

# Acoustic correlates of the accent in Gatika lexicon

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## Abstract

In this article a lexical corpus of a Bizkaian pitch-accent variety is taken as a basis for an analysis of the three acoustic features that influence word accent. On the one hand, we measure the duration, the fundamental frequency and the energy to check whether the number of syllables of the word, the presence of accent or lack of it and the location of the accented syllable influence them. On the other hand, we want to know which of those three features have a greater influence on the accent. The analysis and the presentation of its results are organized in two levels: first, we look at the features of the word itself, and secondly, research is carried out at syllable level.

**Keywords:** phonetics, acoustics, accent

## 1. Introduction

Even though research based on acoustic data of the Basque language has increased over the last years, it still cannot be said it is enough. Research on the acoustic correlates of accent is now starting, and the work done by Hualde, Lujanbio and Torreira (2008) on the Goizueta variety is probably amongst the most recent.

The present paper intends to carry out research on the acoustic correlates of accent in the Gatika variety. For that purpose we shall use the large lexical corpus already built by us. All the words had already been gathered with the intention of compiling a local tongue audio dictionary, and all were gathered from an only local informant.

It is a well known fact that in Gatika accent there is a lexical distinction between accented and unaccented words (Gaminde 1992, 1997, 1998 and 2004). According to the accentual system of this variety, and after the identification of the phonological unit, in unaccented words stress falls on the last syllable; accented words are words with lexical accent on any other syllable. The rules can be simplified in the following way:

- (1) Identify the phonological unit.
- (2) Accent falls on the last syllable (1) of the unit.

In this project we examine words of two, three and four syllables. According to the position of the accented syllable, these are the possibilities:

- (1) Unaccented two-syllable words:  
*burú, samé, miñé, santzó, uyé, begí, atzá, surré, moñó, trentzé, ulé, anké, berné, orpó*, etc.
- (2) Accented two-syllable words:  
*pápu, múmpe, píste, súde, súrpe, txánke, bárre, gústu, móko, kúre, gólpe*, etc.

(3) Unaccented three-syllable words:  
*aurpegí, bixerrá, gorgollé, iduné, kokotá, musturré, okotzá, agiñé, espaná, txatxarrá, unkedé, negarrá, berbotza, durundé, saraté, arnasé*, etc.

(4) Accented three-syllable words:

(4.1.) Accent at the beginning:  
*ókospe, pómulu, sótena, txókiñe, bélarri, páusotza, ñaspi, sánkope, básape, úkondo, bérbete, bérbite, áskure, bómittu*, etc.

(4.2.) Accent in the middle:

*bekóki, bigóte, garúnek, matrálle, betúle, pestáñe, sursíllo, surtzíllo, erráye, erkóro, potxóle, biríki, puxíke, ampólle, arági, baltzúne, pustílle, lomútu, botíke*, etc.

(5) Unaccented four-syllable words:

*garrangillé, aginkedé, atzamarrá, ukubille, estegorrí, kuntzurruné, askordiñé, piltxikedé, sikatrise, txerpakadé, dardakadé, fregasiño, infesiño, kalenturé, gibekekó, perlesiñé*, etc.

(6) Accented four-syllable words:

(6.1.) Accent on the first syllable:  
*dámistiku, básotako, léngusiñe, yáyegune, kákaraka, kúkurruku, kámpotarra, áreñegun, árterako, óstabere, átzeratu, áurreratu, kónturetu, mákiñetu*, etc.

(6.2.) Accent on the second syllable:

*ibílkune, orkátille, eskúrturre, estómagu, bedárléku, erróparri, lotúkere, gosámena, esúngarri, amíllotxe, birégarro, sapáburu, amárratza, arránkari, barékille, epértargi*, etc.

(6.3.) Accent on the third syllable:

*erropéru, yesarléku, kandelére, mosumérke, patxalása, tiragóme, txirimbwéla, errespétu, juraméntu, monagílllo, sakristáne, sepultúre, alargúntze, astesántu, garixúme, txarribóde*, etc.

The work is presented divided in four parts. Section 2 deals with the methodology and the description of the corpus. In Section 3 we analyse the data on the acoustic

features of the words. In Section 4 we do the same but looking at the syllables. Finally, in Section 5 we draw conclusions.

## 2. Methodology

The corpus used in our work comprises 1945 words altogether. The words used are of two, three and four syllables. Although there are more words in the corpus, we have left out those containing more than four syllables; in the same way, words with two consecutive vowels (*biotza*, *mea*, *sear*, etc.) have also been excluded.

The variables considered for the analysis are: the number of syllables (Table 1 and Figure 1), whether the word is accented or not (Table 2 and Figure 2), and the position of the accented syllable (Table 3 and Figure 3).

number of syllables	frequency	%
2	665	34.19
3	918	47.20
4	362	18.61

Table 1: Frequency and percentage of the words according to the number of syllables

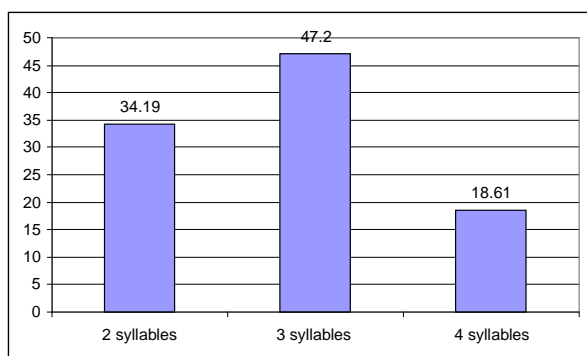


Figure 1: Frequency and percentage of the words according to the number of syllables

accented word	frequency	%
yes	856	44.01
no	1089	55.99

Table 2: Frequency and percentage of accented and unaccented words

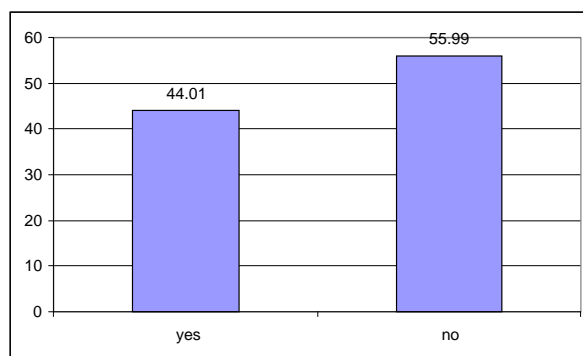


Figure 2: Frequency and percentage of accented and unaccented words

accented/stressed syllable	frequency	%
1	351	18.05
2	879	45.19
3	568	29.20
4	147	7.56

