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REALIZATIONS OF THE FRENCH *r* AND THEIR DISTRIBUTION IN A WORD: A PRELIMINARY STUDY

Denis Ramasse

Université de Caen Normandie & CRISCO (EA 4255)

denis.ramasse@unicaen.fr

Abstract

Acoustic descriptions of the realizations of the French sound represented by the letter *r* (canonically the voiced uvular fricative [ʀ]) show a relative regularity. Besides elisions and realizations as a uvular tap ([r̥]), which are few in number, two main classes of *r*-sounds can be distinguished—one more consonantal (fricative *r*, [ʀ]) and the other more vocalic (approximant *r*, [r̥]). A corpus study (1000 samples from 50 speakers) was carried out. The results showed that voiced fricatives generally appear in initial and medial positions, whereas voiced approximants appear in the final position. Realization in the intervocalic medial position and in contact with a consonant is more precisely studied; those results demonstrated that voiceless fricatives appear medially after a voiceless consonant while voiceless approximants appear medially before a voiceless consonant.

Keywords: French, uvular, fricative, approximant, rhotic, voicing

1 Introduction

An ongoing challenge for phonetic studies is understanding the relationship between the different realizations of the underlyingly same unit. This challenge is particularly acute with segments that are very much influenced by position in their realizations, such as *l* and *r* in languages like English and French. In particular, it is not clearly known exactly how and in which positions *r* (that is, canonically, the uvular fricative voiced phoneme /ʀ/ as described by Grammont, 1914 and Simon, 1967) is realized in Standard French.

The place of articulation for *r* is undisputed. It is a uvular consonant even if, as shown by cineradiographic studies (Bothorel *et al.*, 1986), some realizations are velar. But if there are only two possibilities for realizations when voicing, there are three possibilities for manner: fricative, approximant, or tap. The combination of voicing and manner of articulation results in two fricatives: [χ], [ʀ], two approximants: [r̥], [r̥], and two taps: [r̥], [r̥]. Elision results in a seventh possibility for realization. Therefore, it is essential to understand the role of word position for each of these seven possibilities. There is currently no research to support that elision results in a different realization, so the existence of only one tap has been described. Therefore, five realizations currently have been described for the rhotic.

These five realizations of the phoneme /ʀ/ appear in different word positions. They were previously described as: the tap [r̥] Meunier (1994, 2007), two approximants, voiceless [r̥], and voiced [r̥], (Tranel, 1987; Fougeron & Smith, 1993), and two realizations as voiceless and voiced fricatives, [χ] and [ʀ] (Tranel, 2003). But precise descriptions of the word

position (initial, medial and final), or phonetic environment of the voiceless approximant [ʁ̥] and the voiced fricative [ʁ] have not been described.

The purpose of the present paper is to explore the phonetic realizations of *r* and provide descriptions of the seven realizations that have been proposed above. The following questions are asked: (i) How many realizations of *r* are there in French? (ii) In which word position (*i.e.*, initial, medial or final), do they appear? (iii) In which position is there an influence of the neighboring sounds? (iv) Are there only voiced uvular taps in French? (v) When a rhotic is elided, does it disappear completely or are there traces of what should have been its realization in the acoustic signal?

Previous research has shown that there are five realizations of the rhotic (Meunier 1994, 2007; Tranel, 1987; Fougeron & Smith, 1993; Tranel, 2003). This paper hypothesizes that there are in fact seven realizations of the rhotic. These realizations of the French rhotic depend on word position, but can be subject to coarticulation resulting from the neighboring sounds. Perhaps elision is not a total disappearance of the rhotic, but a discrete manifestation detectable both at the acoustic and the perceptual levels. In addition, there may be an unvoiced uvular tap. Finally, the frequency of occurrence of uvular taps does not appear to be as consistent as the other realizations.

2 Methods

2.1 Production

2.1.1 Subjects. There were 50 participants in the study (25 males, 25 females). The age range of the participants was 27–62 years with a mean age of 47.5 years. All participants were native French speakers, living in metropolitan France since childhood. At the time of interview, all participants were living in France. Their professions included writers, journalists, actors, singers, and sports broadcasters, as well as a bookseller and a photographer. All the participants were free from speech, language and hearing disorders.

2.1.2 Material. The corpus was comprised of interviews broadcast on television news programs, such as the *Journal de 20 heures* (TF1) and *19/20* (France 3); literary programs (*La Grande Librairie*); talk shows (*On n'est pas couché*), and political broadcasts (*Ripostes*). Other interviews were found on websites (*Allociné*, *MusiqueMag*, etc.). The interviews were chosen for their structure, where the interviewer posed short questions and the interviewees gave a spontaneous unscripted answer. These conversations allow for the natural flow of language. The topic of the interview varied from discussing the last book of a writer to the last movie of an actor. The duration of the corpus was 5h 22min and the mean duration of an individual interview was about 6min.

Personal data regarding gender, profession and age was gathered for each interviewee in the corpus. The recordings conducted in Standard (France) French (consisting of soundtracks of videos) were spread over a period of about four years (2009–2013). This was to negate any dialectal influences associated with regional or foreign differences in the syntax, lexicon, or pronunciation.

2.1.3 Analysis of the corpus. Two methods were used for the analysis of the data. A manual analysis and an automatic classification.

a) Manual analysis. Two segmentation criteria were used depending of the nature of the rhotic: (i) The presence of a friction noise; *i.e.*, a fricative was segmented from the beginning

to the end of the friction noise. (ii) The instability of the formants, *i.e.*, an approximant differs from a vowel by the instability of its formants which tend to rise or to go downwards. In this case, the rhotic was segmented at the beginning and at the end of the formant's movement. In some cases, segmentation was done first with a manual segmentation using Praat (Boersma & Weenink, 2014) and then with an auditory analysis. For each studied rhotic, the author estimated the following 3 parameters by manual measurements and segmentation. (i) Sound Pressure Level, expressed on a logarithmic scale in dB SPL (measured at the center of the consonant with Praat software). (ii) Duration and (iii) Voicing (measured with the pitch analysis module of Speech Analyzer (1996–2012; the presence of pitch during the realization of the consonant attesting to its voiced nature). Where the analyzed consonant presents a friction noise, the frequency of the lowest part of the noise was analyzed with Praat and recorded. The median value of these measures is provided in Table 3. Where the analyzed consonant is vocalic, the frequency of the first three formants, F_1 , F_2 and F_3 , were analyzed with Speech Analyzer; the first three maxima above the fundamental in the spectrum were identified as the first three formants and recorded. The median value of these measures is given in Table 2. The nature of the neighboring sounds (vowel, voiced consonant, voiceless consonant) before and after the focal consonant were recorded to describe the coarticulation.

In the recordings, approximately 20 realizations were acoustically analyzed (Sound Pressure Level, duration, voicing, and, for realizations with formants, F_1 , F_2 and F_3 only in the case of the vocalized realizations for each speaker). There were 1000 analyses of the realization of *r*, and with the study of the 29 elisions, 1029 realizations of *r* were analyzed in this study.

This corpus provides information about the phonetic position of each realization of the rhotic and tests a method that may be used later to obtain more significant results with a larger corpus. The realization of the French rhotic depends on word position (initial, medial and final), but can be subject to the coarticulation provoked by the neighboring sounds.

b) Automatic analysis. According to Gendrot *et al.* (2015), French rhotics are aligned on a continuum whose extremes are a voiced approximant on one side and an unvoiced fricative on the other side. This is depicted in Figure 1 (voiced approximant) and Figure 2 (unvoiced fricative). On one side, the rhotic is vocalic and realized with a formant structure (Figure 1). On the other side, the rhotic is consonantal and realized with a friction noise (Figure 2). Between these two extremes, as described by Tubach (1989: 115), the rhotic can present a disparate nature with laryngeal sonorous excitation and a friction noise (Figure 3).

The examination of the bandwidth of the realized rhotic permitted discrimination between a more vocalic and a more consonantal aspect. According to the description of Jakobson *et al.* (1951: 46), the vocalic consonants “are acoustically characterized by the presence of formant with small damping and hence with a relatively narrow band width”. These differences are exemplified in Figure 1 with an approximant and in Figure 3 where the sound is a voiced fricative. Another voiced fricative is illustrated in Figure 4.

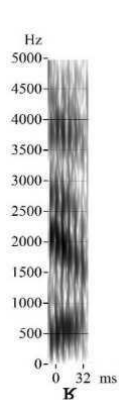


Figure 1. Spectrogram of the realization of /ʁ/ as a voiced approximant [ʁ̥].

