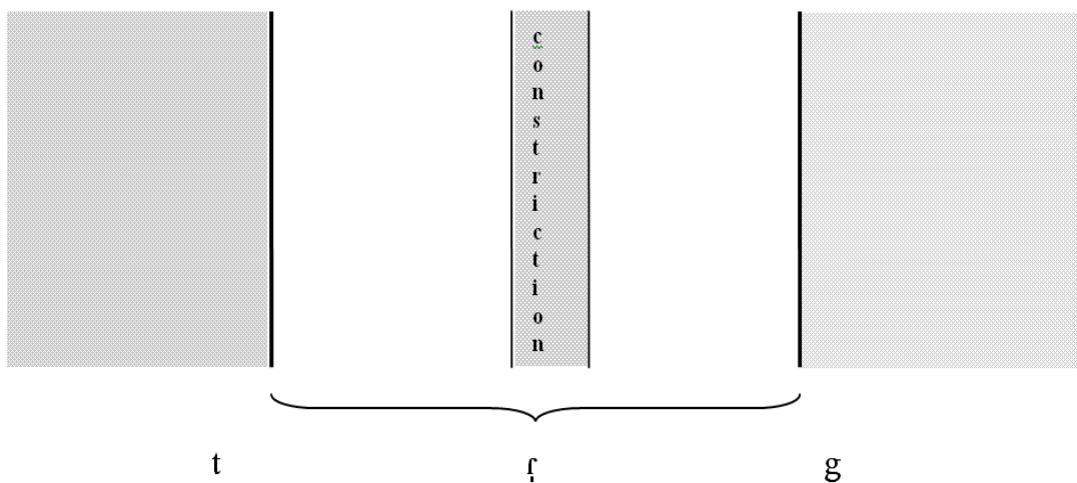
What is interesting is that languages which have syllabic /r/ do not distinguish precisely the vowels in the area where the vocoids of the tap have been shown to cluster. This would solve the problem for Macedonian, if the realization of /r/ in this language turns out to be [r]. Since the tap itself partly consists of mid-high central vocalic elements, a short [ə] is only expected to be perceived by non-native speakers, though native speakers of Macedonian would not recognize it as a separate vowel, since this vowel is not present in the inventory of the language. It would just be a part of [r], albeit a possibly longer one. Thus, any mid central vocoid interfering between the constriction and the consonants in CrC would pass as part of the tap. Therefore, the syllabic /r/ analysis would probably make the best choice for Macedonian. However, since Slovenian has /ə/,

speakers would probably parse a CVrC and not CrC. While this remains a topic for further research, it may be that /ər/ is more suitable for Slovenian.