Table 3: Frequency and percentage of the position of the accented (or just stressed if final) syllable

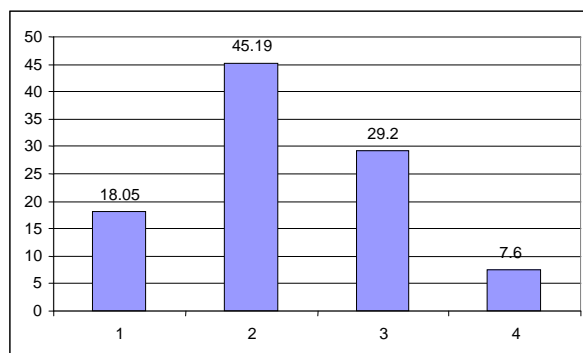


Figure 3: Frequency and percentage of the position of the accented (or just stressed if final) syllable

To begin with, we have labelled all the words using the Praat program (Boersma, P. and Weenink, D. 2009) in order to take measures. The labelling or tagging has been done at two levels: word level and syllable level (Figures 4 and 5).

As we know, in the case of the occlusives and the affricates, we cannot know the duration of the initial explosion (see Figures 4 and 5); we have placed the labels at the beginning of the explosion bar and the friction, respectively.

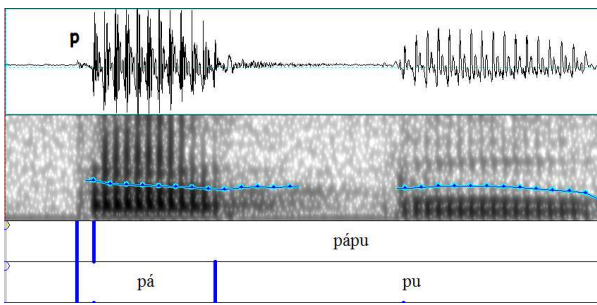


Figure 4: *pápu*  
(The bar of explosion of the first occlusive is noticeable.)

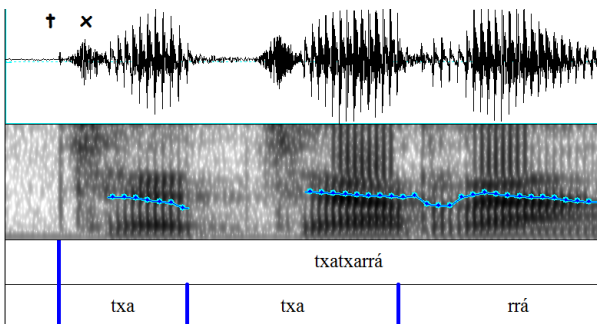


Figure 5: *txatxarrá*

For the analysis we have measured the duration, the fundamental frequency and the energy of each word. The measures were automatically taken using a script (Lyko 2008); it gives the average duration, fundamental frequency and energy for the area between the inserted labels. In all cases we give the word duration (in milliseconds, ms), the minimum, maximum and average fundamental frequency or  $f_0$  (in hertz, Hz), and the minimum, maximum and average energy (in decibels, dB).

Contrarily to earlier works (Gaminde 1992, 1994a and 1994b), this one is carried out using the average fundamental frequencies both at word and at syllable level. In those previous studies, high fundamental frequencies at word level and fundamental frequencies measured at some specific position within the syllable were used.

So, for a detailed examination of the collected data and to bring to the fore the factors that have an influence on the accent, the analysis takes place at two levels: we carry out word analysis, on one hand, and syllable analysis, on the other.

### 3. Word analysis

In this section we shall give the figures for the fundamental frequency and energy rates of the words from our corpus, and then we shall analyse those figures. As mentioned above we shall consider the number of syllables of the word, whether it is accented and the accent position. We shall provide the number of

cases found (N), the average value (X) and the standard deviation (SD).

### 3.1. Fundamental frequency

We shall present and analyse the data on the fundamental frequency according to the number of syllables of the words. We shall also consider accented and unaccented words separately, and in three-syllable and four-syllable accented words, we shall look at the position of the accent.

As shown in Table 4 and in Figure 6, two-syllable words have a lower fundamental frequency when accented, and the average difference is of 7.45 Hz.

accented	N	X	SD
yes	206	137.32	5.74
no	459	144.47	5.88

Table 4: Average fundamental frequencies of accented and unaccented two-syllable words

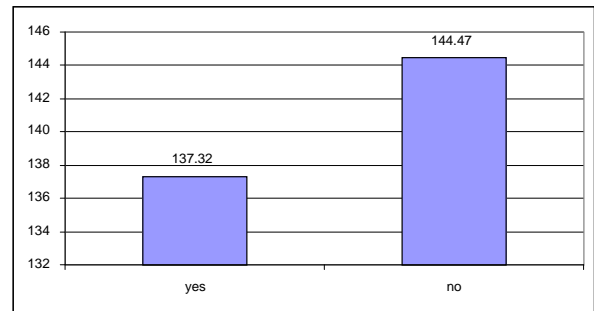


Figure 6: Average fundamental frequencies of accented and unaccented two-syllable words

Table 5 and Figure 7 show that the average fundamental frequency of three-syllable words is higher in unaccented words. Furthermore, in accented words the position of the accent makes a difference: when the accent is placed on the first syllable, the fundamental frequency of the word is slightly higher than when the accent goes on the middle syllable.

accented		N	X	SD
yes	1	128	141.41	5.53
	2	307	138.49	5.45
no		483	146.52	5.92

Table 5: Average fundamental frequencies of accented and unaccented three-syllable words

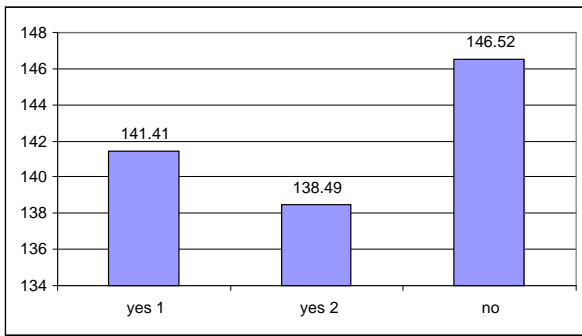


Figure 7: Average fundamental frequencies of accented and unaccented three-syllable words

Similar results can be seen in Table 6 and Figure 8. Accented words present a lower average fundamental frequency than unaccented words, and certain differences depending on the position of the accented syllable are also apparent.

accented		N	X	SD
yes	1	17	141.99	5.7
	2	113	142.33	5.29
	3	85	139.76	6.08
no		147	146.00	4.92

Table 6: Average fundamental frequencies of accented and unaccented four-syllable words

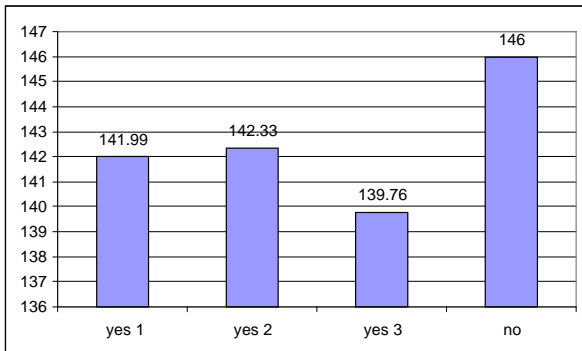


Figure 8: Average fundamental frequencies of accented and unaccented four-syllable words

In short, examining the results shown in the tables, unaccented words present a higher average fundamental frequency than accented words in all cases. This is easy to explain because the fundamental frequency range is wider in accented words.