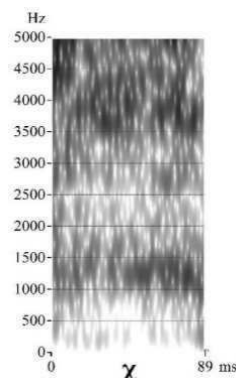
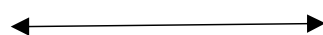


Figure 2. Spectrogram of the realization of /ʁ/ a voiceless fricative [χ].

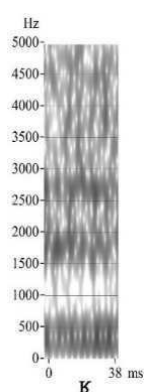


Figure 3. Spectrogram of the realization of /ʁ/ as a voiced fricative [ʁ̥].

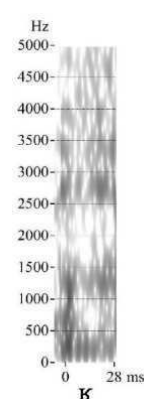


Figure 4. Spectrogram of the realization of /ʁ/ as a voiced fricative [ʁ̥].

In these examples, in particular for F_2 , the bandwidth is a little narrower when an approximant is realized than when a fricative is realized. I used the automatic discrimination algorithm proposed by Fisher (1936) and implemented it with SPSS. “Discriminant Analysis (DA) is an old method (Fisher, 1936) which in its classic form has changed little in the past twenty years. This method, which is both explanatory and predictive, can be used to show the properties of the groups using explanatory variables” (XLSTAT, 1995–2017). It was necessary to have cues (intensity and duration) which could be used in this automatic discrimination and three sources were consulted. (i) Sacia and Beck (1926) measured intensity of vowels and consonants and it appears from their experiment that approximants are between vowels and obstruents on the intensity scale. (ii) Martínez-Celdrán (2004) described the approximants (Figure 1: p. 203) in the following way: “The relevant features are short duration and weakened glottal pulses between vowels”. (iii) Gendrot *et al.* (2015) observed that the voiceless fricative had longer durations than the corresponding reduced form realized as a voiced approximant. Therefore, there are two acoustic cues permitting discrimination between fricatives and approximants: intensity and duration. Intensity distinguishing fricatives and approximants, as well as vowels and approximants. As described by Maddieson and Emmorey (1985: 164): they differ in amplitude or ‘prominence’. Duration and Sound Pressure Level were also considered

in this automatic distinction. Therefore, DA was applied to the corpus in order to distinguish between fricatives and approximants; however, the frequency of the formants was not taken into account in this analysis. For each parameter (duration and SPL data), normality was verified by Kolmogorov–Smirnov and Shapiro–Wilk tests and the homoscedasticity by Levene’s test. The DA revealed that the “manual” attribution of the sound category (approximant or fricative) permitted a correct categorization decision in 74.5% of the cases. Standardized canonical discriminant function coefficients were as follows: SPL coefficient (0.972) had a more predominant role in the classification than duration (-0.199), and there was an inverse correlation between the two coefficients. Automatic allocation of the nature of the consonant by DA, in combination with the results of the analysis of the F_0 curves of the sounds by Speech Analyzer, allowed the precise nature of the sounds to be established.

The ‘elided’ consonant should leave no trace in the acoustic signal. If that is the case, ‘*parce (que)*’ ‘*because*’ should be homophonous with ‘*passe (que)*’ ‘*happens that*’. Is this the case? One could wonder whether the rhotic disappeared from the acoustic signal without leaving any trace. To confirm this, I analyzed the acoustic realizations of [a] and [s] in the word *parce que* where elision occurred and compared these realizations to realizations of the same sounds in *passe que* produced by the same speaker in the same interview. All possible parameters were studied and four parameters appeared to differ: F_1 of the vowel [a], SPL of the consonant [s], duration of [a] and duration of [s]. For each parameter (F_1 , SPL and duration data), the normality was verified on XLSTAT using Kolmogorov–Smirnov and Shapiro–Wilk tests and the homoscedasticity by Levene’s test. I analyzed the uvular taps by observing the spectrographic and oscillographic representations of the consonants, and voicing was measured with the pitch analysis module of Speech Analyzer. The tap itself was visible on both the spectrogram and the oscillogram.

2.2 Perception

If traces of the elided rhotic remain, is this elision real from a perceptual point of view? The reality of the elision should be tested from a perceptual point of view. If that is so, two questions must be considered: (i) Can a listener identify a word with an elided *r* only by hearing the acoustic traces, when the word is out of context? (ii) Can a listener distinguish between a form with an elided *r* and exactly the same form without any elision? If so, the acoustic traces on the neighboring sound of the elided *r* would be audible. Given this, a two perceptual tasks was prepared: an identification test and a discrimination test.

I chose two stimuli in the corpus: The first one was [paskə] *pasque* (*parce que* with an elision) ‘*because*’ pronounced by a female. The second one was [pas] *passe* ‘*happens*’ as in *il se passe que* ‘*it happens that*’ pronounced by the same female. The last part [kə] of the first stimulus was copied and put at the end of the second stimulus, resulting in two stimuli [paskə]. The first one had the traces of the elision of the rhotic, the second one did not.

2.2.1 Identification test. These stimuli were presented in a random order in two series of four stimuli. Before these two series, the two stimuli were presented to acclimate the listeners to the stimuli. The time interval between the stimuli in the series was 3 seconds and the time interval between the two series was 14 seconds. I presented this test to 20 listeners, who were students in French Grammar. Four of them were Erasmus students (from Denmark, Germany, Italy and Poland) and the remaining listeners were French (most of them from Normandy). These students were aged between 20 and 24 years. Each stimulus was judged four times by

twenty subjects; *i.e.*, 80 times. An answer form was provided to each listener. For each stimulus, they had to mark their answer in a square corresponding either to *pa↓ske* or to *passe que*. As there was no significant difference in responses between native and non native speakers of French, all answers were analyzed together.

2.1.2 Discrimination test. The same stimuli were presented in pairs to the same subjects. Each pair was heard 6 times by each subject (three times in the first order, three times in the reverse order). The result was 120 responses, across all subjects ($N = 20$). Each stimulus was also compared to itself, These pairs were not taken into account in the results. All pairs were presented in a random order in two series of four pairs. Before these two series were initiated, two pairs, one with identical stimuli and one with different stimuli, were presented to the listeners for practice. The time intervals between stimuli within the pair was 600 ms, 3 s between pairs, and 14 s between the two series. An answer form was provided to the listeners. For each pair of stimuli, they had to mark their answer in a square corresponding either to *identical* or to *different*.

3 Results

3.1 Fricatives and approximants

The coefficients and the results of the DA are presented in Table 1 and Figure 5. Two coefficients, SPL and duration, in inverse correlation took a part in the discrimination but SPL played a leading part. The mean for each class and the thresholds between these classes for the parameter of Sound Pressure Level are given for fricatives and approximants. The range for fricatives was 34.6–77.4 dB, and the range for approximants was 63.5–83.4 dB, indicating that the SPL threshold between fricatives and approximants was equal to 65.24 dB. The mean values for each category were equal to 59.2 dB and 72.02 dB respectively.

Table 1. Standardized canonical discriminant function coefficients. SPL, as a coefficient, had a more predominant role in the classification than duration and that there is an inverse correlation between the two coefficients.

	Function 1
SPL	.972
Duration	-.199

The uvular consonants (the French *r*-sounds) were studied in three positions: initial, medial and final. The phonetic environment should also be considered as the coarticulation could affect the realization of the consonant in each of these positions. So, consideration was given to the nature of the preceding sound and/or the following sound. Results from the Discriminant Analysis revealed that the sounds of the corpus were distributed into four main classes: voiced approximants, voiceless approximants, voiced fricatives, and voiceless fricatives. In Figure 6, it appears that the two extremes of the continuum (according to Gendrot *et al.*, 2015) formed by the realizations of the rhotic in French are frequently occurring and that voiceless approximants are relatively infrequent.

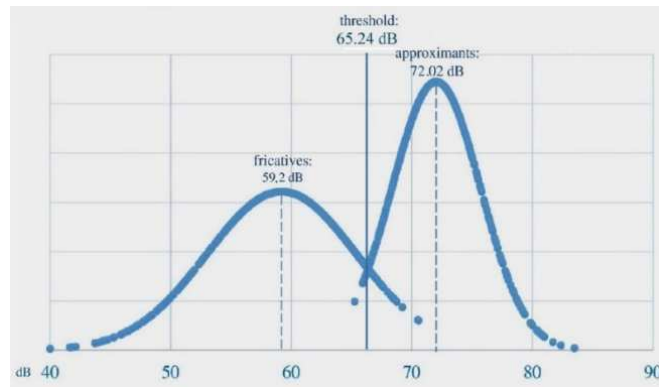


Figure 5. Discriminant Analysis. The fricatives SPL values distribution is lower than approximants SPL values distribution. The threshold between both is 65.24 dB: A rhotic with a SPL value lower than this threshold is considered as a fricative and conversely a rhotic with a SPL value upper than this threshold is considered as an approximant.