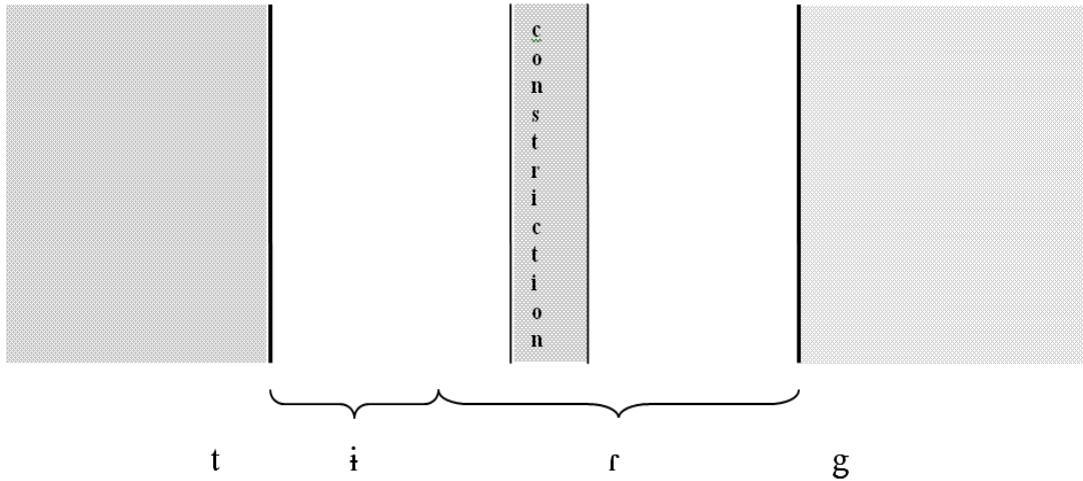
3.2.2 Slavic /CrC/ and Romanian /CirC/

A similar issue to the one discussed in 3.2.1 is the perception of (Slavic) words in the Romanian vocabulary that contain /CirC/ sequences. Such words are perceived as containing /CirC/ in Romanian, but /CrC/ in Serbian or Macedonian. Therefore, Romanian speakers (who distinguish /ə/ and /i/) do the opposite of what Macedonians have been argued to do in 3.2.1. If for a Macedonian or a Serbian the entire vocalic elements are parts of [r], since these languages have syllabic /r/ but no central vowels that are mid or high, for a Romanian there is full vowel similar in quality to the vocoids of the tap.

There is a difference in how speakers of the Slavic languages and speakers of Romanian parse what is between the two consonants at the edges. In short, Romanians “cut” a portion of the first vocalic element, which becomes /i/. Speakers of Serbo-Croatian do not. This idea is sketched in Figure 7.



7a.



7b.

Figure 7: Slavic /CrC/ (7a) and Romanian /CirC/ (7b) in a Slavic word that entered the Romanian vocabulary

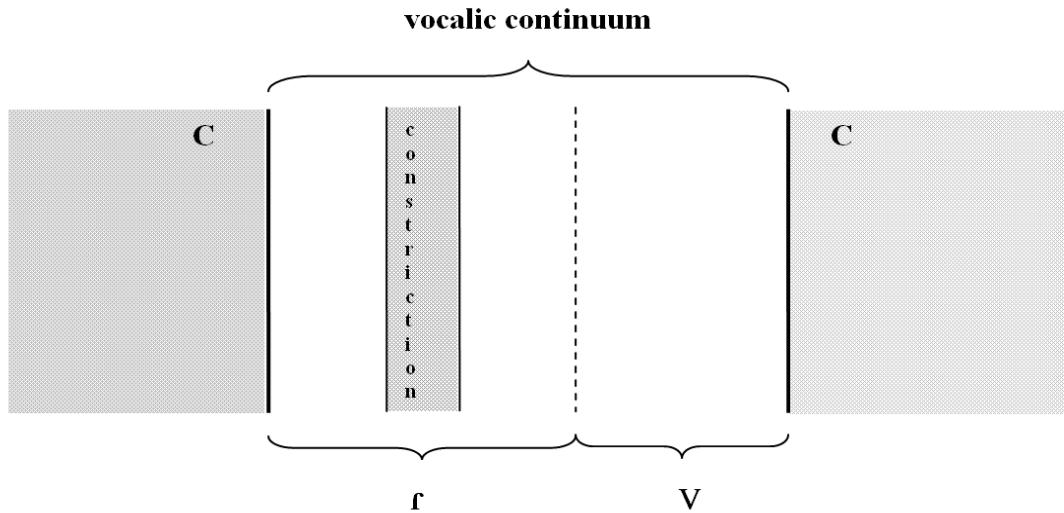
7a. shows the sequence from the perspective of a speaker of Serbo-Croatian. Whatever is between /t/ and /g/ is considered part of [r]. 7b. is a sketch of how Romanians parse the sequence, by considering a part of the first vocoid a full vowel, /i/. This appears to hinge on the vowel inventories of each language, specifically on the presence or absence of /i/.

The line of thought outlined in 3.2.1 and 3.2.2 suggests a possible diachronic development: a language which loses mid or high central vowels may, in turn, develop syllabic /r/. In this case, the loss of the vowels would lead 7b to turn into 7a. Thus, the tap may be seen as “flexible” in that it may “swallow” adjacent vocoids into its structure, if the language does not distinguish them as independent because of their quality.