Tables 7, 8 and 9 and Figures 9, 10 and 11 show the range results.

accented	N	X	SD
yes	206	62.23	12.98
no	459	42.97	15.39

Table 7: Fundamental frequency ranges of accented and unaccented two-syllable words

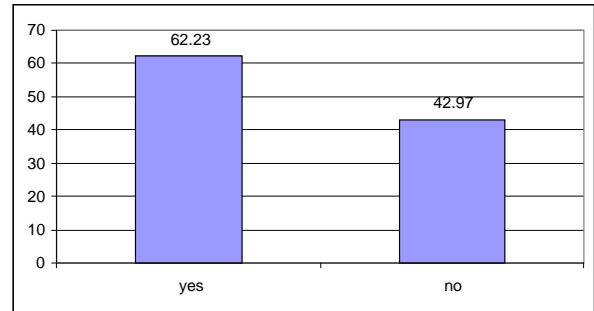


Figure 9: Fundamental frequency ranges of accented and unaccented two-syllable words

accented		N	X	SD
yes	1	128	52.71	12.79
	2	307	61.13	10.80
no		483	43.16	13.33

Table 8: Fundamental frequency ranges of accented and unaccented three-syllable words

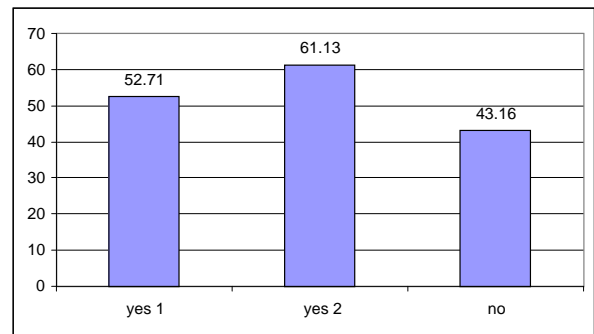


Figure 10: Fundamental frequency ranges of accented and unaccented three-syllable words

accented		N	X	SD
yes	1	17	51.36	8.09
	2	113	52.78	15.70
	3	85	57.42	13.38
no		147	42.65	15.56

Table 9: Fundamental frequency ranges of accented and unaccented four-syllable words

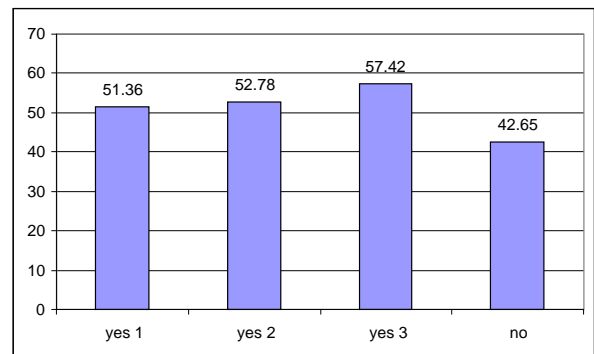


Figure 11: Fundamental frequency ranges of accented and unaccented four-syllable words

It is clear from the tables that unaccented words have a smaller fundamental frequency range than accented words; what is more, the range of unaccented

words varies very little, even in words with a different number of syllables. Besides, in the case of accented words, the range is related to the position of the accented syllable (Table 10).

number of syllables	2]	3]	4]
2	62.23	-	-
3	61.13	52.71	-
4	57.42	52.78	51.36

Table 10: Ranges of accented words with respect to the position of the accented syllable

When the accent falls on the penultimate syllable, it seems that the number of syllables too influences the fundamental frequency range ( $p = 0.002$ ).

### 3.2. Energy

Same as we have done with the data on the fundamental frequency, we shall now present the data on the energy. We shall take into account the number of syllables of the word, whether it is accented or not and the position of the accent; the results are shown in Tables 11, 12 and 13 and Figures 12, 13 and 14.

accented	N	X	SD
yes	206	73.32	1.91
no	459	74.80	1.87

Table 11: Average energy of accented and unaccented two-syllable words

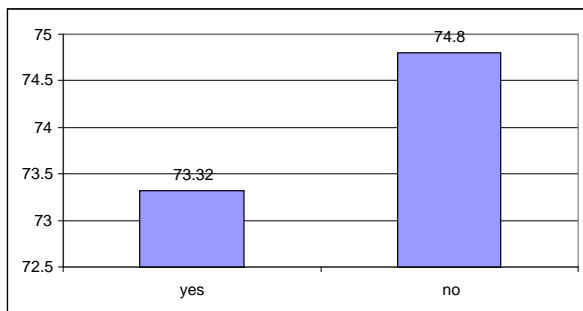


Figure 12: Average energy of accented and unaccented two-syllable words

accented	N	X	SD	
yes	1	128	74.13	1.85
	2	307	74.05	1.72
no	483	74.39	1.74	

Table 12: Average energy of accented and unaccented three-syllable words

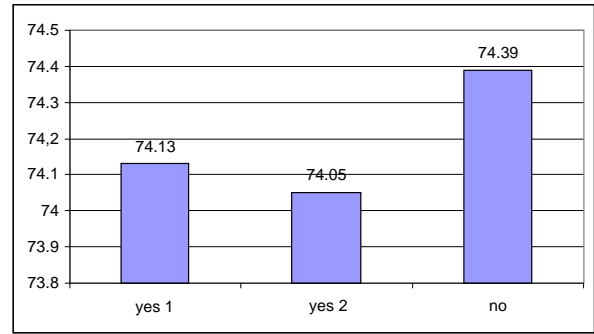


Figure 13: Average energy of accented and unaccented three-syllable words

accented	N	X	SD	
yes	1	17	73.95	1.45
	2	113	74.49	1.52
	3	85	74.56	1.6
no	147	75	1.46	