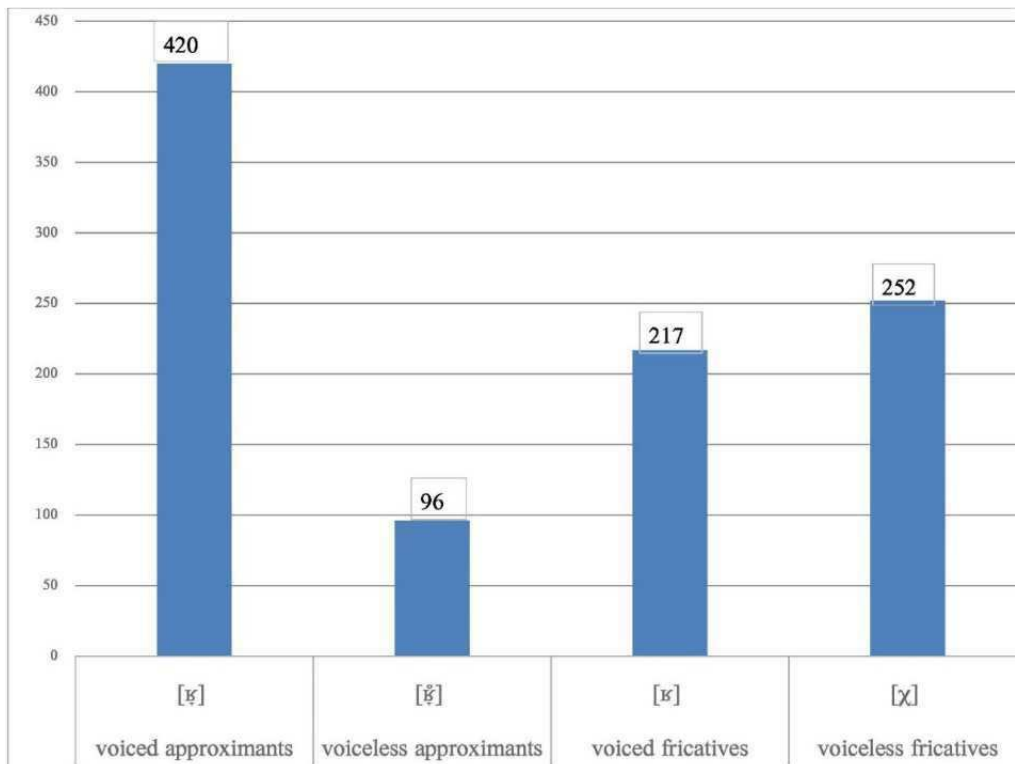


Figure 6. Result of Discriminant Analysis: distribution of the rhotics into four classes.

3.2 Acoustic realization of fricatives and approximants

The acoustic description of the extremes of the continuum (according to Gendrot *et al.*, 2015) formed by the realizations of the French /ʁ/ are described below.

3.2.1 Voiced approximants. According to Tubach (1989), the spectrum of the French rhotic across all dialects is close to the spectrum of the vowel [o]. To confirm this assertion, a comparison of the median value of the frequencies of the first three formants for the rhotic are indicated above the corresponding values of back vowels [ɑ], [ɔ] and [o], as provided by

Tubach (1989) (see Table 2). The median and the standard deviation are given in Hz. The coefficient K_i expresses the relationship between female and male speakers values. K_i was obtained by dividing the female speaker values by the corresponding male speaker values. Results indicated that the F_2 and F_3 of [ʁ] were closer to the F_2 and F_3 values of [ɑ] than [o] and, in general, [ʁ] is acoustically close to a posterior vowel.

3.2.2 Unvoiced fricatives. In unvoiced fricatives, the realization is made by a friction noise whose base is low. The frequency of this base is indicated in Table 2. The corresponding values /extracted from Meunier (2007) for [s] and [ʃ] and from Tubach (1989) for [f]/ for the other French unvoiced fricatives are given below for comparison. The coefficient K_i expressing the relationship between female and male speakers values was obtained by dividing the female speaker value by the corresponding male speaker value. For [χ], this limit was lower than for the three other French fricatives.

Table 2.a,b Median frequencies (Hz) of the three formants for all of the approximant rhotics of the corpus compared to the median of the first three formants (Hz) for the three posterior French vowels: [ɑ], [ɔ], and [o] provided in Tubach (1989). K_i is the ratio between female and male values.

a)		F_1	F_2	F_3
		[ʁ]		
male	median	509	1291	2542
	σ	159	465	491
Ki	$F_{i\text{-female}}/F_{i\text{-male}}$	1.04	1.06	1.09
female	median	530	1363	2781
	σ	150	366	371

b) Tubach (1989)		[ɑ]			[ɔ]			[o]		
		F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
male	median	684	1256	2503	531	998	2399	383	793	2283
	σ	47	32	131	39	60	116	22	63	126
Ki	$F_{i\text{-female}}/F_{i\text{-male}}$	1.15	1.2	1.09	0.19	1.18	1.12	1.2	1.08	1.21
female	median	788	1503	2737	634	1180	2690	461	855	2756
	σ	51	86	174	48	59	198	38	73	240

Table 3. Median frequency (Hz) of the lower part of the friction noise of average value for all the fricative rhotics of the corpus compared to the noise lowest part frequency values (Hz) given by Tubach (1989) for the other French fricatives.

K_i is the ratio between female and male values.

	[χ]		[f]	[s]	[ʃ]
	male	female	(Tubach, 1989)		
Median	839	941	1500	4000	2000
Standard deviation	244	269			
Ki	1.12				

3.2.3 Distribution of fricatives and approximants in a word. Two approaches for describing the distribution of the rhotic were used here. The first one considered the initial, medial and final positions of the word. For the second one, the surrounding sounds were

considered to reveal coarticulation in these positions. The medial context was analyzed more accurately and the influence of three external factors likely to influence the realization of the rhotic were taken into account: (i) A preceding word or a subsequent word, (ii) A preceding pause word or a subsequent pause, and (iii) Prosody (accent).

Study of the initial, medial and final positions of the word. In this first approach, three positions (initial, medial, final) in the word were distinguished. The position of the realizations was analyzed by Correspondence Analysis (CA; Benzécri *et al.*, 1976; Greenacre, 1984, 1993). The contingency table is provided in Figure 7 and the plot obtained from the Correspondence Analysis is presented in Figure 8. Greenacre (1993) calls the CA plot a *map* and describes it in the following terms: “Correspondence analysis is a generalization of a simple graphical concept with which we are all familiar, namely the *scatterplot*. The scatterplot is the representation of data as a set of points with respect to two perpendicular coordinate axes: the horizontal axis often referred to as the x-axis and the vertical one as the y-axis” (1993: 1). “In some cases the x and y variables are similar entities with comparable scales, in which case interpoint distances can be interpreted as a measure of difference, or dissimilarity, between the plotted points. In this special case we call the scatterplot a *map*” (1993: 8). According to him, this plot “can be regarded as a *map*, because the position of each [element] can be regarded as a two-dimensional position, almost like a geographical location in a region defined by latitude and longitude” (1993: 4). He opposes a symmetric map (symmetrically scaled) and prefers “an *asymmetric map*, or a map which is asymmetrically scaled” (1993: 68). “The best-fitting line in each analysis is called a *principal axis*. More specifically it is referred to as the “first principal axis” since there are other principal axes (1993: 60). “In practice ... most of the reported CA displays are two-dimensional, usually with the first principal axis displayed horizontally (the x-axis) and the second principal axis vertically (the y-axis)” (1993: 65).

