

CORRELATIONS BETWEEN THE PATTERNS IN ROMANIAN AND FRENCH /v/ PRONUNCIATIONS AND THE DENTITION STATE

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ABSTRACT

The aim of the paper is to define /v/ fricative features useful for the discrimination between normal and pathological dentistry cases. On one side, we investigate the correlations that appear in the pronunciations of the /v/ fricative in the context $_ /v/ V$ by French and Romanian speakers in their native languages. On the other side, we investigate the correlations between the overall allophonic classes of /v/ in the specified context and the state of the dentition. Tentatively, we analyze the differences that appear between the group of speakers with perfect dentition and the group with dentition deficiencies, at the level of the probabilities of the allophonic classes conditioned by the context. We aim to preliminary determine if dental pathologies can be detected from the /v/ pronunciations. Moreover, we seek to answer the question if a tool based solely on /v/ analysis would be portable between French and Romanian.

Index Terms— /v/ allophones, cluster probability, conditional probabilities, formant space, dental pathologies

1. INTRODUCTION

While the /f/, /s/, /sh/, and /z/ fricatives have received extensive attention in the literature, e.g., [1]-[3], the /v/ fricative was little dealt with. This study has two aims: to detail an inter-language comparison of the /v/ fricative, and to help establishing a basis for the use of the characteristics of the /v/ pronunciation in dental health tests. In the frame of the second purpose, we assess the diagnostic value of the changes in the formants of /v/ in the detection of the dentition state, at the level of /v/ allophones probabilities and conditional probabilities.

The first purpose was partly fulfilled in [4]. We further the research in that direction by adding data on the

probabilities of the /v/ allophones and of the allophones conditioned by the vowels that are common to French and Romanian languages, when /v/ appears in front of the respective vowels. Precisely, in the context $_ /v/ V$, we analyze conditional probabilities $p(/v/ \text{ is } v_{\#k} | V)$, where $v_{\#k}$, $k=1, \dots, 5$ is one of the five allophones we have determined in [4], [5].

The second purpose was enunciated in [5] and dealt with at the level of formants and quartiles characteristics, but not at the level of probabilities of the allophones and of the conditional probabilities of the allophones in dependence of the succeeding vowel. This purpose is to establish a sound basis for the gnathophonic analysis of /v/ with the more distant target of establishing a tool for screening for denture condition.

The relevance of this study is twofold. In the field of phonology, the study clarifies the relationship between the allophones of /v/ and the vowels following /v/ in the context $_ /v/ V$. Moreover, the study addresses similarities and differences between French and Romanian in the formantic characteristics of /v/, in the specified context. On the other hand, the analysis is relevant in the medical field because it shows how the dental condition changes the labiodental fricative /v/ in the given contexts.

2. DATA REPRESENTATION AND DATA MINING FOR ALLOPHONES

The data set used in this study is contained in the gnathophonic database that we reported in [6]. The database is available in the frame of the spoken Romanian corpus SRoL [6] presented in other papers [7], [8]. The methodology for building the SRoL corpus section referred here is largely the same as for the whole SRoL corpus. The database used in this research consists of healthy speakers

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and speakers with various denture conditions. The analysis exclusively refers to the characteristics of the /v/ fricative in the context $_v/V$. French (17 female, 34 male) and Romanian (12 female, 17 male) speakers are included in the database. Data for these subjects are freely available at http://www.etc.tuiasi.ro/sibm/romanian_spoken_language/ro/sunete_gnatofonice_gnatosonice.htm. A summary of the corpus content is given in Table 1.

The method to determine the /v/ classes and the clustering procedure are explained in detail in [4] and [5]. Signal processing procedures are explained in [4], [5] and [6]. The original data is processed and transformed into a set of probabilities of the speaker using one of the five /v/ allophones found in the $_v/V$ context. There are three data mining phases. The first two consist in the search for patterns corresponding to allophones in the formant space and in the space of the probability distribution of the pitch during pronunciations. The last phase corresponds to the comparison of the matrices for conditional probabilities of the /v/ allophones for individuals and the determination of specificities for people with a healthy dentition and for those with dentition conditions. The first phase was presented in [4], while the second phase was detailed in [5]. In these previous researches, we focused on the choice of the features and on the detection of clusters of /v/ pronunciations. As a result, we determined for both French and Romanian, five allophones of /v/ in the specified context.

TABLE 1. Number of /v/ instances in the corpus, in the context $_v/V$ *

Speaker gender, Language	A	E	I	O	Total
M, French	238	67	233	100	638
F, French	118	34	118	51	321
M, Romanian	61	35	88	10	194
F, Romanian	62	34	77	4	177

* Figures are valid as for the content of the data base on 01.29.2012

The data in Table 1 also contains the number of /v/ pronunciations belonging to three male speakers and two female speakers with unknown dental diagnostic. For all computations in this study these pronunciations are eliminated.

