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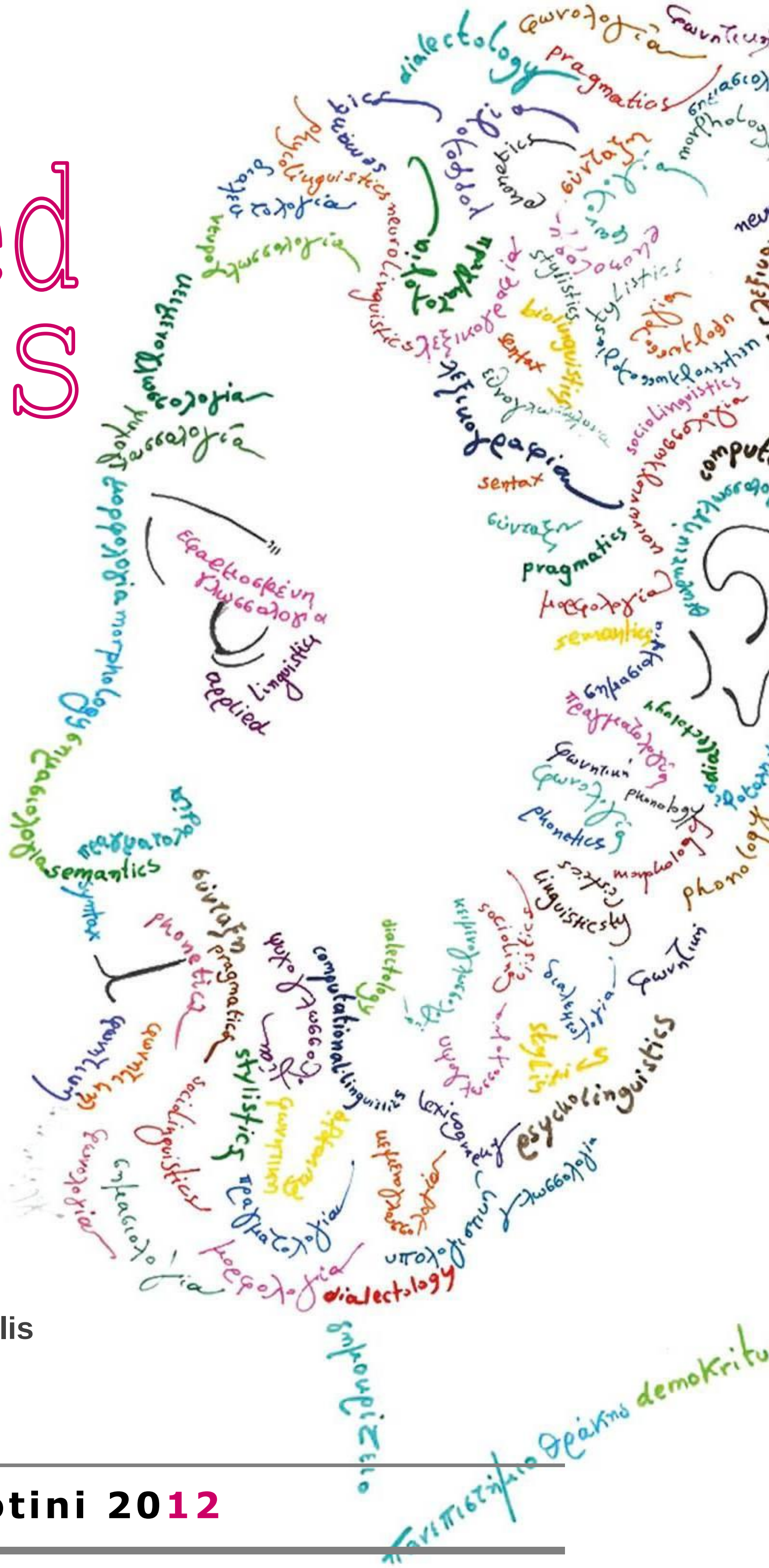

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PRODUCTION OF THE GREEK RHOTIC IN INITIAL AND INTERVOCALIC POSITION: AN ACOUSTIC AND ELECTROPALATOGRAPHIC STUDY

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ABSTRACT

This paper investigates /r/ production in phrase initial, word initial and intervocalic position. Rhotic production was found to include a vocoid preceding the constriction phase in phrase initial position. Duration, formants, place and degree of constriction, and variability due to position, context, and speaker were examined. Typically the vocoid was longer in duration than the constriction, with formants similar to the transconsonantal vowel, suggesting the production of a vocalic gesture upon which the rhotic is superimposed. Electropalatographic data show an alveolar rhotic, although there is variation in place due to context and variability from fully constricted to more open articulations.

Keywords: Rhotic, prosodic position, phrase-initial, word-initial, intervocalic, Greek, duration, electropalatography

1. Introduction

Rhotics exhibit considerable phonetic variety across languages. Variation has been reported as a function of context, position, speech rate and dialect (Lindau 1985; Inouye 1995; Ladefoged & Maddieson 1996; Recasens & Pallarès 1999; Recasens & Espinosa 2007).

In the Greek literature there is no consensus on the nature of the rhotic. Older phonological descriptions classify it as a trill (Φιλιππάκη-Warburton 1992; Nespor 1996). More recent studies describe it as a tap when it is found in intervocalic position (Nicolaidis 2001; Baltazani 2005, 2009) or in initial and intervocalic position (Arvaniti 1999). Experimental studies have reported considerable variability in its acoustic and articulatory characteristics. Both a tap and an approximant realization have been observed (Nicolaidis 2001; Baltazani 2005, 2009) and its place of articulation has been reported to vary across alveolar, retracted alveolar, and postalveolar positions (Nicolaidis 2001; Nicolaidis & Baltazani 2011, (submitted)). Further contextual variation has been detected. While tap productions are typical in initial or intervocalic position, the presence of a vocoid has been documented between the /r/ and the consonant in /Cr/ and /rC/ sequences (Baltazani 2005, 2009; Nicolaidis & Baltazani 2011, (submitted)). Such a realization has also been found in clusters in several Spanish dialects, in Catalan, as well as in French, Finnish, Romanian, Hungarian, and Hamburg German (Navarro Tomás 1918; Rochette 1973; Harms 1976; Jannedy 1994; Bradley & Schmeiser 2003; Bradley 2004; Colantoni & Steele 2005; Recasens & Espinosa 2007; Vago & Gósy 2007; Savu 2012). The production of this more complex articulation in Greek clusters with /r/, which involves a constriction and a vocalic phase, has received different interpretations. Arvaniti (2007) claims that this articulation indicates trill production in clusters while Baltazani (2005, 2009) interprets these findings as evidence for a tap production which involves a vowel-like transition between the consonant and the rhotic. Electropalatographic data reported in Nicolaidis & Baltazani (2011, (submitted)) show that there is typically one constriction present during rhotic production in clusters and sequences in Greek providing evidence of a tap articulation.