Table 13: Average energy of accented and unaccented four-syllable words

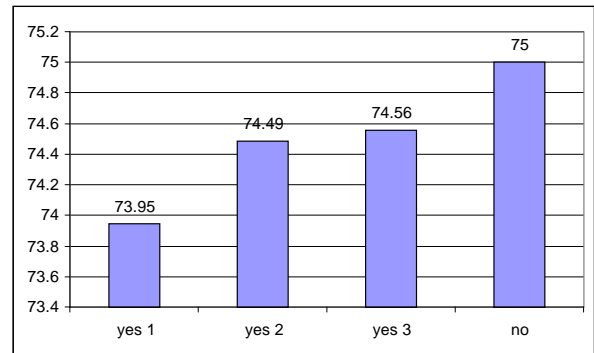


Figure 14: Average energy of accented and unaccented four-syllable words

Looking at the results shown in the tables, we see that the energy of unaccented words is slightly higher than the energy of accented words in all cases; the differences are very weak, though.

Similarly to what we have done with the fundamental frequency, Tables 14, 15 and 16 and Figures 15, 16 and 17 show the energy ranges.

accented	N	X	SD
yes	206	17.93	2.36
no	459	16.57	2.92

Table 14: Energy ranges of accented and unaccented two-syllable words

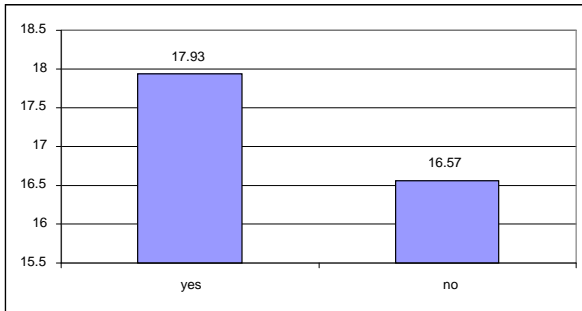


Figure 15: Energy ranges of accented and unaccented two-syllable words

accented		N	X	SD
yes	1	128	17.79	2.53
	2	307	17.91	1.88
no		483	17.13	2.32

Table 15: Energy ranges of accented and unaccented three-syllable words

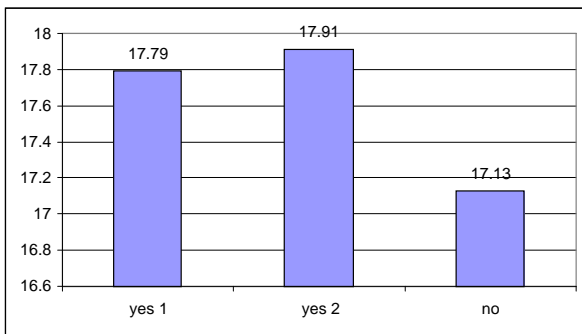


Figure 16: Energy ranges of accented and unaccented three-syllable words

accented		N	X	SD
yes	1	17	18.15	2.03
	2	113	18.19	2.32
	3	85	17.91	2.04
no		147	16.97	2.23

Table 16: Energy ranges of accented and unaccented four-syllable words

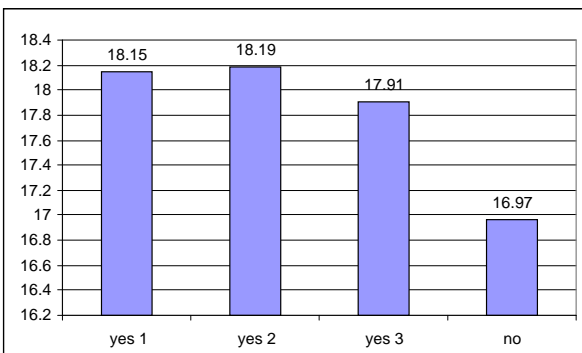


Figure 17: Energy ranges of accented and unaccented four-syllable words

The tables show that, even if the differences are very small, the energy range is smaller in unaccented words than otherwise.

#### 4. Syllable analysis

In this section we shall present the results of the 5055 analysed words. First of all, we shall examine the types of syllables that happen in the lexicon of this dialectal variety together with their features and frequencies. The subsections deal with duration, fundamental frequency and energy.

Before we introduce the types of syllables that appeared in our lexicon, we would like to warn the reader that even if the types of syllables mentioned here reflect quite well the local features, there is room for other possibilities. On one hand, we have not considered monosyllabic words, and on the other, we have limited ourselves to the lexicon. Consequently, some consonant clusters that occur in syllable codas have been left out (*bost, prest*, etc.).

The types of syllables that appear in our corpus and their frequencies and percentages are shown in Table 17 (C stands for consonant, V for vowel and W for any kind of diphthong).

type of syllable	frequency	%
CCV	83	1.64
CCVC	27	0.53
CCW	3	0.06
CCWC	1	0.02
CV	3577	70.76
CVC	630	12.46
CW	64	1.27
CWC	18	0.36
V	389	7.70
VC	229	4.53
W	24	0.47
WC	10	0.20

Table 17: Frequency and percentage of each syllable type

The table shows that 95.45% of the syllables are CV, CVC, V and VC types. CV is the type with the highest frequency (Figure 18).

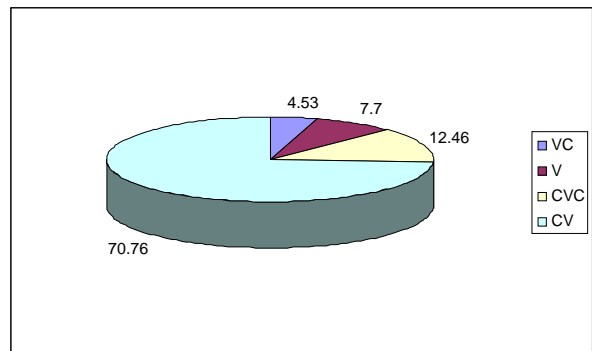


Figure 18: Distribution of the types that sum up to 95.45% of the syllables

Taking into account the usual syllable structure and its components, that is, the onset, the nucleus and the coda, here follow the results of the analysis.

12.9% of the syllables have a null onset. In 84.85% of the syllables the onset consists of a consonant, and in 2.25% of them two consonants occupy the onset (Figure 19).