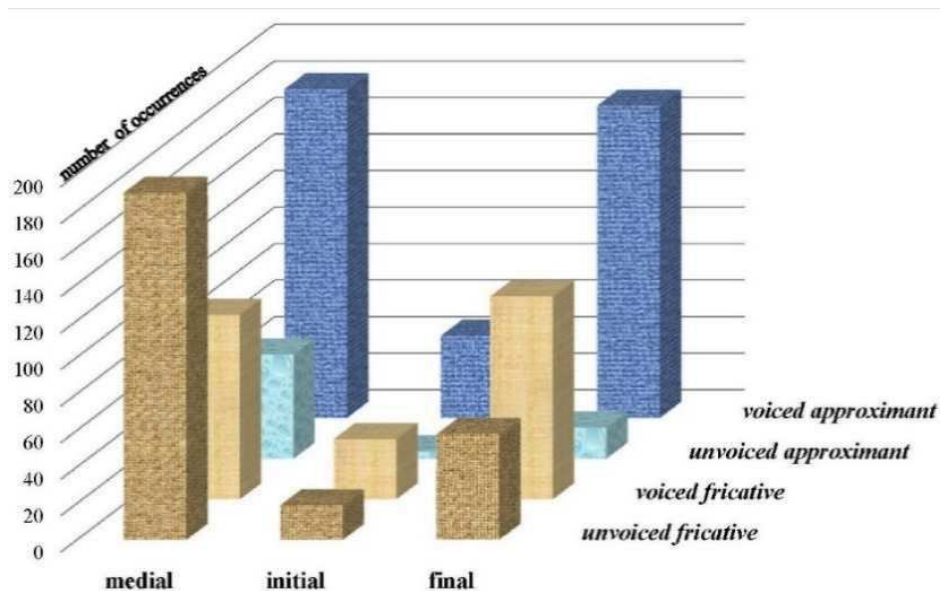


Figure 7. Results of the contingency table depicting positions of different realizations by word position.

In the symmetric maps presented here, the first principal axis displayed horizontally is called *axis 1*; and the second principal axis and the third principal axis displayed vertically are called respectively *axis 2* and *axis 3*. The percentage of explained variance for each axis is given in brackets.

The symmetric map in Figure 8 reveals that the first axis represents voicing as the principal parameter (99.31% of the variance). Unvoiced realizations of *r* appear on the right and the voiced ones on the left. Unvoiced fricatives and unvoiced approximants appear in the medial position. The second axis (0.69% of the variance) shows the distinction between voiced fricatives (below the line) and voiced approximants (above the line) is a less important, parameter. Voiced approximants tend to appear in the final position, whereas voiced fricatives appear in the initial position. There were two different descriptions relative to the context of the voiced approximant: final (Fougeron & Smith, 1999), intervocalic (Meunier, 2007). It appears that Fougeron and Smith (1999) supports the results of this study. There was no previous research to support the distribution of voiced fricatives.

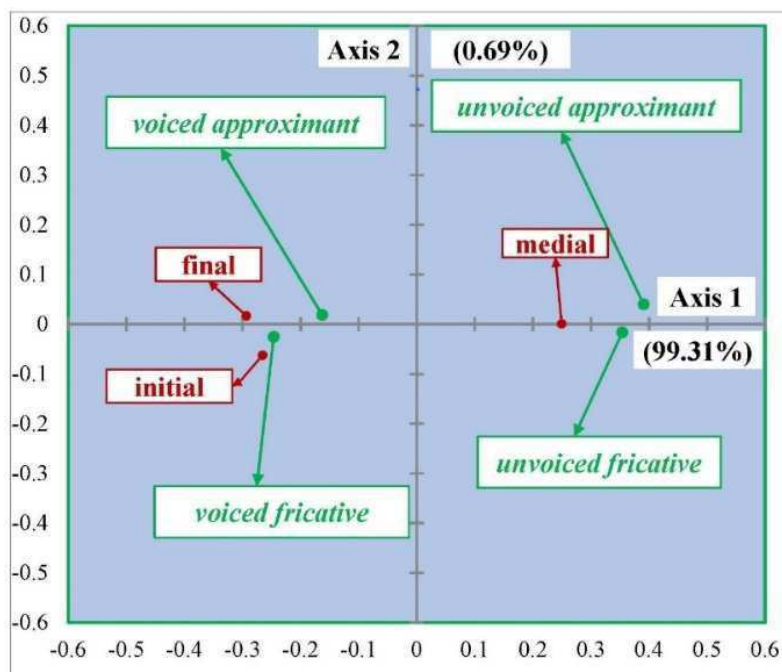


Figure 8. CA symmetric map depicting the position of the different realizations by word position.

3.3 Study of coarticulation in each position

3.3.1 Initial: After a pause. In the initial position, there were five occurrences of the rhotic after a pause, at the beginning of a sentence. Contrary to what was described previously, most of them were unvoiced fricatives, as illustrated in Figure 9.

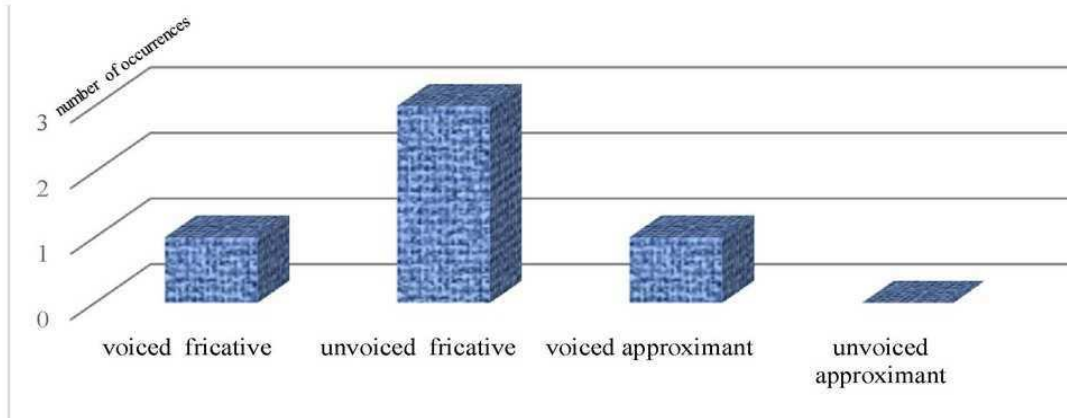


Figure 9. Rhotics in initial position after a pause.

3.3.2 Initial: In contact with a consonant. For an accurate analysis, it was necessary to take into account the sound preceding the rhotic (see Figure 10). There were more voiced fricatives, particularly after a voiced consonant.

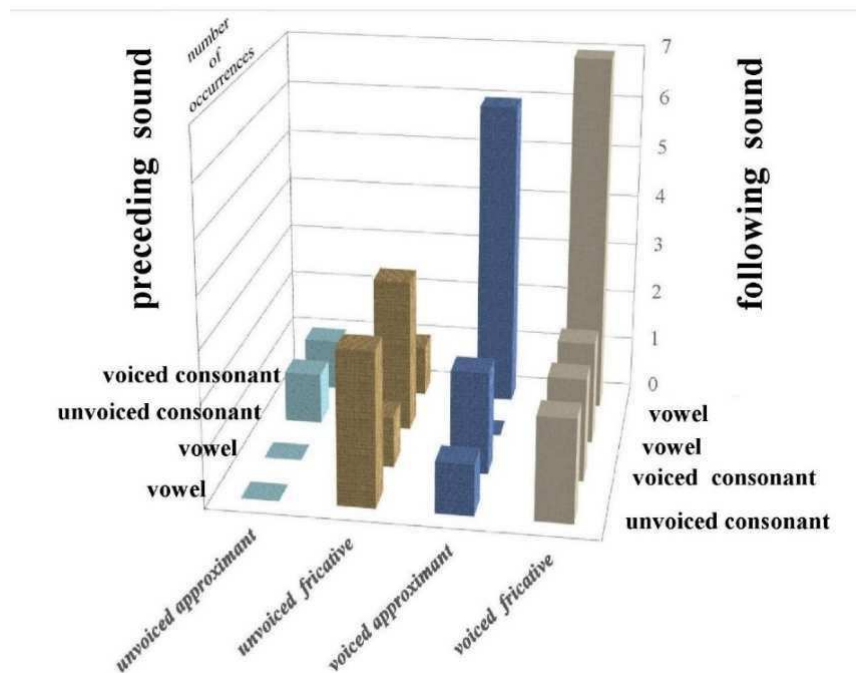


Figure 10. Rhotics in initial position: In contact with a consonant.

3.3.3 Medial: In contact with a consonant. To describe the precise context of each rhotic appearing in this position, the manner of articulation of the neighboring consonants was assessed and considered in the description. However, it appeared that the number of voiceless approximants available in this context was too small to permit a statistically relevant description. Therefore, a complementary analysis of the corpus was made: speakers who pronounced many voiceless approximants in consonant-medial contexts were selected and their entire interviews were taken into account. To identify the approximants in these data, Agglomerative Hierarchical Clustering (AHC) based on the Sound Pressure Level of the

analyzed consonants (fricatives and approximants) was used. In this way, approximately eighty voiceless approximants were identified and considered.