The research presented in this paper is part of a bigger project examining /r/ in several prosodic positions including its realisation in /Cr/ and /rC/ sequences (Nicolaidis & Baltazani 2011, (submitted)). The current study investigates the production of /r/ in (a) phrase initial, (b) word initial but phrase medial, and (c) word medial intervocalic position aiming to clarify the effect of prosodic position on the realization of the rhotic. An important question addressed is whether a vocoid is attested in any of these prosodic positions and if so how frequently it is present. We explore the structure of this element by looking into the vocoid's range of duration compared to the constriction phase of the /r/.

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Moreover, we consider the vocoid's formant structure to uncover possible effects of the vocalic context. In addition, we examine the effect of context and prosodic position on its articulation. Finally, we attempt to shed more light on the characterization of this segment as a tap vs. a trill.

The remainder of this paper is organized as follows: Section 2 explains our methodology, section 3 presents the acoustic and articulatory results and section 4 offers a discussion of the results.

2. Methodology

2.1 Speech material and speakers

Real words containing an /rV/ sequence (V=/i, e, a, o, u/)[1] in three prosodic positions were recorded: phrase initial (/##rV/), word initial within a phrase (/V1#rV2/) and intervocalic (/V1rV2/). In phrase initial position the test word was uttered in isolation. All other test words were embedded in the carrier phrase [I 'leksi _ 'ine a'pli] 'The word _ is simple'. The rhotic found in the /V1#rV2/ condition was preceded by /i/, i.e the last vowel of the word 'leksi' of the carrier phrase, while for the /V1rV2/ condition, V1 was consistently an /a/, resulting in the sequence /arV/. All test words were 2-3 syllables long, stressed on the /rV/ syllable and repeated five times at a comfortable speaking rate by three female (MM, KN, RP) and two male (AT, TP) adult Greek speakers. In total, 375 words were recorded (5 Vs x 3 positions x 5 repetitions x 5 speakers).

2.2. Recording procedure

Simultaneous acoustic and electropalatographic (EPG) data were recorded using the British EPG system marketed by Articulate Instruments. In addition, a separate recording of acoustic data was made on a digital recorder (Marantz PMD 660) with a Røde NT1-A cardiod condenser microphone.

Acoustic data were analysed using PRAAT. We measured the durations of the rhotic constriction phase and of the vocoid, as well as the F1 and F2 formants of the vocoid (in word initial position) and of the V1, V2 vowels to detect possible environment influences on the vocoid. The onset of the constriction phase—together with the onset of the voicebar—was marked at the offset of silence, V1 or vocoid, depending on prosodic position. The offset of constriction was marked at the beginning of the formants for V2 (Figure 1). The beginning and end of the vocoid in phrase initial position was marked at the onset and offset of its formant structure respectively (Figure 2).

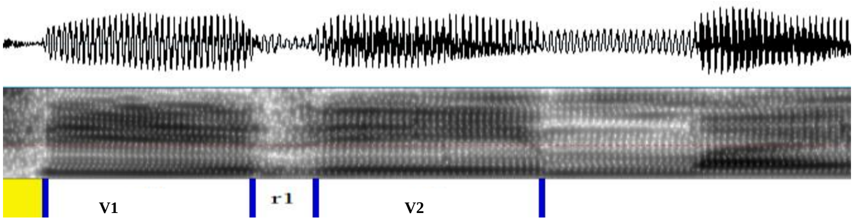

Figure 1 Segmentation criteria for word initial /r/: onset of the constriction was marked at the offset of V1 and offset of constriction at the beginning of the formants for V2. The example sentence here is [I 'leks<u>i 'rima</u> 'ine a'pli] (the underlined part is displayed only)

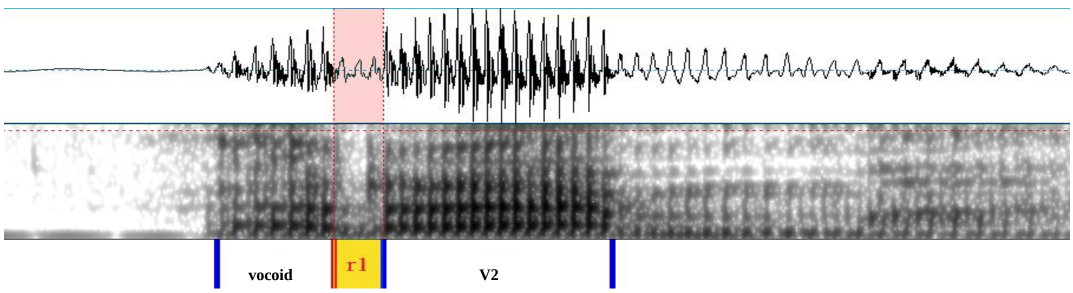

Figure 2 The beginning and end of the vocoid in phrase initial position was marked at the onset and offset of its formant structure respectively. The example here is the word [<u>'</u>rema] uttered in isolation

[1] Throughout the paper the /r/ symbol is used for the Greek rhotic for practical reasons. Similarly, the vowels are transcribed as /i, e, a, o, u/. For a description of the quality of the Greek vowels, see Arvaniti (1999, 2007).

Electropalatographic data were analysed using the Articulate Assistant software (version 1.18) which accompanies the British EPG system used in this study. The artificial palate of this system has 62 electrodes on its surface which detect lingual contact with the palate in continuous speech. Electrodes are distributed in eight rows according to particular anatomical landmarks (Figure 3). The front four rows correspond to the alveolar zone and the back four rows to the palatal zone. The alveolar zone is subdivided to the alveolar and postalveolar regions (rows 1 to 2 and 3 to 4 respectively) (Gibbon & Nicolaidis 1999; Recasens et al 1993).