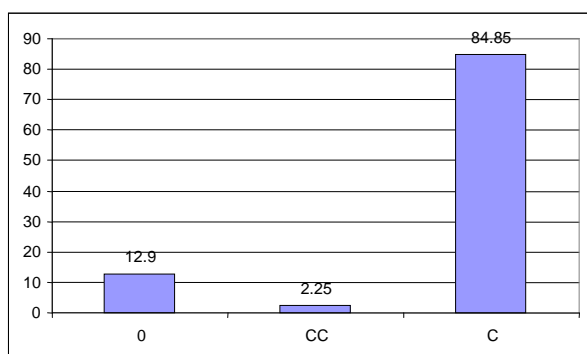


Figure 19: Distribution of syllable onset types

Figure 18 shows the frequency distribution and percentages of single-consonant onsets (4289 altogether).

consonant	frequency	%
<b>b</b>	302	7.04
<b>d</b>	314	7.32
<b>f</b>	26	0.61
<b>g</b>	283	6.60
<b>j</b>	37	0.86
<b>k</b>	469	10.93
<b>l</b>	249	5.81
<b>ll</b>	107	2.49
<b>m</b>	221	5.15
<b>n</b>	135	3.15
<b>ñ</b>	86	2.01
<b>p</b>	218	5.08
<b>r</b>	292	6.81
<b>rr</b>	276	6.44
<b>s</b>	344	8.02
<b>t</b>	500	11.66
<b>tt</b>	56	1.31
<b>tx</b>	127	2.96
<b>tz</b>	143	3.33
<b>x</b>	52	1.21
<b>y</b>	52	1.21

Table 18: Frequencies and percentages of onset consonants

54.01% of the consonants are voiced and 45.98% are voiceless. Looking at the manner of articulation, 51.15% of the consonants are occlusive (including approximants), 10.31% nasal, 10.7% fricative, 8.3% lateral, 13.24% vibrant and 6.3% affricate. And regarding the point of articulation, 17.28% are labial, 19.58% dental, 36.05% alveolar, 8.7% palatal and 18.4% velar; front consonants occur much more frequently than back consonants.

Table 19 shows the frequencies and percentages of the consonant cluster syllable onsets that occur in the lexicon. Word-initial *r*-clusters are more abundant (84.21%) than word-initial *l*-clusters (15.79%).

CC-syllables	frequency	%
<b>bl</b>	1	0.88
<b>br</b>	18	15.79
<b>dr</b>	4	3.51
<b>fl</b>	2	1.75
<b>fr</b>	10	8.77
<b>gl</b>	1	0.88
<b>gr</b>	6	5.26
<b>kl</b>	2	1.75
<b>kr</b>	3	2.63
<b>pl</b>	12	10.53
<b>pr</b>	11	9.65
<b>tr</b>	44	38.60

Figure 19: Distribution of onset consonant clusters

There are nuclei consisting of a single vowel (97.62%), a falling diphthong (1.92%) or a rising diphthong (0.45%). As for the vowel frequencies (Figure 20), *a* has a 28.98% occurrence frequency, *e* 27.8%, *i* 15.08%, *u* 14.41% and *o* 13.74%.

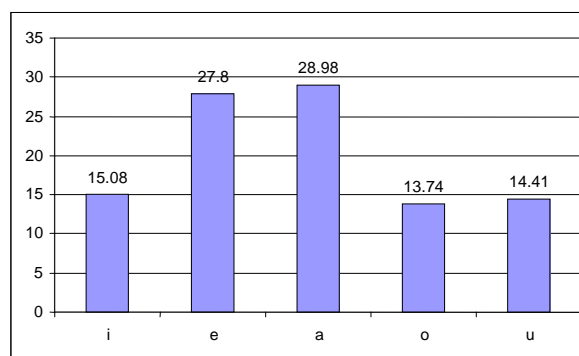


Figure 20: Occurrence frequencies of vowels as syllable nuclei

Tables 20 and 21 show the occurrence frequencies of falling and rising diphthongs.

	<b>i</b>	<b>u</b>
<b>a</b>	23.71	31.96
<b>e</b>	7.22	8.25
<b>o</b>	28.87	-

Table 20: Occurrence frequencies of falling diphthongs as syllable nuclei

	<b>a</b>	<b>e</b>	<b>i</b>	<b>o</b>	<b>u</b>
<b>j</b>	13.04	8.70	-	17.39	4.35
<b>w</b>	30.43	21.74	-	-	4.35

Table 21: Occurrence frequencies of rising diphthongs as syllable nuclei

Syllable codas are null (81.9%) or contain a single consonant (18.1%). *k* occurs in some plural words and is rare in the lexicon; although *p* is used in some monosyllables (*ap*, *eup*) and *t* appears in many words, they never occur in our lexicon. The rest of the consonants are *l*, *n*, *rr* and *s*. Figure 21 shows their occurrence frequencies.

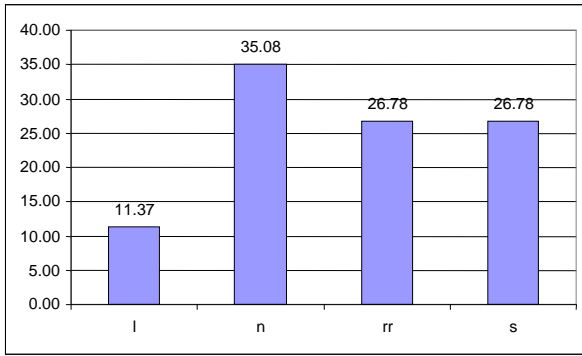


Figure 21: Occurrence frequencies of consonants in syllable codas

Finally, note that, out of the 5055 syllables, those that show zero fundamental frequency because they have not been uttered have been left out for the presentation of the results of the acoustic analysis. The total number of syllables is thus 5038.

#### 4.1. Duration

It is reasonable to think that syllable duration varies according to the number of segments comprised in it. Table 22 and Figure 22 show the average value for each syllable type.

type of syllable	N	X
CCV	83	172
CCVC	27	217
CCW	3	263
CCWC	1	290
CV	3577	166
CVC	630	194
CW	64	192
CWC	18	217
V	389	73
VC	229	129
W	24	115
WC	10	158

Table 22: Amount of syllables of each type and average duration

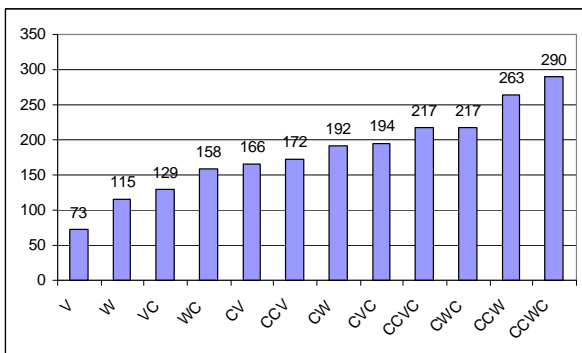


Figure 22: Average duration of each syllable type

Next, we shall study the influence of the accent, the accent location and the number of syllables of the word on the duration. Tables 23, 24 and 25 show the data

according to the number of syllables of the word; what has previously been commented regarding occlusives and fricatives should be taken into account.

	no			yes		
	N	X	SD	N	X	SD
start	434	143.50	48.48	180	170.78	52.45
end	191	192.83	36.37	422	229.34	39.30

Table 23: Syllable duration of two-syllable words

The presence of accent and the location of it influence the duration. Indeed, accented initial syllables are 27 ms longer than unaccented ones, and the stressed final syllables of unaccented words are 37 ms longer than the unstressed final syllables of accented words. Something similar happens with respect to the position of the syllable: unstressed and stressed final syllables are 49 ms and 59 ms longer than initial unaccented and accented syllables, respectively (Figure 23).