In a first symmetric map (axis 1 represented the most important factor and axis 2 explained a small part of the variance), the second axis allowed the specification of the surrounding of unvoiced fricatives and unvoiced approximants (see Figure 11). Unvoiced fricatives tended to appear after an unvoiced obstruent or a voiced fricative, and unvoiced approximants tended to appear before an unvoiced plosive. A second symmetric map (axis 1 and axis 3), depicted the distribution of the voiced fricatives and voiced approximants (see Figure 12). It appears that the voiced fricative [ʁ] is systematically realized in contact with a voiced obstruent. There were two exceptions: (i) the unvoiced fricative [χ] was realized after a voiced fricative and (ii) the voiced approximant [ʁ̥] was realized before a voiced fricative.

3.3.4 Intervocalic: Initial, medial and final. To study the realizations of the rhotic at the intervocalic position, it was more important to compare them according to their position in the word; Figures 13 and 14 show the results of these comparisons. In the initial position, there were approximately the same number of voiced approximants and voiced fricatives. It appeared that the realization of the *voiced fricative* was statistically more significant. In the medial position, the realization of the *voiced approximant* was statistically more significant. In the final position, surprisingly, what was significant was the realization of the *unvoiced fricative*. Vocal folds stop vibrating at the end of the word, even if the next word begins with a vowel. This was statistically significant at 0.03.

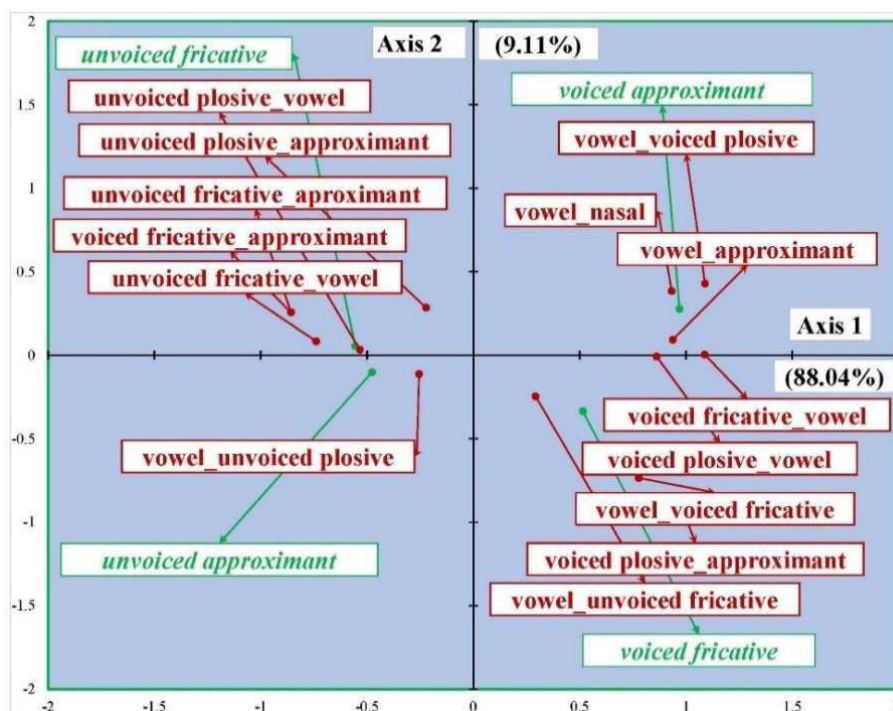


Figure 11. Symmetric map of the rhotics in the medial position and in contact with a consonant.

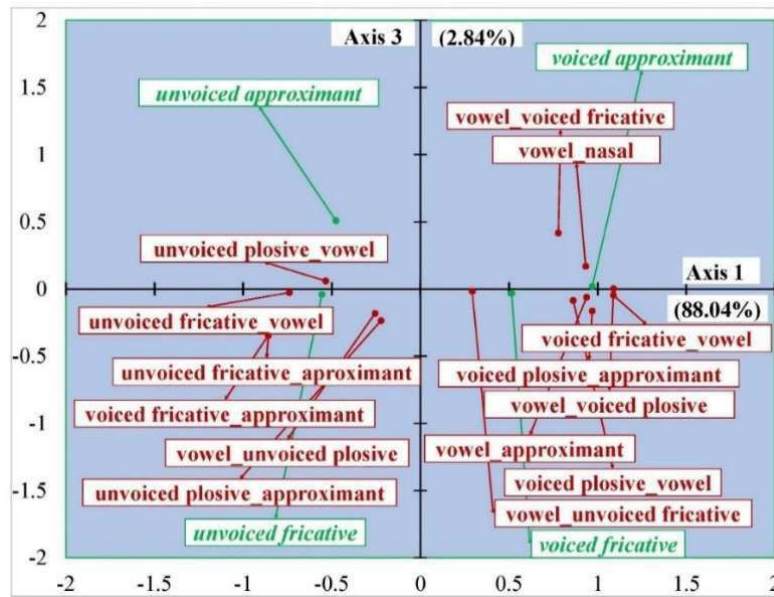


Figure 12. Symmetric map of the rhotics in the medial position and in contact with a consonant.

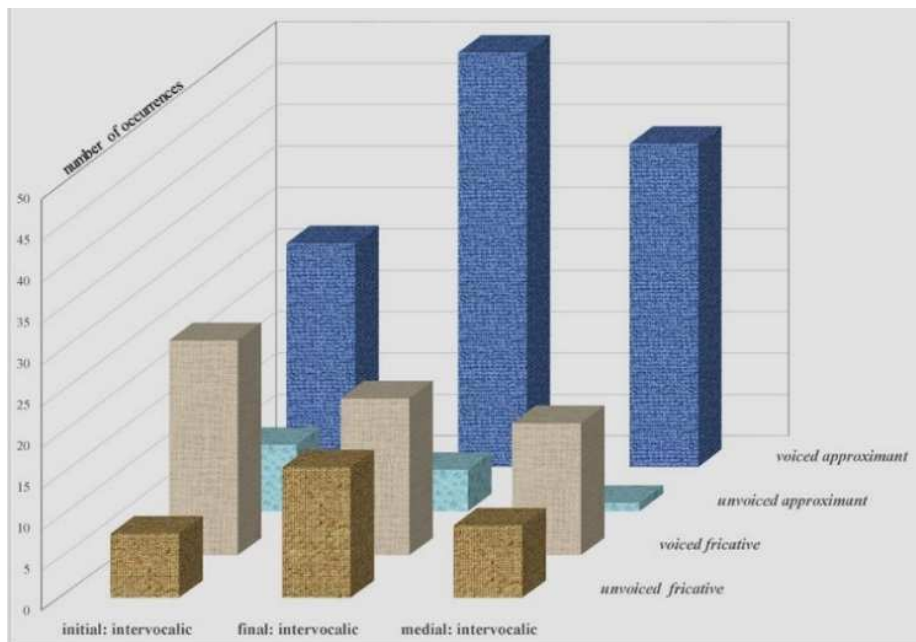


Figure 13. Different intervocalic realizations according to word position.

The studied uvular consonant is in the intervocalic position, not only in the medial position but also in the initial and final positions. According to Robins (1964:197) “French is often cited as a language wherein little information is given by phonological criteria on word divisions in connected discourse”. The present analysis shows that word division is revealed by the nature of the rhotic realized in each intervocalic context: a voiced approximant appears in the medial position, while a voiced fricative appears in the initial position. This comparison reveals a tendency for unvoiced fricatives to appear in the final position.

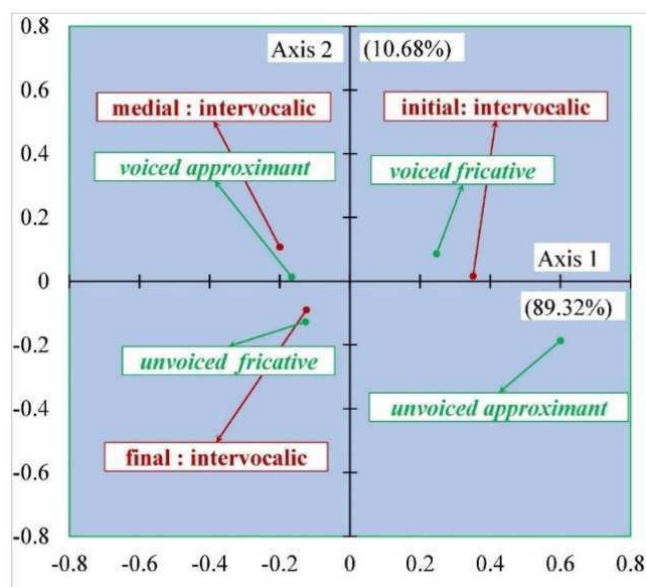


Figure 14. CA symmetric map of the nature of the different intervocalic realizations according word position.