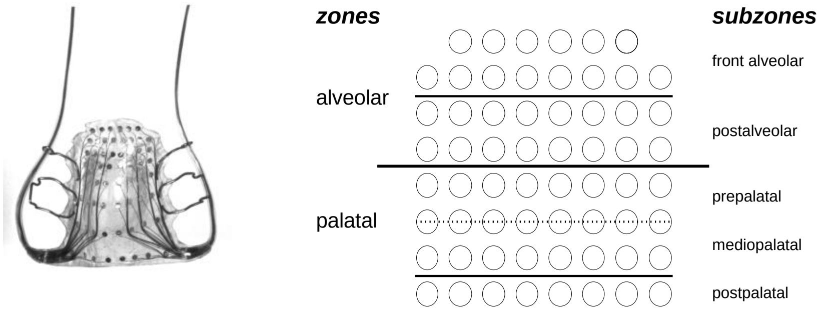

Figure 3 The artificial palate used for the British EPG system marketed by Articulate instruments (left). Schematic representation of electrodes and division of electrodes into zones and subzones (right)

For the articulatory analysis, the first EPG frame of maximum contact/constriction in the four front rows was identified for each rhotic (Figure 4). The four front rows were selected because the place of articulation of the rhotic always occurred in the alveolar zone. The frame of maximum contact typically coincided with the frame of maximum constriction during the rhotic. In the few instances that it did not, the frame of maximum constriction in the alveolar zone was annotated. Following data annotation, the percentage frequency of electrode activation of the entire palate over five repetitions was calculated for the rhotic in each test word (see, e.g., Figure 5).

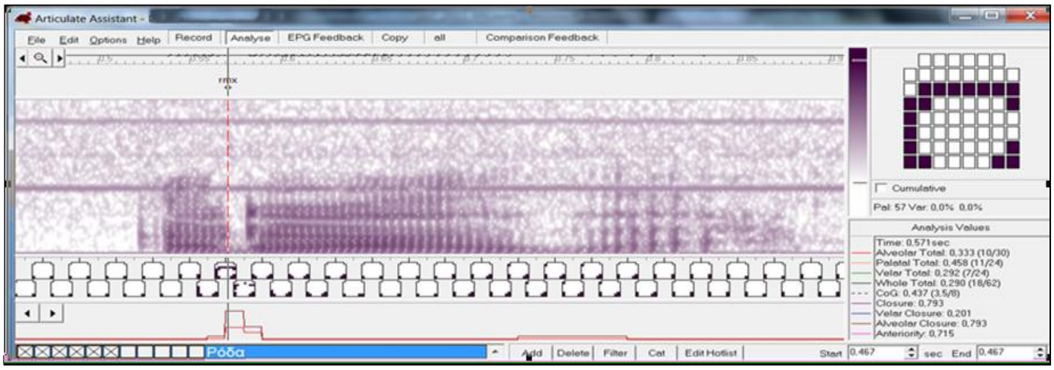

Figure 4 Screen display from Articulate Assistant showing acoustic waveform, spectrogram, EPG palatograms and contact totals display (whole and alveolar totals) for the rhotic in the word ['roða] produced in phrase initial position by the female speaker MM. The annotation line corresponds to the first frame of maximum contact/constriction in the alveolar zone. The corresponding palatogram is shown at the top right of the display

3. Results

3.1 Acoustic analysis

The analysis of the acoustic data (and of the articulatory data, section 3.2) clearly showed that the Greek rhotic is produced as a tap and not a trill. In phrase initial position, i.e. when it is preceded by silence and is unaffected by a preceding sound, its production is typically realized with an initial vocoid followed by a single constriction phase (Figures 2, 4). In word initial position within a phrase and in word-medial position, the typical realization is again a tap with a single constriction of short duration. In these positions, the existence of a vocoid was not as easy to determine because of the presence of V1 before the tap: in word initial, phrase medial position the /r/ initial word was preceded by a vowelending word and obviously in intervocalic position the rhotic was placed between two vowels. There is, however, acoustic evidence suggesting the presence of a vocoid even in these positions. A number of tokens in both prosodic positions showed abrupt amplitude and formant changes during V1 like those shown in Figure 5. The top two panels of Figure 5 show the same sequence, [i#'ru], which is part of the words /'leksi 'rumi/ ‘word rum’ pronounced by the same male speaker, TP, in two different repetitions. Note that the panels show different degrees of disjunction between the two words (no disjunction in the top, clear separation in the bottom), something which permits the detection of the vocoid in the acoustic signal with different degrees of clarity.

The top panel shows an increase in amplitude and a discontinuity in formants approximately in the middle of V1. These acoustic events suggest that the vocalic stretch that we labeled ‘V1’ changes in quality halfway through its duration from the unstressed final [i] of the word /'leksi/ to the vocoid, which is similar in amplitude and formants to the stressed [u] of the word /'rumi/. On the other hand, in the middle panel a pause occurs after the [i], which in turn is followed by a vocoid before the rhotic constriction. Interestingly, the vocalic stretch before the rhotic constriction in the top panel is much longer (over 100ms) than what is expected for an unstressed [i], while in the middle panel [i] lasts less than 60ms. Thus, the middle panel corroborates our analysis of the acoustic events in the top panel.

The bottom panel of Figure 5 shows the sequence [i#'re], part of the words /'leksi 'rema/ ‘word stream’, where the last 1/3 of V1 also shows an abrupt change in amplitude, becoming as loud as the stressed V2. In other words, the acoustic events described above suggest the presence of a vocoid which is adjacent to V1 and to some degree overlaps with it. Although a more in-depth analysis and precise methodology for identifying this vocoid interval in a consistent manner is needed—an issue which we leave open for future investigation—the preliminary evidence provided above indicates that this vocalic gesture is an essential part of the rhotic itself (cf. Blecua 2001 for Peninsular Spanish).