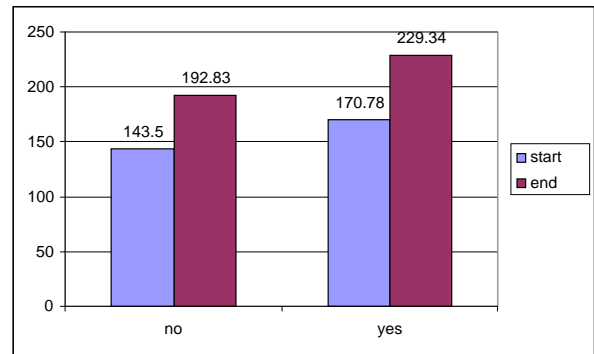


Figure 23: Syllable duration of two-syllable words

	no			yes		
	N	X	SD	N	X	SD
start	718	119.40	44.34	116	129.91	50.64
middle	570	153.81	37.89	279	170.43	36.27
end	399	184.76	33.16	452	209.47	34.50

Table 24: Syllable duration of three-syllable words

The same applies to trisyllabic words. Figure 24 shows the differences in accented (or just stressed in the case of final syllables) and unaccented syllables depending on the position of the syllable.

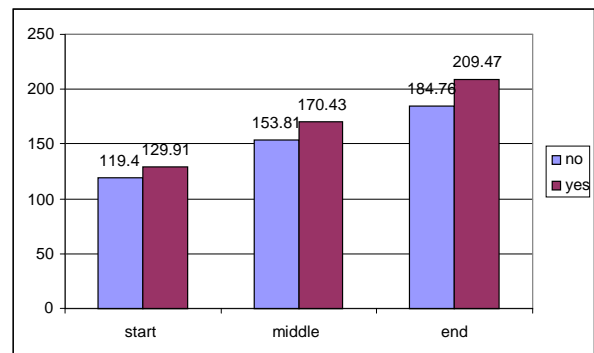


Figure 24: Syllable duration of three-syllable words



	no			yes		
	N	X	SD	N	X	SD
start	303	103.73	37.85	15	119.33	22.65
middle1	216	132.27	32.43	104	143.94	29.92
middle2	247	141.54	32.93	73	161.23	31.01
end	192	187.29	37.75	127	185.28	31.17

Table 25: Syllable duration of four-syllable words

The duration difference between accented/stressed and unaccented syllables changes only in the case of final syllables of four-syllable words (Figure 25).

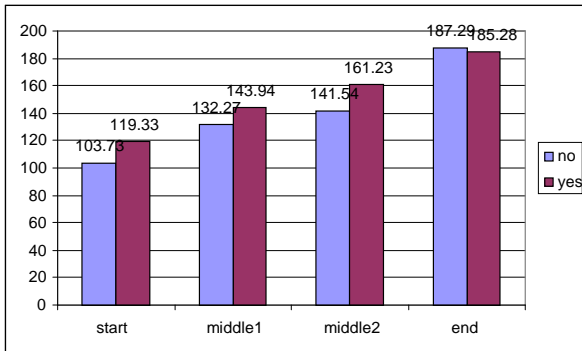


Figure 25: Syllable duration of four-syllable words

The CV syllable type is the most frequent (3577, i.e. 70.76%). Table 26 shows how duration values of CV-syllables change according to the number of syllables of the word, the presence or absence of accent and the position of the accented/stressed syllable.

number of syllables	location	accented/stressed	
		no	yes
2	start	142	140
	end	189	226
3	start	122	126
	middle	140	156
	end	183	208
4	start	115	112
	middle1	124	136
	middle2	137	154
	end	186	185

Table 26: Average duration of CV-syllables

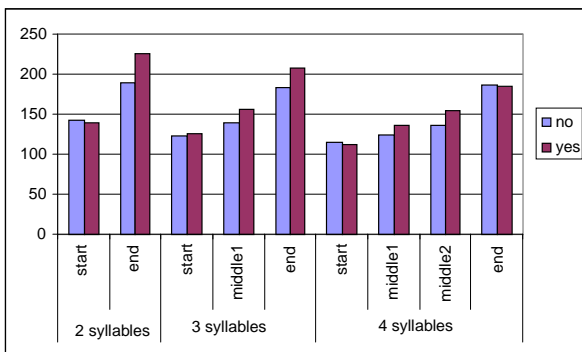


Figure 26: Average duration of CV-syllables

The results in Table 26 and Figure 26 clearly prove that the position of the syllable is a more determining factor than the presence of accent. Therefore, we could say that, although all three factors are influential, the type of syllable and its position are the most determining.

## 4.2. Fundamental frequency

The data on the fundamental frequencies according to the number of syllables of the word are displayed in Tables 27, 28 and 29.

	no			yes		
	N	X	SD	N	X	SD
start	434	140.29	7.93	180	155.75	9.29
end	191	121.10	8.54	422	147.08	6.79

Table 27: Syllable fundamental frequencies of two-syllable words

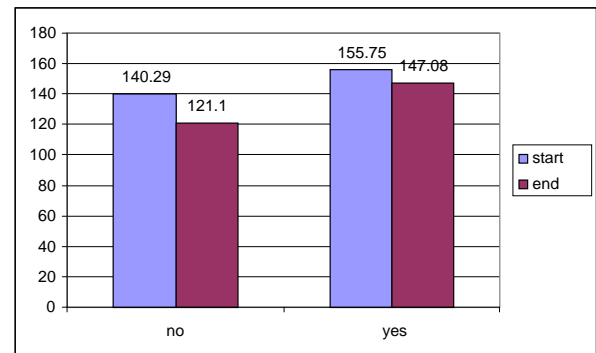


Figure 27: Syllable fundamental frequencies of two-syllable words

	no			yes		
	N	X	SD	N	X	SD
start	718	141.38	8.66	116	157.73	8.29
middle	570	147.50	8.20	279	155.20	7.14
end	399	125.56	8.92	452	148.33	6.56