3.3.5 Final: In contact with a consonant. In the final position, the rhotic can be in contact with a preceding consonant, a consonant at the beginning of the subsequent word or both, in this case between two consonants. Two symmetric maps, one with axis 1 and axis 2 (Figure 15), another one with axis 1 and axis 3 (Figure 16), are required to give a correct description of the distribution. A voice approximant appeared between two voiced consonants or between a vowel and a voiced consonant. A voiced fricative appeared after a vowel and before an unvoiced consonant. An unvoiced fricative appeared after or before an unvoiced consonant. It was followed by a vowel, when it was after an unvoiced consonant and it was preceded by a voiced consonant when it was before an unvoiced consonant. An unvoiced approximant appeared before or after an unvoiced consonant. It was preceded by a vowel, when it was before an unvoiced consonant and it was followed by a voiced consonant when it was after an unvoiced consonant. Therefore, a voiced approximant is always in contact with a voiced consonant; however, there are two exceptions: (i) It is realized as an unvoiced approximant when it follows an unvoiced consonant, and (ii) it is realized as an unvoiced fricative when it precedes an unvoiced consonant.

3.3.6 Final before a pause. In the final position, there were only 63 occurrences of the rhotic before a pause. Figure 17 shows the contingency table and Figure 18 displays the symmetric map. The results indicated that an unvoiced fricative appears after an unvoiced consonant. A voiced fricative and an approximant (voiced or unvoiced) appear after a voiced consonant or a vowel.

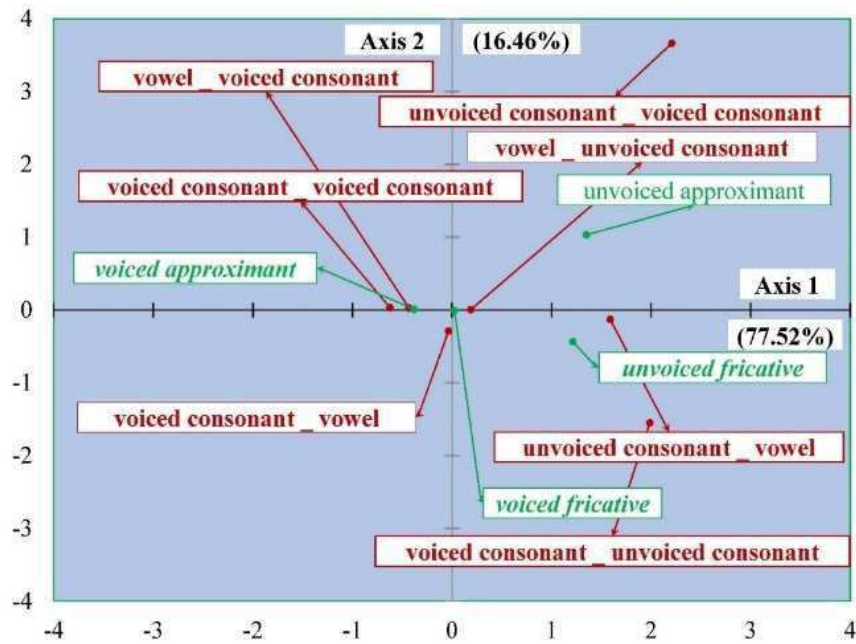


Figure 15. The first CA symmetric map of the different realizations of a final rhotic in contact with a consonant (axis 1 and axis 2)

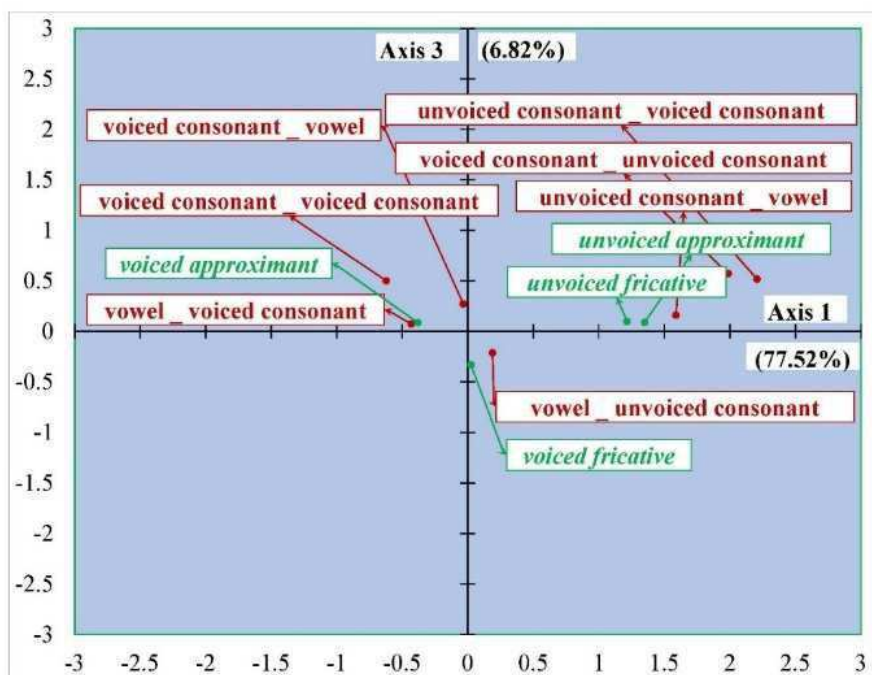


Figure 16. Second CA symmetric map of different realizations of a final rhotic in contact with a consonant (axis 1 and axis 3).

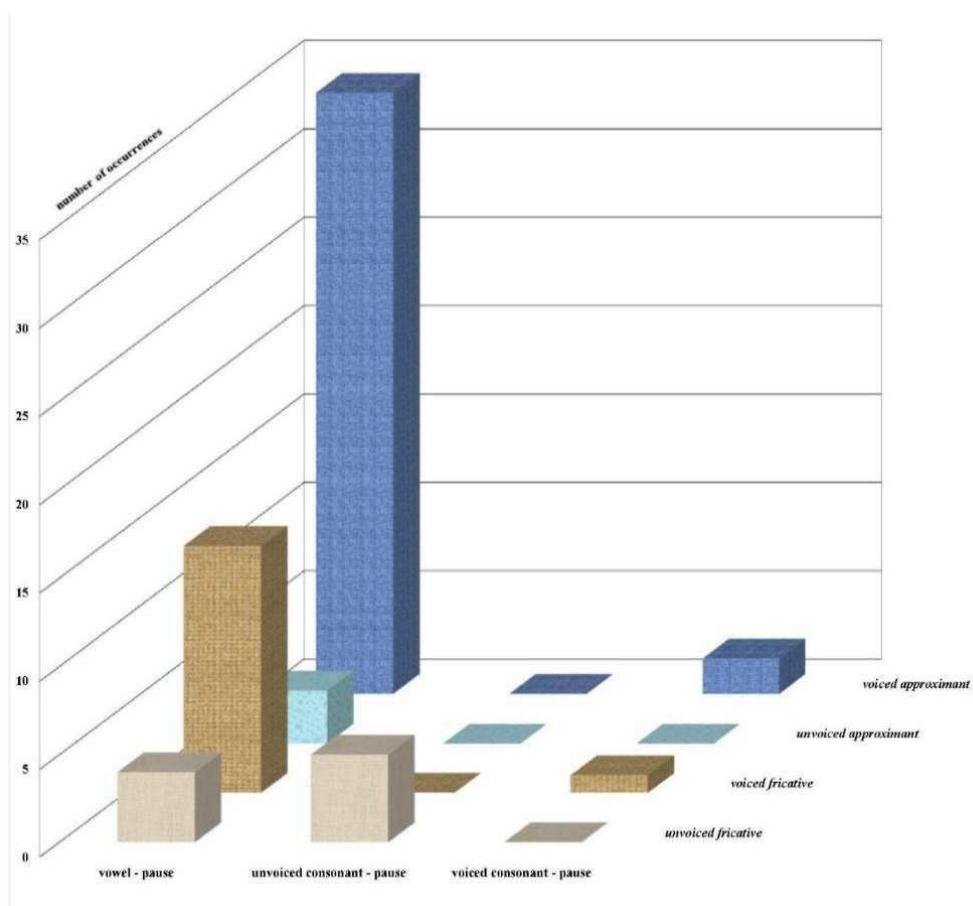


Figure 17. Contingency table of rhotics in final position before a pause.