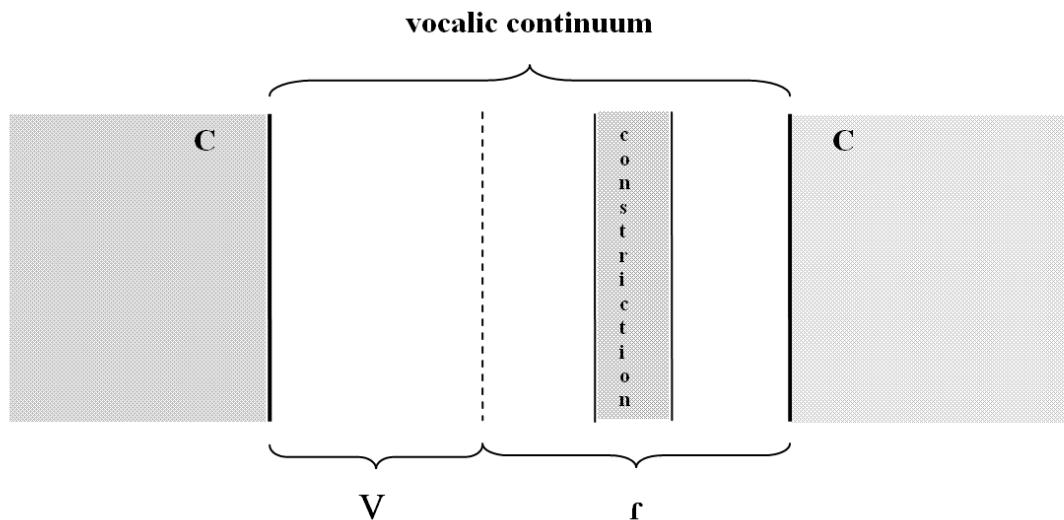
3.2.3 Metathesis

The tap’s vocoids also suggest a phonetic explanation of vowel-rhotic metathesis between two consonants (CrVC and CVrC).

If we consider that between the consonants at the edges there is a “vocalic continuum” (the full vowel plus the vocoids of the tap) interrupted by the constriction, the difference between CrVC and CVrC would be in where the constriction is placed on said vocalic continuum since [r] requires the constriction. This is illustrated in Figure 8.



8a.



8b.

Figure 8: CrVC and CVrC

As figure 8 shows, **CrVC** is represented as having the constriction on the left side of the vocalic continuum, close to the first consonant (8a). In **CVrC**, the constriction is on

the right, close to the second consonant (8b). The place of the constriction determines where the tap is perceived. Metathesis could, therefore, be conceived of as the movement of the constricted interval towards the other side of the vocalic continuum. Thus, moving the constricted interval to the left in **CVrC** would turn it into **CrVC**. Likewise, turning **CrVC** into **CVrC** would imply moving the constriction to the right.

Conclusions

The present study is a detailed acoustic phonetic description of [r], accompanied by a brief discussion of some phonological implications thereof.

By putting together all the phonetic contexts in which the tap appears (including #rC, CrC and Cr#, which are found in the Slavic languages), we get a complete picture of the general structure of [r], which is presented in Chapter 1 of the dissertation. The vocoids reported in contexts in which the tap is flanked by one consonant or pause on one side and a full vowel on the other are argued to be parts of [r]. The tap has the structure “vocalic element – constricted interval – vocalic element” in all contexts, but the vocoids are not saliently delimited when the sound is flanked by a full vowel. What this means for Lindau’s (1985) “family of rhotics” is that the relationship of the tap with other “family members” is strengthened. The vocoids make it similar to other rhotics like trills and approximants.

In Chapter 2, data gathered from an experiment on the tap in Romanian, as well as data from Polish, are used for a detailed study quality of the vocoids, in order to pinpoint their area in the vowel space (i.e. the limits within which they may vary). The vocoids systematically cluster in the mid-high, central-to-front area. There are differences between phonetic contexts. The Romanian data show that Cr allows the vocoids to vary the most and #rV the least. The comparison with the Polish data suggests that when the tap does not have any full vowel in its vicinity, the vocoids stay in the central area, without going front.

Chapter 2 also analyzes the systematic formant changes that occur immediately before and after the constriction in context VrV, using nonsense sequences uttered by Romanian speakers. The findings suggest that, towards the constriction, the vowel quality changes to that of a mid-high, central vowel, which supports the hypothesis that, even in VrV, the tap contains vocalic elements.