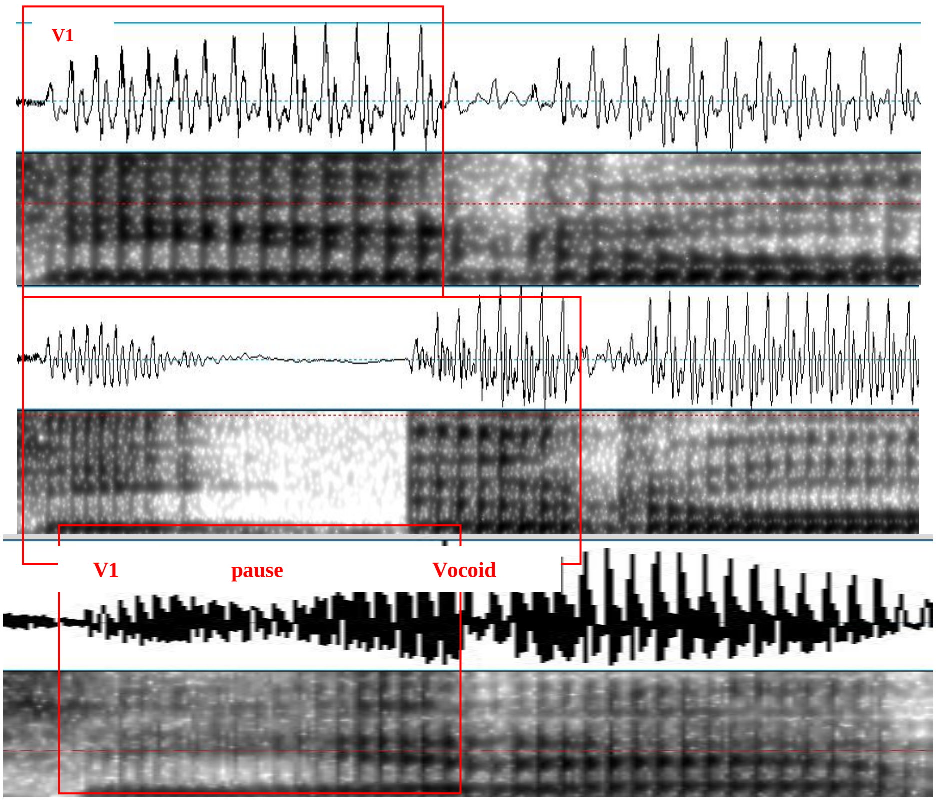

Figure 5 Abrupt formant and intensity discontinuities in V1. The top two panels show the same sequence, [i#'ru], which is part of the words /'leksi 'rumi/ ‘word rum’ pronounced by the same speaker in two different repetitions (please see text for details). The bottom panel shows the sequence [i#'re] in /'leksi'rema/ ‘word stream’. The last 1/3 of V1 also shows an abrupt change in amplitude, becoming as loud as the stressed V2.

The following two sections present the duration and formants results of the acoustic analysis.

3.1.1 Duration results

The duration of the rhotic was compared across the three prosodic conditions in this experiment. Figure 6 presents the results for the constriction durations across all positions and the vocoid duration in phrase initial position. It should be pointed out that the vocoid duration was only measured in phrase initial position (see section 3.1 for an explanation). The number at the top of each column in Figure 6 gives the average duration in ms.

The results showed that the constriction is longest in word initial within phrase position. No difference was found in the constriction duration between the phrase initial and intervocalic positions[2]. Note, furthermore, that the differences in the duration of the constriction across the three prosodic positions are small, with only a 8.5ms difference between the average longest and shortest duration. When comparing these constriction durations to those in /Cr/ and /rC/ sequences reported in Nicolaidis & Baltazani (2011, (submitted)), the duration in word initial position is comparable to its duration in /rC/ sequences (mean 32ms), while the phrase initial and intervocalic position durations are comparable to the average duration in /Cr/ clusters (24ms).

The vocoid, on the other hand, is considerably longer, being more than double in length compared to the constriction phase in phrase initial position. The vocoid in phrase initial position in this experiment was also found to be longer than in /rC/ and /Cr/ sequences reported in Nicolaidis & Baltazani (2011, (submitted)). These comparisons indicate that the different prosodic positions exert an asymmetric influence on the two components of the rhotic. One possible reason for such asymmetries relates to the articulatory nature of these components. The tap, which has been described as a short ballistic gesture in the literature (Lindau 1985; Ladefoged & Maddieson 1996; Recasens & Pallarès 1999; Recasens & Espinosa 2007), is not as free to lengthen as the vocoid. A comparison across more prosodic positions, including data from /Cr/ and /rC/ sequences, which is discussed in more detail in Baltazani & Nicolaidis (forthcoming), can shed more light on questions like these.

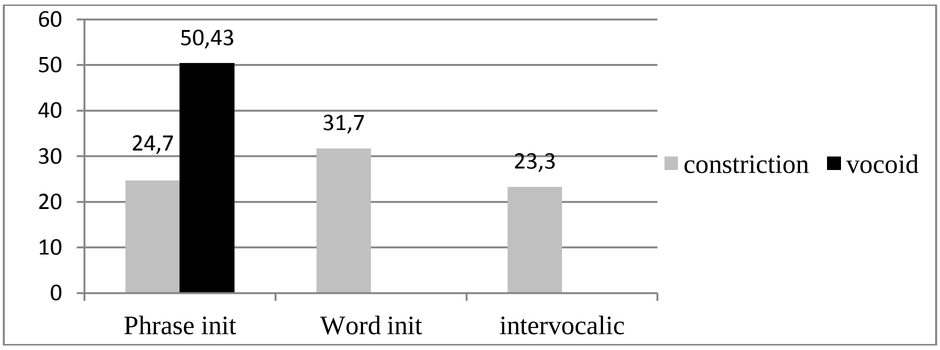

Figure 6 Duration comparison across the three prosodic conditions

3.1.2 Formant results

Measurements of F1 and F2 for the vocoid and the transconsonantal vowel V2, in phrase initial position showed that the formant values of the vocoid in phrase initial position are similar to those of the transconsonantal nuclear vowel, with a tendency to be more centralized than V2.

The four panels in Figure 7 present comparisons of the average formant values for V2 (black line) and the vocoid (grey line) in the F1XF2 vowel space. Centralization tendencies are clearly evident for all speakers for the vocoid.

[2] Tables with details on durations for all conditions broken down by speaker are given in Appendix B.