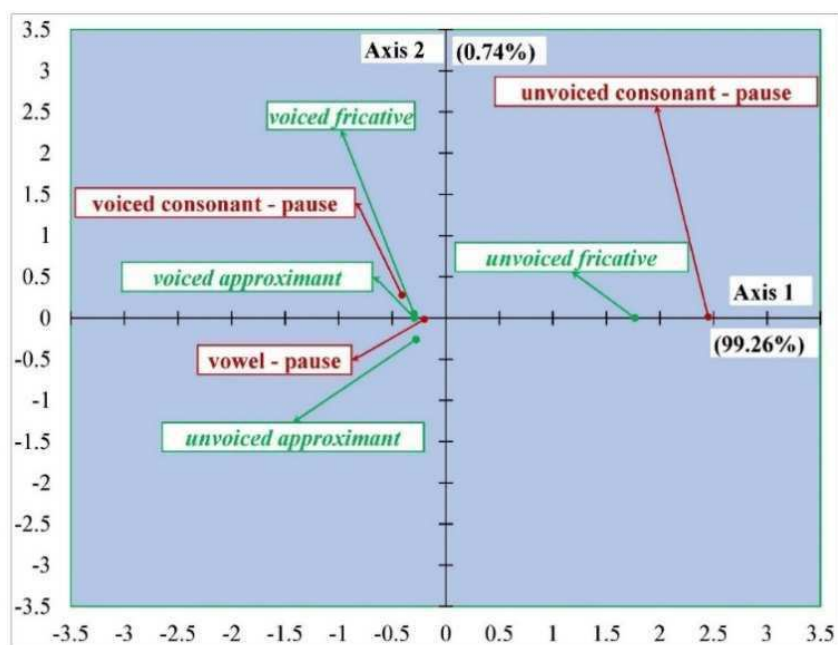


Figure 18. A symmetric map of the Rhotics in the final position before a pause.

3.4 Study of the effect of the accent on final rhotics before a pause

The primary accent in French is not a word accent but an accent delimitating a group or group accent. The delimited group is called the rhythmic group (Léon, 1992: 26; Dahan, 1996). This accent is expressed by two complementary parameters: either a rise in fundamental frequency or a significant lengthening of the last syllable of the rhythmic group (Lacheret-Dujour, 2000).

A rhotic preceding a pause is likely to belong to a stressed syllable. Therefore, this study assessed whether each realization was accented. It appears that there are few unstressed syllables. However, it is possible to distinguish two groups of syllables finishing with a rhotic: one with stressed syllables and the other with unstressed syllables. The mean and standard deviation for the duration of the rhotic differs according to the presence or absence of an accent. It appears that rhotics in stressed syllables are longer (84.5 ms, $\sigma = 35.3$ ms) than the ones in unstressed syllables (56 ms, $\sigma = 14.9$ ms) and that the influence of the accent on the realization of the rhotic is statistically significant at 0.008 (Wilcoxon-Mann-Whitney test). The stressed syllable is longer.

3.5 Elisions

Of the 1029 tokens containing potential realizations of the rhotic, only 29 elisions were noted (*ca.* 2.8% of the uvulars considered in this study). These elisions were produced by an approximately equal number of female (13) and male (16) speakers (see the contingency table provided in Figure 19. This illustration shows that, as described by Tubach (1989), elisions of the rhotic occur in the final position.

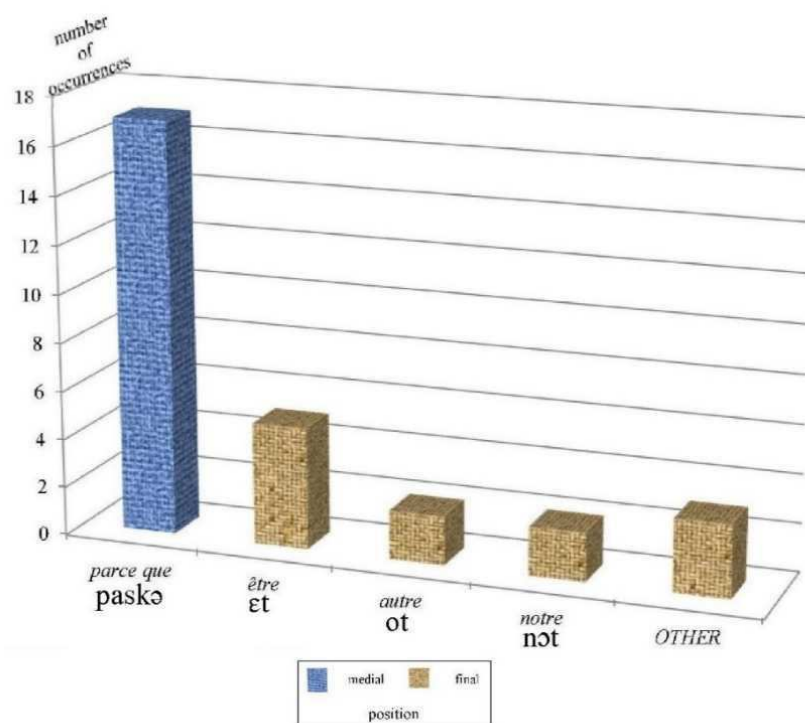


Figure 19. Elisions: number of elisions; OTHER stands for: *sur, pour, connaître*.

3.5.1 Final elisions. Final elisions date back to the XVIIth century. Bourciez (1937: 251) writes: “At the XVIIth century, forms *quat(re)*, *not(re)*, *vot(re)*, were admitted as proclitics even in formal conversation”. Lindblom (1990), in his H&H theory, states that speakers are expected to vary their output along a continuum of **hyper-** and **hypospeech**. It seems that the final elisions became less permissible about three centuries later. According to Lindblom’s theory, elisions moved toward hypospeech on this continuum. At the beginning of the twentieth century, they no longer appeared in formal conversation, but were, according to Martinon (1913: 295-296), permissible in quick and informal conversations: “final *r* followed by a mute *e* falls easily before a consonant in quick conversation after a voiceless consonant or one of the spirants *f* and *v*: *maît(re) d’hôtel*. It is certainly admissible in informal conversation between two words like the examples provided. It is especially frequent with *notre*, *votre* and *quatre*: *vot(re) cheval* ‘your horse’, *quat(re) sous* ‘four sous’”. Articulatory effort here seems consistent with hypo-articulation.

3.5.2 Medial elisions. Surprisingly, elisions occurred more often (17 times) in the medial position, specifically in the word [**paskə**] *parce que* ‘because’ (This is only one word despite the space between *parce* and *que* in the written form). Medial elisions have been described for a long time. Bourciez (1937: 247) mentioned an elision in [mɛʁkʁɛdi] pronounced [mɛkʁɛdi] *mercredi* ‘Wednesday’ back in the seventeenth century. But at the beginning of the twentieth century, the hypo-articulation of this form seems very important. So much so that Martinon (1913: 296) prohibited this pronunciation: “Me(r)credi ([mɛkʁɛdi] *mercredi* ‘Wednesday’) was in the past correct... I would not advise too strongly against this pronunciation.”

What was described for [mɛkʁɛdi] applies to [paskə]. In each case, a sequence of three consonants [χkʁ] or [χsk] loses the first consonant, the [χ], and becomes [kʁ] and [sk], respectively.

Today, [paskə] is probably more hypo-articulated than [ot] or [nɔt]. Listener’s access to sources of information independent of the signal and demands for explicit signal information, according to Lindblom’s terms, seems to have changed differently for each context of elision.

3.5.3 Traces of elisions in the acoustic signal. Table 3 summarizes the differences between sounds surrounding an elided rhotic and the same sounds when this elision did not occur. It appears that in the context of the elision, the sounds are not fully realized. They are shorter, and in particular, the vowel is less open and less intense.

Table 3. Acoustic differences between sounds surrounding an elided rhotic and the same sounds in a word where no elision occurred.

	parameter	[pas]	mean	σ	p
vowel [a]	F ₁	with elision	491 Hz	66 Hz	< .01
		without elision	616 Hz	78 Hz	
	SPL	with elision	74 dB SPL	6 dB SPL	< .05
		without elision	78 dB SPL	5 dB SPL	
consonant [s]	duration	with elision	52 ms	17 ms	< .01
		without elision	86 ms	29 ms	
consonant [s]	duration	with elision	72 ms	31 ms	< .05
		without elision	98 ms	35 ms	

a) Results of the identification test. In this study, only 25 words (31%) were recognized with the elision of the rhotic. The word with the elision is not distinguished from the word without the elision. The context is needed to obtain an understandable sentence.

b) Results of the discrimination test. The discrimination test showed that 85 of 120 pairs of different stimuli (71%) were correctly discriminated. The difference between a form with an elision and a form without was perceived significantly differently (chi square significant at .01). It thus appears that, in this elision of the rhotic, hypo-articulation was also revealed in the sounds surrounding the elided consonant and that listeners could not identify the word where the elision occurred from acoustic information alone.