In Chapter 3 some of the phonological implications of the structure of the tap argued for in the previous two chapters are discussed. It is argued that the vocoids of [r]

are the ones allowing it to be a syllabic nucleus and be treated as a vowel of the language in Slavic languages like Serbo-Croatian and Slovak. [r] may even bear phonemic length and pitch distinctions, yielding minimal pairs. Since the tap has vocoids, it may be assumed that they are the ones bearing these distinctions, just like any other vowel would. The structure of [r] may also shed light on the status of syllabic /r/ in Macedonian, as well as the differences in the way speakers of Serbo-Croatian and Romanian perceive the same acoustic input. Finally, the structure of [r] suggests a phonetic explanation of vowel-rhotic metathesis, in terms of movement of the constriction along a vocalic continuum situated between two consonants.

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Appendix A – Romanian words used in the experiment, with gloss and IPA transcription

CONTEXT	WORD	GLOSS	IPA
#rV	<i>ratat</i>	‘loser’ (ADJ. MASC. SG.)	/ra'tat/
	<i>retoric</i>	‘rhetorical’	/re'torik/
	<i>rituri</i>	‘rites’	/riturj/
	<i>rotar</i>	‘wheeler’	/ro'tar/
	<i>rutină</i>	‘routine’	/ru'tine/
	<i>rătăcit</i>	‘lost’ (ADJ. MASC. SG.)	/rətə'tʃit/
	<i>rîtaş</i>	‘recently stubbed field’	/rî'taʃ/
	<i>Radu</i>	proper name	/radu/
	<i>reducere</i>	‘reduction’	/re'duʃere/
	<i>riduri</i>	‘wrinkles’	/ridurj/
	<i>rod</i>	‘fruitage’	/rod/
	<i>rudă</i>	‘relative’	/rudə/
	<i>rădăcină</i>	‘root’	/rədə'tʃinə/
	<i>rîde</i>	‘he/she laughs’	/ride/
VrV	<i>parapet</i>	‘rails’	/para'pet/
	<i>perete</i>	‘wall’	/pe'rete/
	<i>pirită</i>	‘pyrite’	/pi'ritə/
	<i>poros</i>	‘poriferous’ (ADJ. MASC. SG.)	/po'ros/
	<i>purulent</i>	‘purulent’ (ADJ. MASC. SG.)	/puru'lent/
	<i>părăsit</i>	‘abandoned’ (ADJ. MASC. SG.)	/pərə'sit/
	<i>pîrît</i>	‘person being told on’ (MASC.SG.)	/pî'rit/
	<i>carapace</i>	‘shell’	/kara'patʃe/
	<i>părere</i>	‘opinion’	/pə'rere/
	<i>spirit</i>	‘spirit’	/spirit/
	<i>scorojit</i>	‘barked’ (ADJ. MASC. SG.)	/skoro'ʒit/
	<i>buturugă</i>	‘wood stub’	/butu'ruga/
	<i>fără</i>	‘without’	/fərə/
rC (C=/t, d/)	<i>tîrîtor</i>	‘crawler’ (ADJ. MASC. SG.)	/tîri'tor/
	<i>partaj</i>	‘divorce settling’	/par'taʒ/
	<i>oferte</i>	‘offers’	/o'ferte/