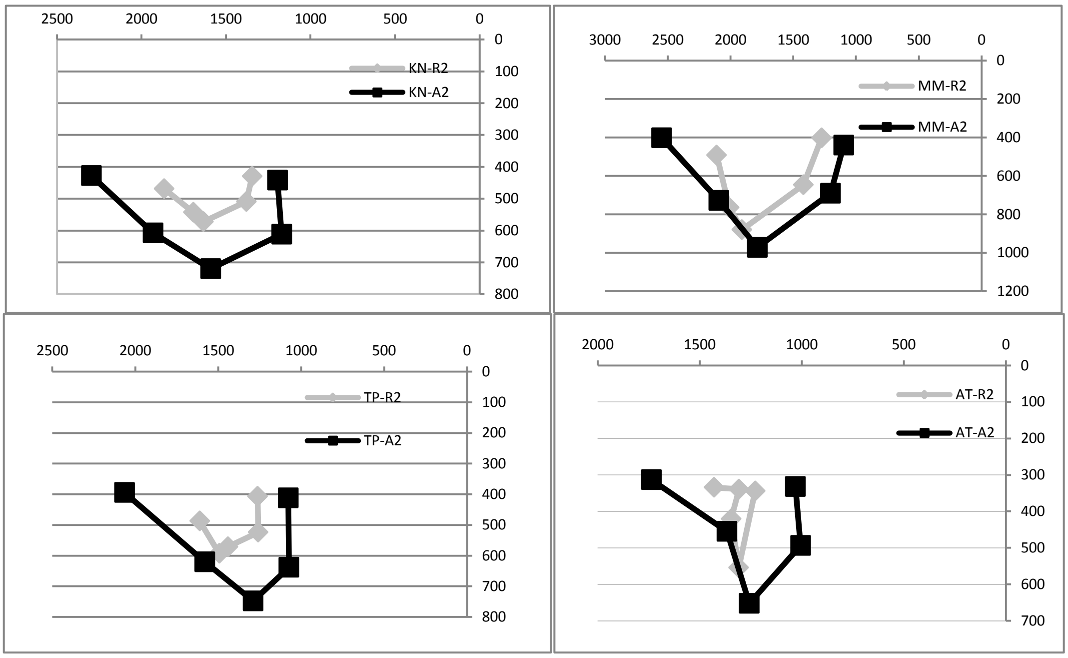

Figure 7 Comparison of V2 (black line) and vocoid (grey line) formant values for four speakers

Variability in the realization of both the vocoid and V2 was found as a function of speaker and of vowel. Figure 8 presents the Euclidean distance between the vocoid and V2 across speakers and vowels. This distance is the square root of the sum of the squares of the difference between the vowel formant frequencies[3] and bigger numbers indicate greater distance between the vocoid and V2 formants, hence a greater amount of centralization for the vocoid. The vowel /i/ shows the greatest amount of centralization overall and the vowel /u/ the smallest, but all vowels show variability across speakers. Among speakers, RP shows the smallest amount of centralization for the back vowels /o, u/ and the greatest amount for /e/, but otherwise the most consistent trend is variation.

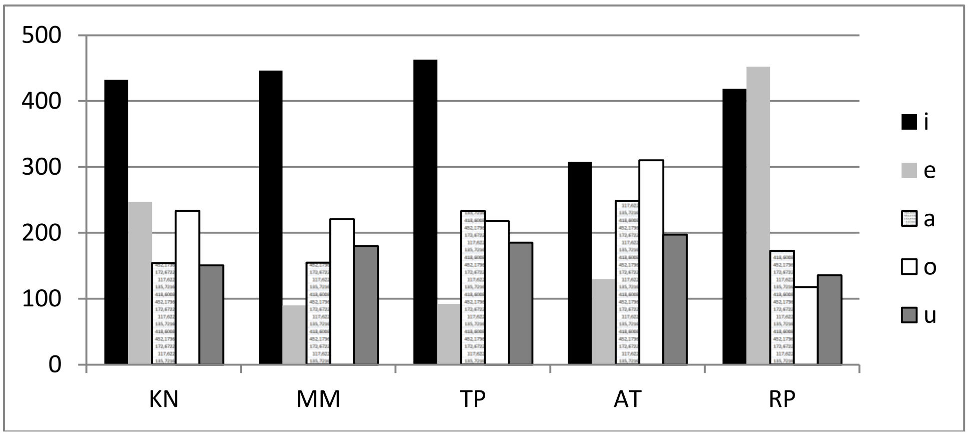

Figure 8 The Euclidean distance between the vocoid and V2 across speakers and vowels

3.2 Articulatory data

The articulatory analysis, consistently with the acoustic analysis, showed that the typical realization of the rhotic involves a single constriction across all three prosodic conditions. The EPG data showed that the articulation of the rhotic varied as a function of the vocalic context, the prosodic position, and the speaker. Variation was evident both in place of articulation and degree of constriction. Figure 9 shows

[3] ED= $\sqrt{((F1V1–F1V2)^2 + (F2V1–F2V2)^2)}$.

an example of variation in place of articulation due to the following vocalic context. More advanced production is evident in the front vowel contexts /i, e/. The palatograms show that in the environment of /i/ and /e/ there is a front alveolar production present with contact in the first and/or second row of electrodes. In the remaining vowel contexts, there is a retraction of the place of articulation with presence of contact in the third row of electrodes especially in the context of /o, u/. The data thus provide evidence of a retracted alveolar or advanced postalveolar articulation in the back vowel contexts.

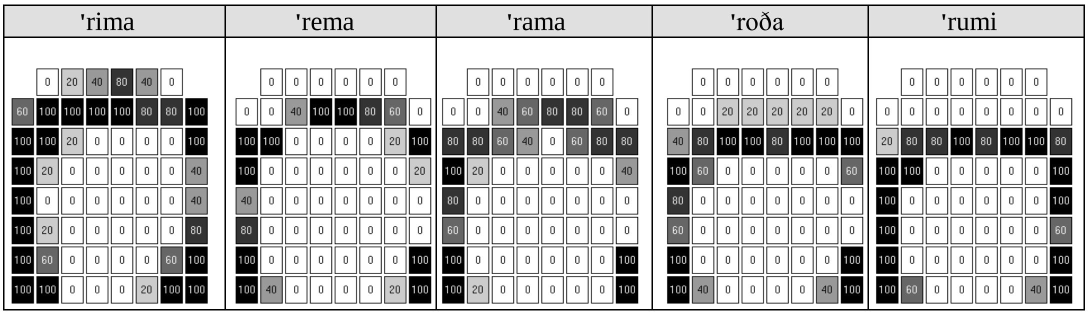

Figure 9 EPG palatograms displaying percentage frequency of electrode activation over five repetitions during the production of the /r/ in phrase initial position in the words (from left to right) /'rima, 'rema, 'rama, 'roða, 'rumi/ by the female speaker MM

In addition, the EPG data showed variation in the degree of constriction of the rhotic. Constriction varied from complete contact, usually across one row of electrodes, to incomplete constriction. Tokens with incomplete constriction ranged from very constricted to very open articulations. An example of complete and incomplete constriction can be seen in Figure 10a, b. In 10b, the very open articulation and the presence of formants throughout the constriction phase of the rhotic indicate the production of an approximant.