The feature space is constituted by the tertiary variable with values “voiced”, “partly voiced”, and “unvoiced”, and by the median values of the formants F1-F4. After having established the /v/ classes, we determine the probabilities of these classes for male and female speakers, for the two languages, and distinctly for healthy subjects and for subjects with dental conditions.

Notice that, in natural language studies, the probabilities of the bigrams $p(_vV)$, where V is one of the vowels /a/, /e/, /i/, /o/, /u/, are determined by the language

model. These probabilities do not apply to our study, because we used a pre-determined set of words, moreover because the words were recited in a variable number by the speakers. In order to define the feature vectors composed by the occurrences probabilities of the /v/ classes specific to the healthy and pathological groups of speakers, we performed the following steps of processing:

i) The separation of the corpus in two sets of speakers with healthy denture (H) and with dental pathologies (P).

ii) The computation of occurrence probabilities of the /v/ classes, namely C1, C2, C3, C4, and C5 for each set of speakers using the equation:

$$p(v \in C_m) = n_m / \sum_{m=1}^5 n_m \quad (1)$$

where n_m is the number of occurrences of the /v/ pronunciations from the C_m class, $m = \overline{1:5}$, and $\sum_{m=1}^5 n_m$ is

the total number of occurrences of the /v/ pronunciations from the C1-C5 classes.

iii) Building the features vectors for the healthy cases (VH) and for the pathological cases (VP):

$$\begin{aligned} VH &= [p(v^H \in C1), p(v^H \in C2), \dots, p(v^H \in C5)] \\ &= [p_1^H, p_2^H, \dots, p_5^H], \end{aligned} \quad (2)$$

$$\begin{aligned} VP &= [p(v^P \in C1), p(v^P \in C2), \dots, p(v^P \in C5)] \\ &= [p_1^P, p_2^P, \dots, p_5^P], \end{aligned} \quad (3)$$

where v^H and v^P are the /v/ pronunciations specific to the healthy, respectively to the pathological cases.

Apart from clustering in allophonic /v/ classes using as features F1-F4 median values (C1-C5 classes), we also attempted another feature space, based on the quartiles of the F1 formant (Q1-Q3 values). The resulted clusters, denoted C1*-C5*, are compatible with the classes C1-C5 [5].

3. PROBABILITIES OF THE /V/ ALLOPHONES

In this section we report on the probabilities of the $v_{\#k}$ allophones in the $_v/V$ contexts, for French and Romanian languages. The vowels that we considered equivalent in the two languages are /a/, /i/, /o/; the Romanian vowel /e/ was associated to é, è, and ê, but not to e [*e muet*] in French.

The /v/ allophones probabilities were computed on the French speech corpus presented in [5]. A distinction was not made at this level between subjects with healthy and subjects with pathological dentition considering the conditional probabilities of the /v/ classes, but the analysis was performed for male and for female speakers apart. The

results are exemplified in Table 2 for French healthy female speakers and in Table 3 for French female speakers with a dental condition.

TABLE 2. Number of instances of /v/ depending on the context vowel and classes; total; overall class probability. Healthy female speakers, French

HF	A	E	I	O	Pronunciations per class	Probability per class
C1	10	1	5	3		
C2	2	0	6	2	10	0.11
C3	17	6	4	8	35	0.37
C4	6	3	20	1	30	0.32
C5	0	0	0	1	1	0.01
Total, per context	35	10	35	15	95	

Notice in Fig. 1 that the probabilities of the classes C2, C3, C4 and C5 for healthy Romanian and French female speakers are very close, while for pathological cases are different. For example, for the class C2, the probability specific to the pathological Romanian and French female speakers are almost equal, while for the class C3 the probability corresponding to the French female speakers is larger than for the Romanian female speakers.

TABLE 3. Number of instances of /v/ depending on the context vowel and classes; total; overall class probability. French female subjects with a dental condition

PF	A	E	I	O	Pronunciations per class	Probability per class
C1	8	2	1	3		
C2	5	1	9	1	16	0.07
C3	61	17	13	30	121	0.54
C4	7	4	59	1	71	0.31
C5	2	0	1	1	4	0.02
Total, per context	83	24	83	36	226	

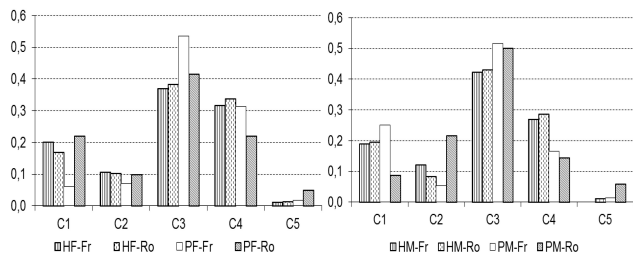


Fig. 1. Probabilities per class (C1-C5), for French (Fr) and Romanian (Ro) female speakers (F) – left, and male speakers (M) - right. H - healthy; P - dental condition.