CONTEXT	WORD	GLOSS	IPA
Cr (C=/t, d/)	<i>mirt</i>	'myrtle'	/mirt/
	<i>portocală</i>	'orange'	/porto'kalə/
	<i>turturele</i>	'turtle dove'	/turtu'rele/
	<i>Tărtăria</i>	toponym	/tărtă'rija/
	<i>învîrt</i>	'I/they spin'	/in'vert/
	<i>retardat</i>	'retarded'	/retar'dat/
	<i>verde</i>	'green'	/verde/
	<i>IRDI</i>	company name	/irdi/
	<i>cordon</i>	'belt'	/kor'don/
	<i>burduşit</i>	'filled up'	/burdu'sit/
	<i>bărdăcuță</i>	'hatchet' (DIM.)	/bărdă'kutsə/
	<i>dîrdiit</i>	'tremble'	/dîrdi'it/
rC (C=/p, b/)	<i>atracție</i>	'attraction'	/a'traktsije/
	<i>petrecere</i>	'party'	/pe'tretjere/
	<i>citrice</i>	'citrus plants'	/t̪ifritsje/
	<i>cotropit</i>	'persecuted'	/kotro'pit/
	<i>trucaj</i>	'trick'	/tru'kaʒ/
	<i>cătrânit</i>	'someone who looks black' (MASC. SG.)	/kətrə'nit/
	<i>trîntor</i>	'bumble bee'	/trîntor/
	<i>cadran</i>	'quadrant'	/ka'dran/
	<i>redresare</i>	'rectification'	/redre'sare/
	<i>clorhidric</i>	'hydrochloric'	/klor'xidrik/
	<i>drog</i>	'drug'	/drog/
	<i>drujbă</i>	'chainsaw'	/druʒbə/
rC (C=/p, b/)	<i>drămuire</i>	'weighing carefully'	/drəmu'ire/
	<i>drîmbă</i>	type of drum	/drîmbə/
	<i>Carpați</i>	'Carpathians'	/kar'patsj/
	<i>serpentine</i>	'turns in a mountain road'	/serpen'tine/
	<i>pirpiriu</i>	'weak'	/pirpi'riw/
	<i>corpolent</i>	'massive (person)' (MASC. SG.)	/korpo'lent/
	<i>purpuriu</i>	'purple' (ADJ. MASC. SG.)	/purpu'riw/
	<i>Cărpărești</i>	fictional toponym	/kərpə'reʃtj/

CONTEXT	WORD	GLOSS	IPA
Cr (C=/p, b/)	<i>pîrpîru</i>	nonsense word	/pirpi'riw/
	<i>iarba</i>	'the grass'	/'jarba/
	<i>berbec</i>	'ram'	/ber'bek/
	<i>știrbit</i>	'deprived of something'	/ʃtir'bit/
	<i>corb</i>	'raven'	/korb/
	<i>turbulențe</i>	'turbulences'	/turbu'lentse/
	<i>sărbătoare</i>	'holiday'	/sərbə'toare/
	<i>scîrb</i>	'disgusting' (ADJ. MASC. SG.)	/skirb/
rC (C=/k, g/)	<i>praz</i>	'scallion'	/praz/
	<i>pres</i>	'rug'	/'pref/
	<i>Ciprian</i>	proper name	/fipri'jan/
	<i>șopron</i>	'barn'	/ʃo'pron/
	<i>cupru</i>	'copper'	/kupru/
	<i>căprării</i>	'categories'	/kəprə'ri/
	<i>prînz</i>	'lunch'	/prînz/
	<i>abraziv</i>	'abrasive'	/abra'ziv/
	<i>brebenel</i>	'evergreen'	/brebe'nel/
	<i>ibric</i>	'kettle'	/i'brik/
	<i>obron</i>	'open barn'	/o'bron/
	<i>lugubru</i>	'gloomy' (ADJ. MASC. SG.)	/lu'gubru/
rC (C=/k, g/)	<i>brățară</i>	'bracelet'	/brə'tsarə/
	<i>brînză</i>	'cheese'	/brînzə/
	<i>parcare</i>	'parking lot'	/par'kare/
	<i>perchezitie</i>	'perquisition'	/perke'zitsije/
	<i>circ</i>	'circus'	/tjirk/
	<i>corcoduș</i>	'perch tree'	/korko'duʃ/
	<i>curcubeu</i>	'rainbow'	/kurku'bew/
	<i>încărcătură</i>	'load'	/inkərkə'turə/
	<i>cocostîrc</i>	'stork'	/koko'stirk/
	<i>argat</i>	'hired man'	/ar'gat/
rC (C=/k, g/)	<i>alerг</i>	'I run'	/a'lerg/
	<i>pirg</i>	'defense tower'	/pirg/