3.6 Uvular tap realization

3.6.1 Context. According to Meunier (1994), the main realization of the *r* in contact with another consonant was a voiced uvular tap. Thirteen years later, Meunier (2007) restricted the context of the French [ʀ] to the following situations: after a voiced plosive or voiced fricative. Fifteen uvular taps were found in the corpus studied here, 14 voiced (appearing after a voiced obstruent) and 1 voiceless (appearing after an unvoiced obstruent). These uvular taps were realized by thirteen speakers, 7 males and 6 females. The mean age of these speakers was 47 years. Figure 20 summarizes the nature (voiced or unvoiced) of these realizations and their context. Most of them (14) appear in the medial position; however one voiced tap appeared in the final position after a dental plosive. Most of them (13) appeared after a plosive and only two voiced taps appeared after a labio-dental fricative. More than the half (7) of the voiced taps following a plosive appearing after a velar plosive. The unvoiced uvular tap appeared after a dental plosive in medial position.

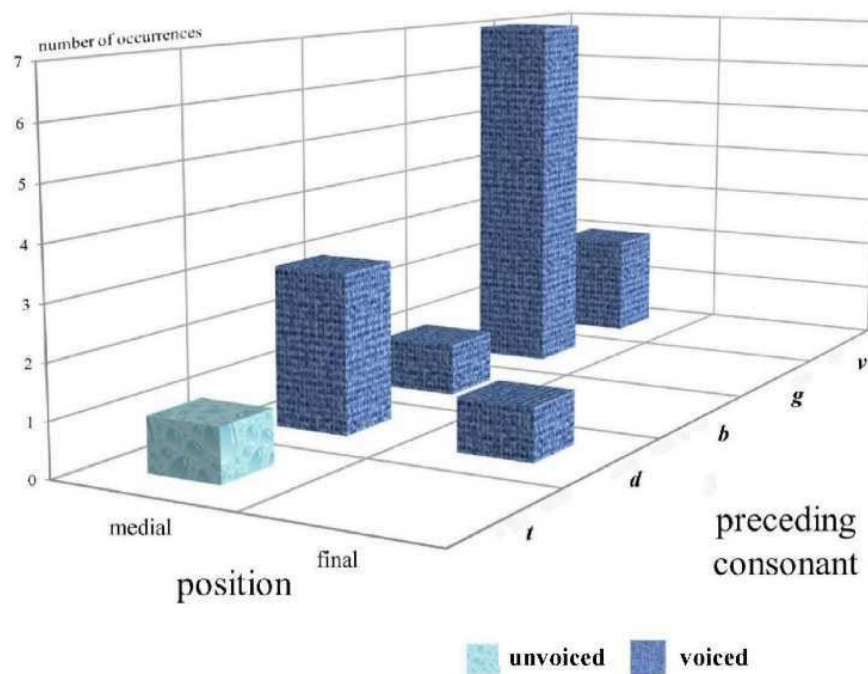


Figure 20. Description of uvular tap realizations by word position.

3.6.2 Acoustic realization

a) Voiced taps

Meunier (1994, 2007) analyzed the realizations of [ř] in three parts: two vocalic parts interrupted by the tap itself. It can be identified as follows: the first vocalic part, the tap, and a second vocalic part. In the present analysis, only two realizations corresponded exactly to Meunier's description and these comprised three segments (see Figure 21).

The twelve other taps have only two segments. An example is given in Figure 22, where the uvular tap is realized in two parts: a tap preceded by a prothetic vowel-like segment followed by a short closure as described by Ladefoged and Maddieson (1996: 240). These researchers noted that a sound of this type occurred in an Australian language.

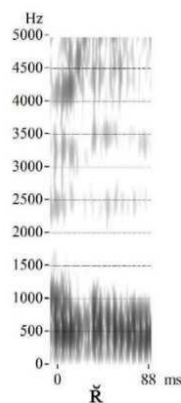


Figure 21. Uvular tap in three parts

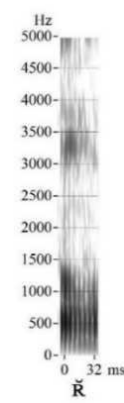


Figure 22. Uvular tap in two parts

b) Voiceless tap

The uvular voiceless tap was realized by a short and weak noise (see Figure 23). This noise was about 5 dB less than the burst noise of the plosive [t] and it appeared 24 ms after this burst, which was about a third of the time noted, 75 ms, between the plosive and the following vowel [ə]. The tap itself appeared as a vertical line after the burst noise. It was realized by a 28 year old woman who was a native of a suburb of Paris.

Differences between the descriptions and importance of this realization: There was no voiceless uvular tap described before by Meunier (1994, 2007). In this study, the voiced tap realizations were in two parts : a vocalic segment followed by the tap itself. These differences (presence/absence of the voiceless tap and its realization in two/three parts) can be explained by the specific context of each corpus. The corpus studied here used spontaneous speech while Meunier's (1994) corpus used words read in an exaggerated way. The importance of this description of the uvular tap in comparison to Meunier's description should be given further consideration because the number of tap realizations represented only 1.5% of the rhotics described here. However, 26% of the speakers whose production were analyzed realized this uvular tap. Moreover, it was not a realization of lesser importance because this articulation represented about 23% (22.95%) of the rhotics appearing after a voiced obstruent. Meunier did not indicate any other realization of the rhotic in this position, giving the impression that the tap is systematic in this position).

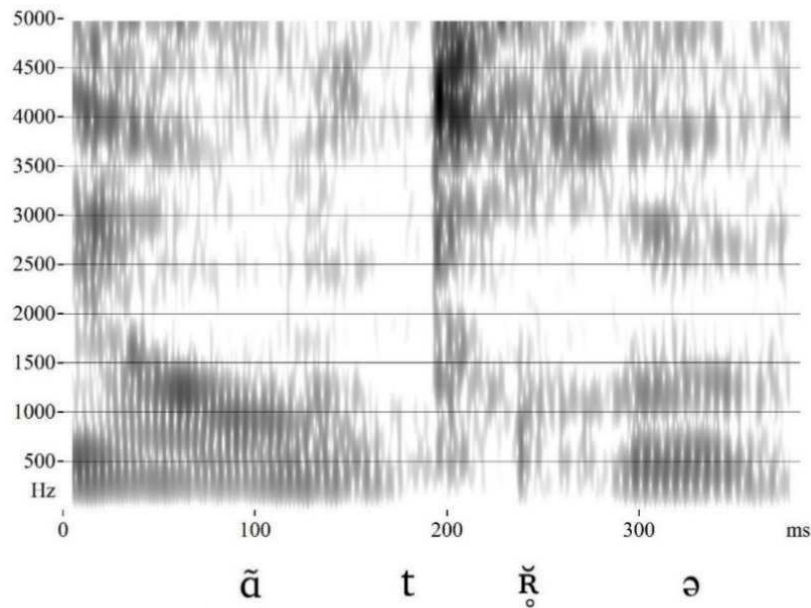


Figure 23. Spectrogram of an unvoiced uvular tap

4 Conclusions

The purpose of this paper was to describe the nature of *r* realizations in French. There were five realizations of *r* given in preceding descriptions: a voiced approximant, an unvoiced approximant, a voiced fricative, an unvoiced fricative and a voiced tap. This paper confirmed these descriptions and added two other realizations: an unvoiced uvular tap and a seventh realization involving elision. An acoustic analysis and a perceptual test showed that there was an acoustic manifestation of an elided consonant in specific phonetic contexts and that this acoustic manifestation had a perceptual reality. Therefore, there are seven possible realizations of the French *r*: two fricatives, two approximants, two taps and elision.

The place where each realization usually appears was described in terms of position in the word and completed by a description of the nature of the neighboring sounds in each word position. However, even if the neighboring sounds shared phonetic characteristics, the position in the word appeared to be preeminent. An intervocalic *r* was not realized in the same way in the initial position, as in the medial position or final position. In the final position, it was shown that the accentuation increases the duration of the rhotic situated at the end of a rhythmic group. This study should be repeated with a larger corpus with a greater variety of phonetic contexts.

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