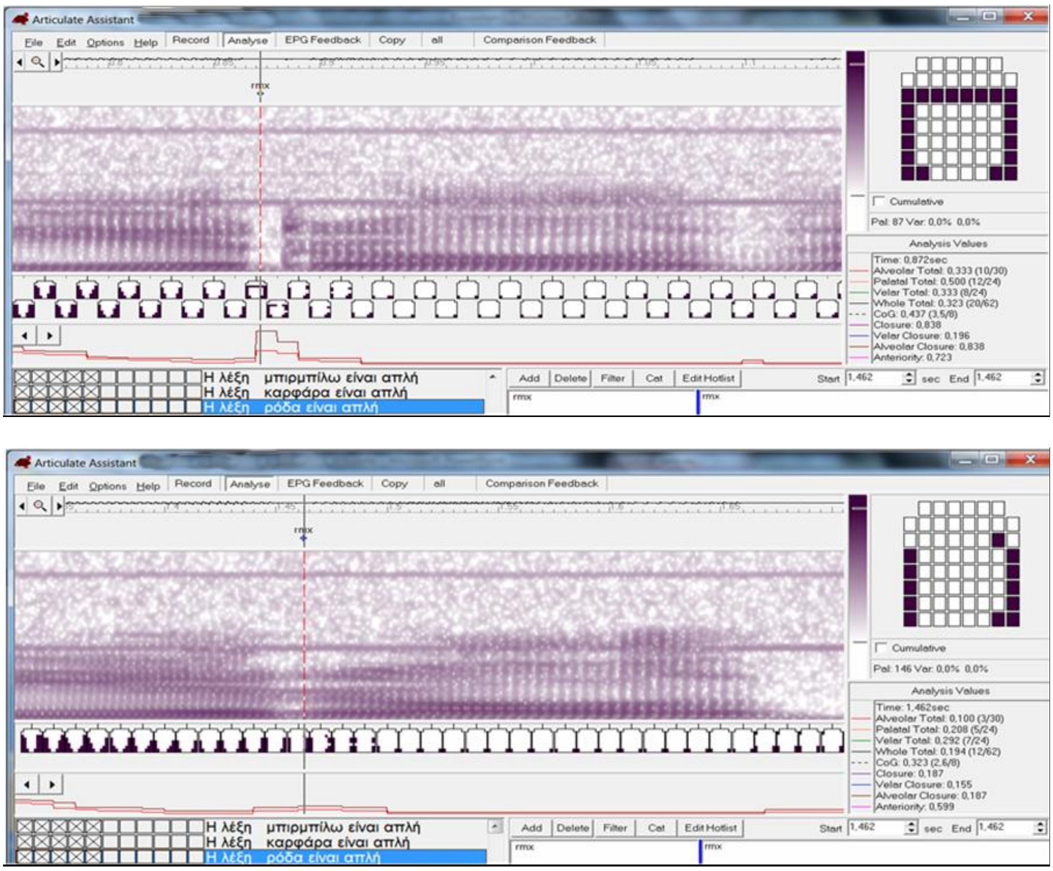

Figure 10 (a, b) Acoustic and electropalatographic data for the rhotic in the word ['roða] in word initial within phrase position. In (a) the rhotic is produced as a tap with complete constriction; in (b) there is incomplete constriction and further acoustic evidence of approximant production

Evidence of an effect of prosodic position on the degree of constriction was found in the data. In particular, more open articulations were observed for the rhotic in word initial within a phrase position compared to the other prosodic positions. A comparison of the data in Figures 9 and 11 for the rhotic in phrase initial and word initial position shows such variation in the degree of constriction.

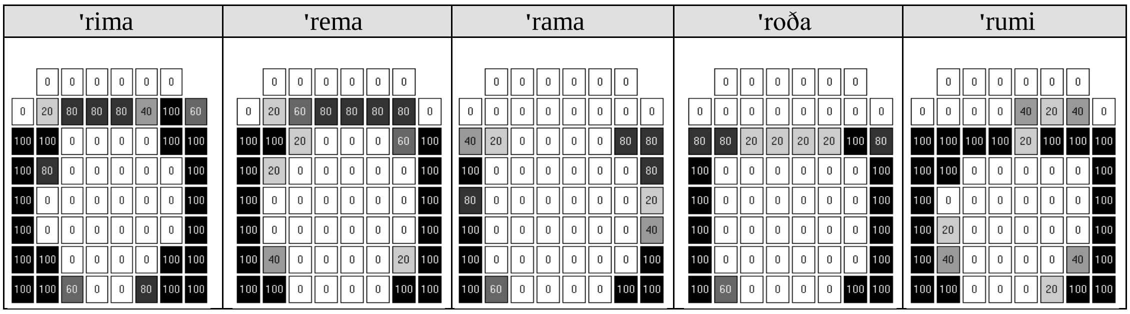

Figure 11 EPG palatograms displaying percentage frequency of electrode activation over five repetitions during the production of the /r/ in word initial within a phrase position in the words (from left to right) /'rima, 'rema, 'rama, 'roða, 'rumi/ by the female speaker MM

Variation in degree of contact, place of articulation and degree of constriction was also evident as a function of speaker. Both within and across speaker variation was observed. Figure 12 presents data from two speakers illustrating such differences in place and degree of constriction. Speaker TP shows overall more advanced and more constricted productions compared to AT. Differences in the amount of contact in the alveolar and palatal zones are also evident.