CONTEXT	WORD	GLOSS	IPA
Cr (C=/k, g/)	<i>gorgonă</i>	'harpy'	/gor'gonə/
	<i>curg</i>	'I/they flow'	/kurg/
	<i>gărgăuni</i>	'hornets'	/gərgə'unj/
	<i>tîrg</i>	'bazar'	/tîrg/
	<i>sacralitate</i>	'sacredness'	/sakrali'tate/
	<i>decret</i>	'decree'	/de'kret/
	<i>icrișoară</i>	'spawn' (DIM.)	/ikri'ʃoarə/
	<i>ocrotit</i>	'protected' (ADJ. MASC. SG.)	/okro'tit/
	<i>lucru</i>	'work' (NOUN)	/lukru/
	<i>lăcrămioară</i>	'lily-of-the-valley'	/ləkrə'mjоarə/
	<i>crîncen</i>	'atrocious'	/krinʃen/
	<i>agrар</i>	'agrarian'	/a'grar/
	<i>gresie</i>	'stoneware'	/'gresije/
	<i>tigrișor</i>	'tiger' (DIM.)	/tigri'ʃor/
	<i>gropar</i>	'grave digger'	/gro'par/
	<i>grup</i>	'group'	/grup/
	<i>grădină</i>	'garden'	/grə'dinə/
	<i>grînar</i>	'granary'	/grî'nar/

Appendix B – Average formant values and duration of the vocalic element and constriction for each word

WORD		VALUES		WORD		VALUES	
ratat				Carpați			
vocalic part	F1	648	vocalic part	F1	589	constriction	duration
	F2	1547		F2	1498		
	duration	53		duration	28		
constriction	duration	24	constriction	duration	24		
retoric				serpentine			
vocalic part	F1	572	vocalic part	F1	459	constriction	duration
	F2	1646		F2	1700		
	duration	41		duration	29		
constriction	duration	28	constriction	duration	31		
rituri				pirpiriu			
vocalic part	F1	489	vocalic part	F1	412	constriction	duration
	F2	1729		F2	1970		
	duration	56		duration	34		
constriction	duration	30	constriction	duration	37		
rotar				corpolent			
vocalic part	F1	534	vocalic part	F1	512	constriction	duration
	F2	1309		F2	1274		
	duration	51		duration	30		
constriction	duration	25	constriction	duration	25		
rutină				purpuriu			
vocalic part	F1	455	vocalic part	F1	416	constriction	duration
	F2	1293		F2	1295		
	duration	44		duration	34		
constriction	duration	29	constriction	duration	25		
rătăcit				Cărpărești			
vocalic part	F1	552	vocalic part	F1	487	constriction	duration
	F2	1518		F2	1491		
	duration	52		duration	33		
constriction	duration	27	constriction	duration	27		
rîtas				pîrpîrîu			
vocalic part	F1	497	vocalic part	F1	397		
	F2	1492		F2	1536		

WORD		VALUES	WORD		VALUES
	duration	61		duration	32
constriction	duration	27	constriction	duration	29
Radu			iarba		
vocalic part	F1	621	vocalic part	F1	563
	F2	1513		F2	1470
	duration	51		duration	32
constriction	duration	29	constriction	duration	28
reducere			berbec		
vocalic part	F1	586	vocalic part	F1	476
	F2	1645		F2	1676
	duration	52		duration	39
constriction	duration	29	constriction	duration	28
riduri			știrbit		
vocalic part	F1	502	vocalic part	F1	410
	F2	1547		F2	1864
	duration	56		duration	33
constriction	duration	37	constriction	duration	39
rod			corb		
vocalic part	F1	524	vocalic part	F1	489
	F2	1337		F2	1366
	duration	53		duration	37
constriction	duration	27	constriction	duration	31
rudă			turbulențe		
vocalic part	F1	458	vocalic part	F1	422
	F2	1267		F2	1288
	duration	57		duration	36
constriction	duration	36	constriction	duration	28
rădăcină			sărbătoare		
vocalic part	F1	548	vocalic part	F1	492
	F2	1495		F2	1459
	duration	45		duration	29
constriction	duration	29	constriction	duration	27
rîde			scîrb		
vocalic part	F1	481	vocalic part	F1	429
	F2	1465		F2	1500
	duration	63		duration	42