Like for the female speakers, there is a strong resemblance between French and Romanian, for healthy male speakers, at the level of the distribution of the allophonic classes. Notice that the differences between languages are more pronounced in case of male subjects with dental conditions. For the male speakers, small but

statistically significant differences between languages occur for the probabilities of the classes C1, C2 and C5 for pathological cases (see right-side of Fig. 1). The right graphic presented in Fig. 1 demonstrates that there is a significant difference between the probabilities of healthy and pathological male speakers, for both languages.

4. CONDITIONAL PROBABILITIES OF THE /V/ ALLOPHONES

Labiodental fricatives (voiced /v/, unvoiced /f/) and dental fricatives (voiced /ð/, unvoiced /θ/) provide direct information on the state of the frontal dentition state. Less specific, yet valuable information also provide the apical sibilants in languages where they appear. While small deficiencies of the frontal dentition may be compensated by the speakers up to becoming imperceptible to the listener, the compensation may still leave its acoustic marks, at the acoustic level. These marks would help determining the dental condition if the acoustical changes were suitably detected. Along this reasoning, our study aims to determine if such acoustical signatures of the dentition condition can be determined using a comparison between the distribution of the /v/ allophones in healthy subjects and in subjects with a dental condition.

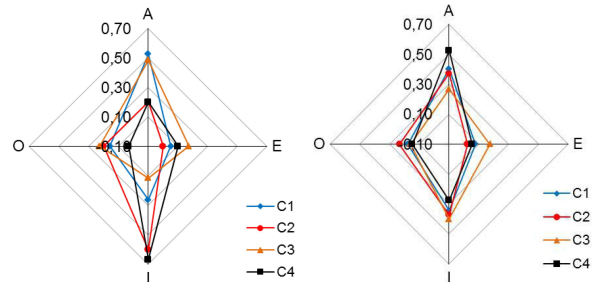


Fig. 2. Conditional probabilities of the classes C1-C4, for healthy French female (left) and male speakers (right).

We recall that the conditional probabilities are computed as $p(x|y) = p(x \& y) / p(y)$, where x and y are the events. The conditional probabilities obtained for the classes C1-C4 are diagrammatically presented in the Fig. 2, in the left graph for French, healthy female speakers, respectively in the right graph for French, healthy male speakers. Class C5 was not included because of the insignificant number of /v/ instances in this class. All very low (less than 0.1) conditional probabilities, moreover /e/-conditioned probabilities for female speakers must be regarded with reserve, because of the small number of /v/ instances in those contexts in the database. Nevertheless, the graphs in Fig. 2 show that there are significant differences between the French healthy male and the female speakers at the level of conditional probabilities.

5. CHANGES DUE TO DENTURE CONDITIONS – MALE VS. FEMALE SPEAKERS

In this section we exemplify the differences between healthy and pathological cases for Romanian and French male and female speakers. After separating the healthy subjects and the subjects with dental conditions, we recomputed the probabilities of the /v/ allophones. The results, shown in Fig. 3, indicate significant differences between the probabilities.

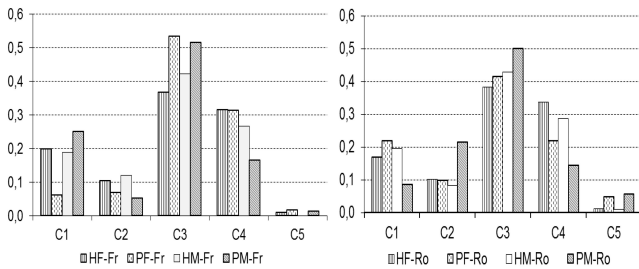


Fig. 3. Probabilities per class (C1-C5), for French female (F) and male (M) speakers (left) and Romanian F and M speakers (right). H - healthy; P - dental condition.

The left-side graph in Fig. 3 points to several useful rules:

- * The probability of the class C3 looks to be higher in case of pathologic dentition.

- * An inverse effect seems to occur for the class C2.

Other differences between normal and pathological dentition speakers are also present in the data, but at this stage of the research we cannot derive significant conclusions with a high enough confidence.

Several differences seem to occur in the conditional probabilities for subjects with a dental condition, compared to healthy subjects. In Table 4, we show for French female speakers, the differences between the conditional probabilities. The results must be regarded with caution because of the statistical spreading.