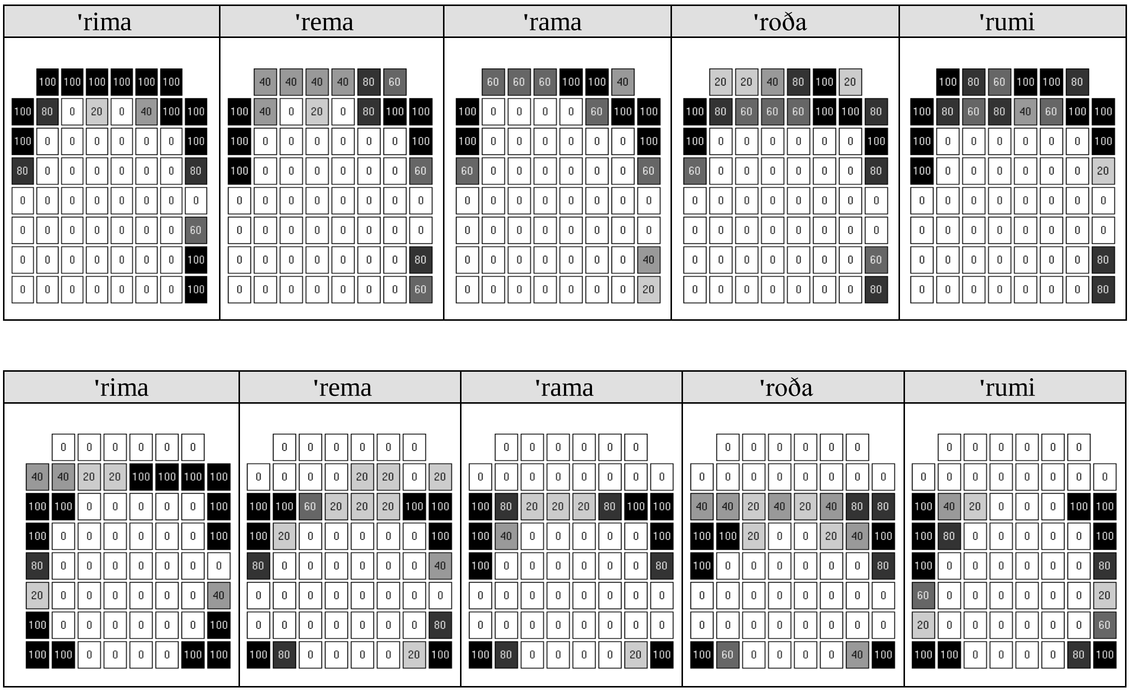

Figure 12 EPG palatograms displaying percentage frequency of electrode activation over five repetitions during the production of the /r/ in phrase initial position in the words (from left to right) /'rima, 'rema, 'rama, 'roða, 'rumi/ for speakers TP (top) and AT (bottom)

The analysis showed that a substantial number of rhotics, 236 out of 375 tokens (63%), were produced with incomplete constriction (Table 1). Both the prosodic position and the speaker influenced production. In particular, more tokens were produced with incomplete closure when the rhotic was in word initial position within a phrase. Speakers KN, AT and RP show considerably more instances of open productions compared to MM and TP; over 80% of tokens for AT and RP and 70% for KN had incomplete closure.

	KN	AT	RP	MM	TP
phrase initial	14	21	21	7	8
word initial	23	25	22	17	11
word medial	18	17	21	8	**3**
Total	**55**	**63**	**64**	**32**	**22**

Table 1 Number of rhotics produced with incomplete constriction in the different prosodic positions by the five speakers

Finally, ten tokens of trill production were found for speaker RP in phrase initial position. Figure 13 illustrates the production of the trill with acoustic and articulatory evidence of two constriction phases and vocoid intervals. The cursor on the spectrogram corresponds to the second constriction phase which is produced with incomplete constriction in the alveolar zone (see palatogram on the top right).

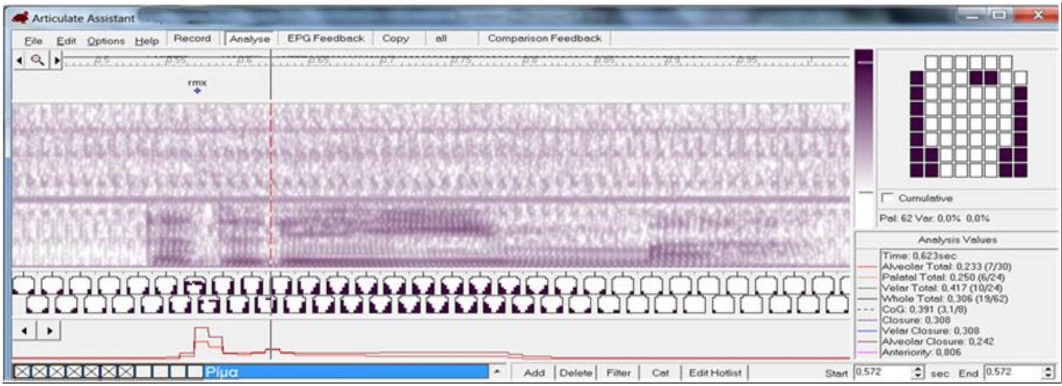

Figure 13 Acoustic and electropalatographic data for the rhotic in the word ['rima] in phrase initial position produced by the female speaker RP. Trill production of the rhotic is illustrated

4. Discussion

The acoustic and articulatory data has shown that there is typically just one constriction present during the production of the rhotic, providing clear evidence for a tap rather than a trill in phrase initial, word initial and word medial position. It should be noted that there were a few tokens of trill production in phrase initial position by one speaker. The duration of the constriction phase was short ranging from 23 to 31 ms, similarly to previous findings from several languages (Lindau 1985; Recasens 1991; Recasens & Espinosa 2007). Such extreme brevity of the tap stems from a ballistic gesture whereby the tongue tip is thrown up against the alveolar ridge (cf. Ladefoged 1993: 168).

In addition to the constriction phase, a vocoid was also found in phrase initial position. Such a vocoid has been documented previously to occur in consonantal clusters or sequences with /r/ in several languages (see section 1). Evidence of its presence in phrase initial position suggests that this vocoid is an inherent part of the articulation of the rhotic which is necessary for the upcoming ballistic movement to take place (cf. Romero 1996 and Blecua 2001 for the rhotic in /Cr/ and rC sequences). Some first indications that this vocoid may be present in word initial within a phrase and word medial position, where the rhotic is flanked by vowels, was also provided. Such instances need to be further investigated but provide preliminary evidence that the rhotic is superimposed on a rhotic-specific vowel-to-vowel gesture (cf. Öhman 1966).

The quality of the vocoid depends on the nuclear vowel of the syllable with /r/. In particular, the vocoid shows similar but somewhat centralized frequencies compared to the nuclear vowel. Similar results were obtained in Nicolaidis & Baltazani (submitted) for /rC/ sequences where the vocoid had somewhat more centralized formant values than V1, the homosyllabic vowel in nuclear position. The similarity between the vocoid and the vowel on the other side of the tap constriction, especially for /Cr/ and /rC/ sequences, has been documented for other languages as well, for example, in several Spanish dialects, Catalan, Romanian, and Hungarian (Navarro Tomás 1918; Bradley & Schmeiser 2003; Bradley 2004; Colantoni & Steele 2005; Recasens & Espinosa 2007; Vago & Gósy 2007; Savu 2012). The fact that a similar structure for the tap has been found for phrase initial position in our data, in an environment that does not involve a second consonant, further indicates that the vocoid is part of the articulation of the rhotic, with the short tap constriction being embedded on a longer vocalic gesture, which it momentarily interrupts (cf. Öhman 1966).