WORD		VALUES	WORD		VALUES
constriction	duration	34	constriction	duration	33
parapet			praz		
vocalic part	F1		vocalic part	F1	617
	F2			F2	1458
	duration			duration	30
constriction	duration	24	constriction	duration	26
perete			pres		
vocalic part	F1		vocalic part	F1	553
	F2			F2	1598
	duration			duration	27
constriction	duration	27	constriction	duration	23
pirită			Ciprian		
vocalic part	F1		vocalic part	F1	403
	F2			F2	1904
	duration			duration	25
constriction	duration	45	constriction	duration	33
poros			şopron		
vocalic part	F1		vocalic part	F1	458
	F2			F2	1210
	duration			duration	29
constriction	duration	22	constriction	duration	20
purulent			cupru		
vocalic part	F1		vocalic part	F1	436
	F2			F2	1261
	duration			duration	27
constriction	duration	25	constriction	duration	27
părăsit			căprării		
vocalic part	F1		vocalic part	F1	496
	F2			F2	1403
	duration			duration	24
constriction	duration	28	constriction	duration	24
pîrît			prînz		
vocalic part	F1		vocalic part	F1	494
	F2			F2	1538
	duration			duration	31
constriction	duration	33	constriction	duration	29

WORD		VALUES	WORD		VALUES
carapace			abraziv		
vocalic part	F1		vocalic part	F1	551
	F2			F2	1439
	duration			duration	27
constriction	duration	24	constriction	duration	23
părere			brebanel		
vocalic part	F1		vocalic part	F1	513
	F2			F2	1605
	duration			duration	33
constriction	duration	36	constriction	duration	23
spirit			ibric		
vocalic part	F1		vocalic part	F1	432
	F2			F2	1999
	duration			duration	32
constriction	duration	44	constriction	duration	31
scorojít			obron		
vocalic part	F1		vocalic part	F1	477
	F2			F2	1210
	duration			duration	46
constriction	duration	26	constriction	duration	22
buturugă			lugubru		
vocalic part	F1		vocalic part	F1	394
	F2			F2	1213
	duration			duration	39
constriction	duration	35	constriction	duration	25
fără			brățără		
vocalic part	F1		vocalic part	F1	521
	F2			F2	1451
	duration			duration	36
constriction	duration	31	constriction	duration	22
tîritor			brînză		
vocalic part	F1		vocalic part	F1	451
	F2			F2	1461
	duration			duration	30
constriction	duration	34	constriction	duration	31

WORD		VALUES	WORD		VALUES
partaj			parcare		
vocalic part	F1	572	vocalic part	F1	550
	F2	1553		F2	1682
	duration	21		duration	34
constriction	duration	28	constriction	duration	22
oferte			percheziție		
vocalic part	F1	441	vocalic part	F1	417
	F2	1791		F2	2037
	duration	26		duration	35
constriction	duration	32	constriction	duration	26
mirt			circ		
vocalic part	F1	464	vocalic part	F1	418
	F2	1891		F2	1785
	duration	31		duration	30
constriction	duration	33	constriction	duration	35
portocală			corcoduş		
vocalic part	F1	495	vocalic part	F1	473
	F2	1365		F2	1237
	duration	25		duration	31
constriction	duration	22	constriction	duration	21
turturele			curcubeu		
vocalic part	F1	404	vocalic part	F1	419
	F2	1429		F2	1260
	duration	29		duration	30
constriction	duration	25	constriction	duration	23
Tărtăria			încărcătură		
vocalic part	F1	464	vocalic part	F1	483
	F2	1606		F2	1641
	duration	29		duration	34
constriction	duration	23	constriction	duration	23
învîrt			cocostîrc		
vocalic part	F1	412	vocalic part	F1	403
	F2	1590		F2	1615
	duration	28		duration	30
constriction	duration	34	constriction	duration	31