Table 28: Syllable fundamental frequencies of three-syllable words

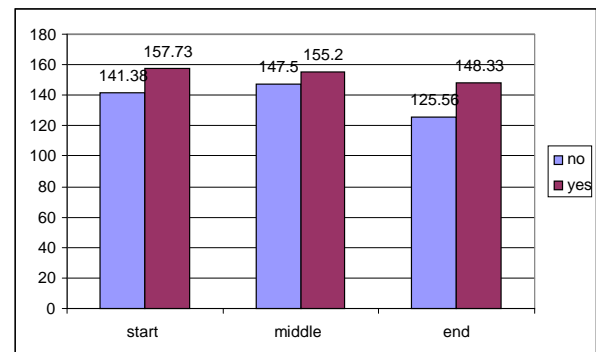


Figure 28: Syllable fundamental frequencies of three-syllable words

	no			yes		
	N	X	SD	N	X	SD
start	303	140.85	8.30	15	157.45	8.12
middle1	216	146.28	6.94	104	156.50	7.64
middle2	247	145.15	9.22	73	153.19	7.53
end	192	131.20	10.40	127	145.86	6.58

Table 29: Syllable fundamental frequencies of four-syllable words

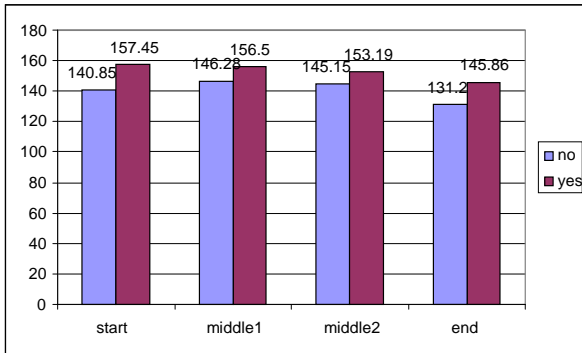


Figure 29: Syllable fundamental frequencies of four-syllable words

In all cases the average fundamental frequency is higher in accented/stressed syllables than in unaccented ones. As shown in Figure 30, the average fundamental frequency of unaccented syllables is affected by the number of syllables of the word and its position; it is higher in word-initial position than in word-final position, and it reaches the highest peaks in the middle syllables. Note that the fundamental frequency of final syllables follows a fall after a peak at the accented syllable, and the fundamental frequency of middle syllables follows a rise after the beginning of the word.

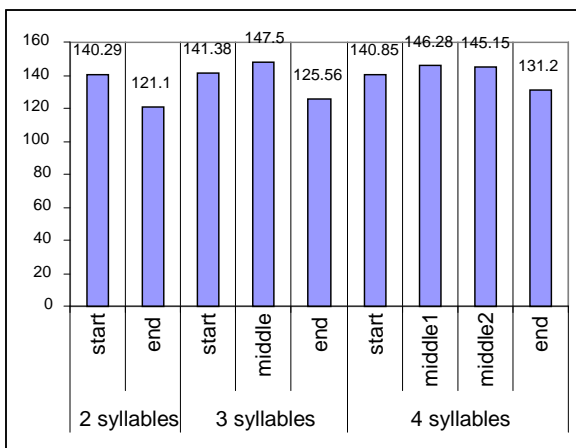


Figure 30: Fundamental frequency of unaccented syllables according to their position

As shown in Figure 31, the fundamental frequency of final stressed syllables is lower than the rest; this happens in unaccented words, and it is related to the poor fundamental frequency range of such words. The initial accented syllables present the highest  $f_0$  values;

the  $f_0$  diminishes in the middle syllables and towards the end.

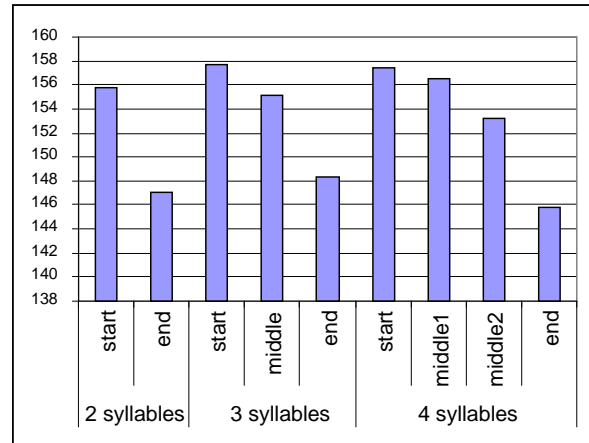


Figure 31: Fundamental frequency of accented/stressed syllables according to their position

### 4.3. Energy

The data on energy according to the number of syllables of the word are given in Tables 30, 31 and 32.

	no			yes		
	N	X	SD	N	X	SD
start	434	75.85	2.25	180	76.78	2.11
end	191	70.81	2.80	422	74.27	2.32

Table 30: Average syllable energy of two-syllable words

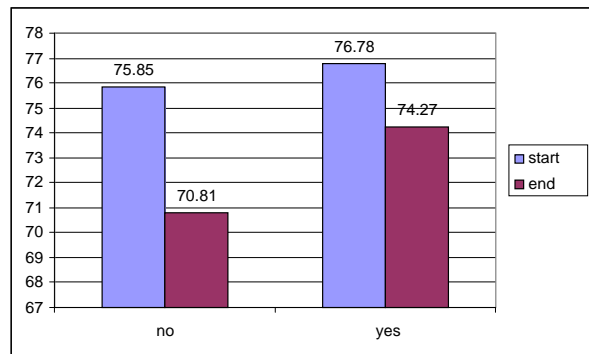


Figure 32: Average syllable energy of two-syllable words

	no			yes		
	N	X	SD	N	X	SD
start	718	75.98	2.44	116	77.51	2.05
middle	570	74.64	2.95	279	75.35	2.77
end	399	72.05	2.40	452	73.72	2.24