The duration differences found between the vocoid and the constriction further corroborate our interpretation of the rhotic as a tap. Standard descriptions of trills mention equal durations for the vocalic and consonantal intervals of the trill, something which is in accord with their articulatory descriptions as an involuntary trilling which is set in motion by aerodynamic forces (e.g. Recasens 1991). The duration data for phrase initial /r/ show that the vocoid is on average twice as long as the constriction, clear evidence that the Greek rhotic is not a trill.

In addition, variation in the duration of the rhotic (both for the constriction and vocoid intervals) and the formant structure of the vocoid were found due to speaker and prosodic position with an added influence of vowel quality on the formant structure of the vocoid. Smaller differences were found for the constriction than the vocoid, since the articulatory nature of the extremely short ballistic movement necessary for the production of the tap do not leave much freedom for lengthening.

The electropalatographic data provided evidence of variability in the place of articulation of the rhotic and in the degree of constriction as a function of the context, the prosodic position and the speaker. With reference to the place characteristics of the rhotic, it was consistently produced in the alveolar zone but its production ranged from front alveolar to retracted alveolar or postalveolar (cf. Nicolaidis 2001; Nicolaidis & Baltazani 2011, (submitted)). More fronted productions in the environment of the front vowels /i, e/ and more retracted productions in the back vowel environments were evident. Such contextual effects suggest that the tongue tip/blade adapts to the gestures for neighbouring phonetic segments during the production of the rhotic. Similar findings have been reported for taps in other languages (e.g. Recasens & Pallarès 1999; Recasens 1991).

In addition, the degree of constriction ranged from complete contact across one of more rows in the alveolar zone to very open articulations. Evidence that 63% of the tokens were produced with incomplete contact indicated that the rhotic frequently involves approximation of the lingual gesture to the palate (cf. Nicolaidis 2001; Nicolaidis & Baltazani 2011, (submitted)). For these tokens, presence of formant structure during the constriction phase provided further evidence of approximant production (cf. Baltazani 2005, 2009). Across the three prosodic positions examined, more open productions in word initial position within a phrase were found, compared to intervocalic and phrase initial positions, providing evidence of influence of prosodic position on the articulation of the rhotic. Interestingly, these results suggest that the factor regulating the amount of contact in the three prosodic positions is not solely the strength of the boundary since, for instance, more tokens with complete constriction were found intervocallically than in word initial position. This finding together with the variation reported for the duration of the constriction phase and the vocoid in the different prosodic positions (including the /Cr/ and /rC/ sequences examined in Nicolaidis & Baltazani 2011, (submitted)) suggest that more investigation is necessary to account for the spatial and temporal variation present during the production of the rhotic as a function of prosodic position.

Finally, the speaker was also an important source of variation with substantial differences in place of articulation (more fronted productions for some speakers and more retracted for others), constriction degree (more open productions vs more constricted productions) and overall amount of contact.

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Appendix A

The experimental material shown below in A, B, and C corresponds to the prosodic positions explained in the text. The target sequences measured are shown in bold.

A. [r] in intervocalic position, in a carrier sentence.

Η λέξη	Μαρίκα μαράκα μαρέγκα Μαρόκο μαρούλι	είναι απλή	[i 'lek**si**	ma'**ri**ka ma'**ra**ka ma'**re**ga ma'**ro**ko ma'**ru**li	'ine a'pli]	'The word	'marika' 'maraka' 'marega' 'maroko' 'maruli'	is simple.'

B. [r] in phrase initial position.

Ρίμα	*Ρόδα*	*Ρέμα*	*Ράμα*	*Ρούμι*
['**ri**ma]	['**ro**ða]	['**re**ma]	['**ra**ma]	['**ru**mi]
'Rhyme'	'Wheel'	'stream'	'Stitch'	'Rum'

C. [r] in word-initial, phrase medial position.

Η λέξη	ρίμα ρόδα ρέμα ράμα ρούμι	είναι απλή	[i 'lek**si**	'**ri**ma '**ro**ða '**re**ma '**ra**ma '**ru**mi	'ine a'pli]	'The word	'rima' 'roda' 'rema' 'rama' 'rumi'	is simple.'

Appendix B

Vocoid duration: phrase initial /r/

	/'rima/	**/'rema/**	**/'rama/**	**/'roða/**	**/'rumi/**	**Cross word avg**
TA	67,96	71,17	61,42	68,27	57,43	**65,25**
AP	42,36	42,90	57,71	45,19	55,83	**48,80**
KN	61,77	64,25	48,00	59,43	45,42	**55,77**
MM	30,51	36,88	50,58	33,86	38,74	**38,11**
RP	31,34	47,86	trill	55,43	42,23	**44,21**
Cross sp avg	**46,79**	**52,61**	**54,43**	**52,44**	**47,93**	**50,43**

Constriction duration: phrase initial /r/

	/'rima/	**/'rema/**	**/'rama/**	**/'roða/**	**/'rumi/**	**Cross word avg**
TA	21,09	28,19	24,75	24,32	23,34	**24,33**
AP	30,43	25,52	27,60	42,57	18,48	**28,92**
KN	23,95	28,77	21,80	25,67	23,21	**24,68**
MM	19,35	23,08	17,81	21,37	18,76	**20,07**
RP	22,73	25,95	21,80	22,28	35,87	**25,73**
cross sp avg	**23,51**	**26,30**	**22,75**	**27,24**	**23,93**	**24,75**

Constriction duration: word initial /r/

	/'rima/	**/'rema/**	**/'rama/**	**/'roða/**	**/'rumi/**	**Cross word avg**
TA	28,97	24,77	32,22	24,24	33,68	**28,78**
AP	31,09	35,77	39,85	25,49	30,95	**32,63**
KN	25,76	32,55	37,41	34,47	36,87	**33,41**
MM	22,25	26,09	29,81	29,16	36,76	**28,81**
RP	29,48	30,57	52,60	24,59	39,32	**35,31**
Cross sp avg	**27,51**	**29,95**	**38,38**	**27,59**	**35,52**	**31,79**

Constriction duration: intervocalic /r/

	/ma'rika/	**/ma'rega/**	**/ma'raka/**	**/ma'roko/**	**/ma'ruli/**	**Cross word avg**
TA	25,68	25,94	25,89	29,33	27,09	**26,78**
AP	31,06	30,56	21,89	23,15	26,51	**26,63**
KN	23,14	17,83	20,39	16,42	26,95	**20,95**
MM	17,36	18,31	20,11	22,47	27,49	**21,15**
RP	21,86	21,04	19,06	19,81	23,78	**21,11**
Cross sp avg	**23,82**	**22,73**	**21,47**	**22,24**	**26,36**	**23,32**