WORD		VALUES	WORD		VALUES
retardat			argat		
vocalic part	F1	546	vocalic part	F1	517
	F2	1533		F2	1680
	duration	31		duration	41
constriction	duration	28	constriction	duration	24
verde			alerг		
vocalic part	F1	472	vocalic part	F1	434
	F2	1732		F2	1736
	duration	37		duration	38
constriction	duration	33	constriction	duration	36
IRDI			pирг		
vocalic part	F1	403	vocalic part	F1	392
	F2	1786		F2	1773
	duration	45		duration	39
constriction	duration	41	constriction	duration	38
cordon			gorgonă		
vocalic part	F1	491	vocalic part	F1	451
	F2	1388		F2	1239
	duration	35		duration	38
constriction	duration	27	constriction	duration	23
burduşit			cург		
vocalic part	F1	415	vocalic part	F1	411
	F2	1359		F2	1487
	duration	32		duration	33
constriction	duration	26	constriction	duration	29
bărdăcuță			gărgăuni		
vocalic part	F1	496	vocalic part	F1	447
	F2	1551		F2	1644
	duration	30		duration	35
constriction	duration	26	constriction	duration	23
dîrdît			тîрг		
vocalic part	F1	410	vocalic part	F1	397
	F2	1647		F2	1554
	duration	41		duration	39
constriction	duration	29	constriction	duration	37

WORD		VALUES	WORD		VALUES
atractie			sacralitate		
vocalic part	F1	623	vocalic part	F1	578
	F2	1609		F2	1614
	duration	31		duration	27
constriction	duration	22	constriction	duration	23
petrecere			decret		
vocalic part	F1	517	vocalic part	F1	529
	F2	1796		F2	1832
	duration	30		duration	34
constriction	duration	24	constriction	duration	26
citrice			icrișoară		
vocalic part	F1	390	vocalic part	F1	362
	F2	2063		F2	2043
	duration	23		duration	21
constriction	duration	38	constriction	duration	35
cotropit			ocrotit		
vocalic part	F1	503	vocalic part	F1	461
	F2	1459		F2	1230
	duration	28		duration	26
constriction	duration	22	constriction	duration	19
trucaj			lucru		
vocalic part	F1	403	vocalic part	F1	422
	F2	1427		F2	1185
	duration	24		duration	30
constriction	duration	24	constriction	duration	28
cătrăniti			lăcrămioară		
vocalic part	F1	517	vocalic part	F1	457
	F2	1666		F2	1687
	duration	27		duration	18
constriction	duration	25	constriction	duration	20
trîntor			crîncen		
vocalic part	F1	471	vocalic part	F1	396
	F2	1690		F2	1626
	duration	31		duration	32
constriction	duration	27	constriction	duration	30

WORD		VALUES	WORD		VALUES
cadran			agrар		
vocalic part	F1	554	vocalic part	F1	524
	F2	1697		F2	1705
	duration	35		duration	46
constriction	duration	23	constriction	duration	25
redresare			gresie		
vocalic part	F1	511	vocalic part	F1	455
	F2	1765		F2	1867
	duration	34		duration	38
constriction	duration	23	constriction	duration	25
clorhidric			tirişor		
vocalic part	F1	407	vocalic part	F1	394
	F2	1986		F2	2151
	duration	31		duration	32
constriction	duration	31	constriction	duration	28
drog			gropar		
vocalic part	F1	473	vocalic part	F1	445
	F2	1544		F2	1415
	duration	39		duration	37
constriction	duration	22	constriction	duration	25
drujbă			grup		
vocalic part	F1	412	vocalic part	F1	404
	F2	1501		F2	1262
	duration	36		duration	40
constriction	duration	24	constriction	duration	28
drămuire			grădină		
vocalic part	F1	483	vocalic part	F1	451
	F2	1671		F2	1752
	duration	37		duration	38
constriction	duration	27	constriction	duration	28
drîmbă			grînar		
vocalic part	F1	455	vocalic part	F1	431
	F2	1720		F2	1740
	duration	39		duration	45
constriction	duration	27	constriction	duration	30

VOWEL	F1	F2
a	825	1269
e	528	2169
i	309	2354
o	551	901
u	380	797
ə	590	1220
ɪ	416	1318

(Formant frequencies are expressed in Hz and durations in ms)