Table 31: Average syllable energy of three-syllable words

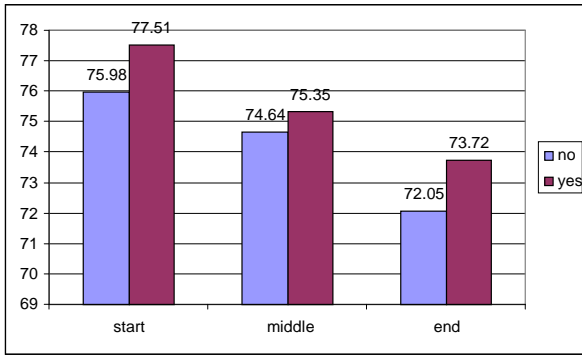


Figure 33: Average syllable energy of three-syllable words

	no			yes		
	N	X	SD	N	X	SD
<b>start</b>	303	76.07	2.36	15	77.13	2.05
<b>middle1</b>	216	75.52	2.98	104	75.88	3.16
<b>middle2</b>	247	75.20	2.98	73	75.86	2.73
<b>end</b>	192	72.44	2.41	127	74.09	1.91

Table 32: Average syllable energy of four-syllable words

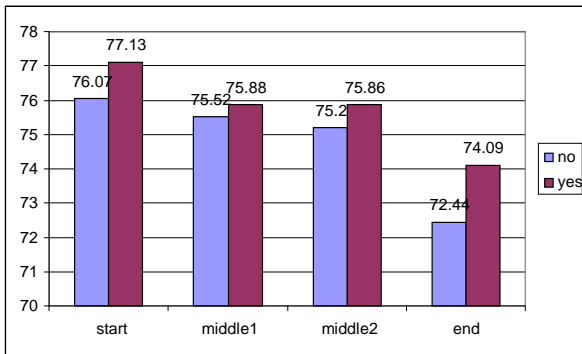


Figure 34: Average syllable energy of four-syllable words

The average energy values are higher in accented/stressed syllables than in unaccented ones in all cases.

Same as what happens in the case of the average fundamental frequency, the position of the accented/stressed syllable has an effect on the energy too. In Figure 35 we see that the average energy of initial unaccented syllables is higher; the energy of unaccented syllables in four-syllable words clearly decreases towards the end.

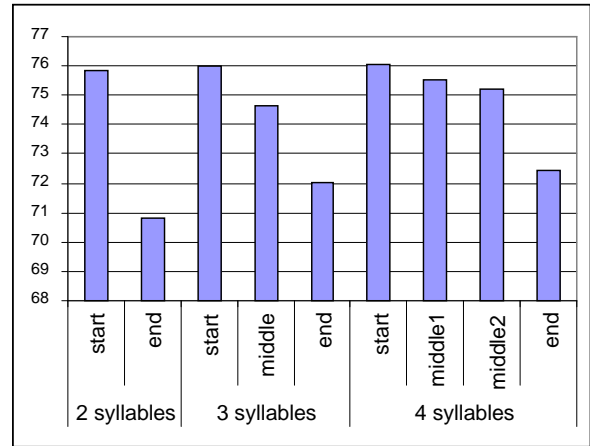


Figure 35: Average energy of unaccented syllables according to their position

In Figure 36 we see that the same applies to initial accented syllables.

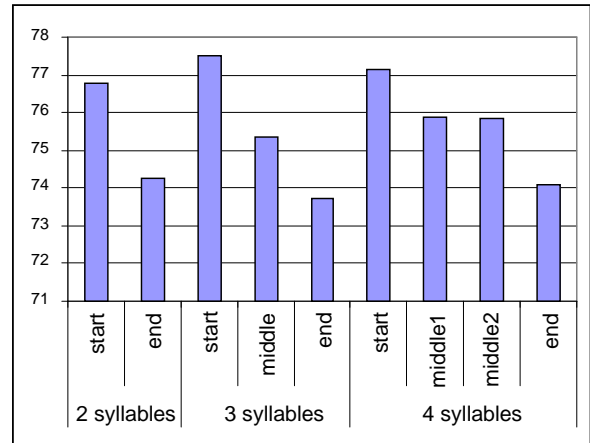


Figure 36: Average energy of accented/stressed syllables according to their position

## 5. Conclusions

Summarizing the results of the analysis of the fundamental frequency and the energy at word level, we clearly see that the fundamental frequency is more important than the energy in the distinction between accented and unaccented words.

As far as the fundamental frequency is concerned, unaccented words have a higher average than accented ones; this is due to the poorer fundamental frequency range of these words (see Figures 37, 38 and 39). Besides, the fundamental frequency range is related to the position occupied by the accented (or stressed if final) syllable, and to a lesser extent, to the total amount of syllables of the word.

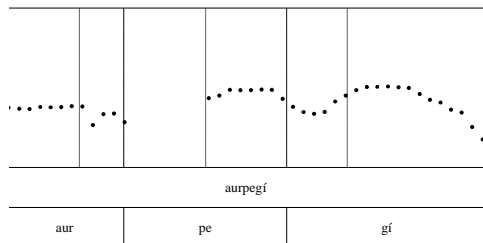


Figure 37: Fundamental frequency of the unaccented word *aurpegi*

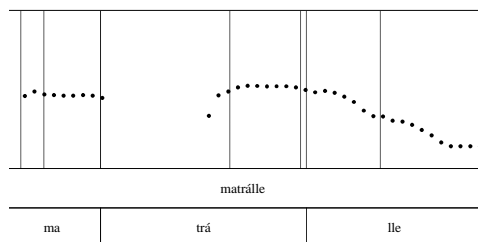


Figure 38: Fundamental frequency of the accented word *matraille*

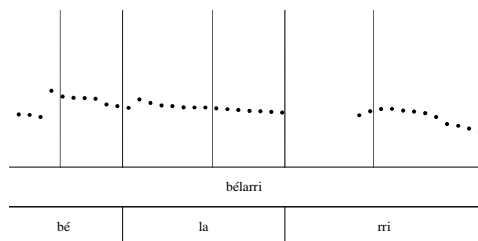


Figure 39: Fundamental frequency of the accented word *bélarri*

The differences of energy are very small; however, the average is higher in unaccented words than otherwise.

The first conclusion that can be drawn from the syllable analysis is that the accented/stressed syllable is longer, higher and stronger (Table 33).

feature	accented/stressed		unaccented	
	X	SD	X	SD
duration	190.54	49.99	146.07	48.2
f0	151.07	8.4	139.14	11.75
energy	74.94	2.68	74.66	3.1

Table 33: Results on the acoustic features of accented/stressed, 1768, and unaccented, 3261, syllables

Having applied the ANOVA analysis, only the duration and the fundamental frequency are closely connected with the presence of accent in the syllable ( $p = 0.000$ ,  $p = 5.6E-18$  for the duration and  $p = 2.2E-20$  for the fundamental frequency); the energy has no influence on the accented/stressed syllable ( $p = 1$ ). Nonetheless, the position of the syllable within the word and the number of syllables of the word affect all the features, although to a different extent.

## 6. References

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