TABLE 4. Differences between the conditional probabilities for female French subjects with a dental condition compared to healthy subjects

Diff. H-P, F	A	E	I	O	/v/ instances per class, HF	/v/ instances per class, PF
C1	0.03	0.07	0.19	0.03	19	14
C2	0.13	0.06	0.03	0.11	10	16
C3	0.02	0.03	0.01	0.02	35	121
C4	0.10	0.04	0.13	0.02	30	71
C5	0.50	0.00	0.25	0.75	1	4

Similarly, the differences for French male speakers are given in Table 5. In these tables, the total numbers of /v/ instances per class are also given, for appraising the confidence of the results. These tables complement the left-

side bar graph in Fig. 3. Notice in Table 4 that for the French female speakers there are differences greater than 0.10 for C1 and C4 classes conditioned by /i/ vowel.

TABLE 5. Changes in the conditional probabilities for male subjects

Diff. H-P, M	A	E	I	O	/v/ instances per class, HM	/v/ instances per class, PM
C1	0.03	0.05	0.08	0.09	67	71
C2	0.21	0.02	0.23	0.03	43	15
C3	0.04	0.04	0.01	0.00	150	146
C4	0.04	0.01	0.00	0.04	95	47
C5	0.25	0.00	0.50	0.25	0	4

For the French male speakers, the highest differences between the conditional probabilities of the /v/ classes of normal and pathological cases occur for C2 class conditioned by /a/ and /i/ vowels (see Table 5).

6. DISCUSSION

The study shows that French and Romanian languages are very similar in the use of the /v/ allophones in the context $_v/V$. We also found that male and female speakers have significantly different changes in the probabilities of the allophones and in the conditional probabilities of the allophones, when dental conditions occur.

This study has several limitations that must be corrected in the future. In the first place, a deficiency in our study is that the number of Romanian speakers is too low. Second, the ratio of the pronunciations by Romanian and French speakers of the contexts $_v/V$ is not the same for all contexts: about 1/3 for /a/, M-Ro vs. M-Fr, but only 1/10 for /o/. These methodological limitations restricted us in our conclusions regarding the conclusions on the conditional probabilities.

For both genders and for both languages the results support the hypothesis that dental conditions may be identified from repeated pronunciations of the $_v/V$ phoneme sequences. In the next phase of this research we are attempting building a tool for detecting denture condition. Further details will be given in another paper.

The perceptual identity of the /v/ allophones for Romanian and French listeners is not documented in this study. We will make a simple test consisting in sectioning French words starting with $_v/V$ and providing them to a set of Romanian listeners who will be asked to assess the naturalness (correctness for a native Romanian) of the pronunciations.

The probabilities of the allophonic variations of /v/ and the related conditional probabilities can be a starting point in creating speaker-signature vectors for speaker recognition and health state detection using a cohort method similar to the one reported in [9]. A study aiming to

health state recognition based on /v/ allophones statistics will be presented elsewhere.

The three main /v/ classes, voiced, unvoiced and partially voiced are well motivated by phonetic reasons and relate only to the vocal folds. Subclasses C1, C2, respectively C3, C4 were found automatically by the clustering procedures applied. Still these subclasses are phonetically motivated at the allophonic level.

To increase the confidence in classification results in pathological respectively normal cases medical experiments are mandatory, for example, checking the voice change before and after prosthetics treatment.

7. CONCLUSIONS

We conclude that, based on the corpus we have, we can determine a good similarity of use of the /v/ allophones in French and Romanian and a change of the allophones for subjects with dentition conditions compared to the healthy subjects, for both French and Romanian speakers. On the other hand, the corpus is too small to derive statistically significant (that is, with high degree of confidence) differences between healthy and diseased dentition speakers at the level of conditional probabilities, except a few cases, like the C1 and C4 classes for French female speakers and C2 class for French male speakers conditioned by /i/ vowel.

The probabilities of /v/ allophones provide hints on the dentition state. Moreover, changes in the statistical distributions of the F1 is correlated to the dentition state, as show the possibility to detect the state of the dentition from the Q1- Q3 parameters of the F1 statistics.

At this stage of the research, there are reasons to assume that the vector of /v/ allophone probabilities is a good indicator for the dentition state. Also, there are statistically results that seem to support the strong resemblance of Romanian and French similarity with respect to the /v/ allophones.

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Authors' contribution. H.-N. T. has conceived the principles and methods of research and of data processing, contributed to data processing, interpreted the data, and largely wrote the paper.

A. U. (H.) made the recordings, preprocessed them, performed the classification of the Romanian and French /v/ types, wrote the Matlab™ programs for data processing and /v/ clustering and contributed to computing the conditional probabilities of the /v/ types for normal and pathological cases used in this study and contributed writing and correcting the paper.

C. D. supervised the recordings for French language, recruited the students,

proposed the A4 hybrid method used for the /v/ clustering, and contributed to witting and correcting the paper.

Correction. Through the paper [5], /u/ must be replaced with /y/.

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