Vowel reduction and Catalan speech rhythm

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Abstract

Some of the contemporary rhythm measures are believed to capture the degree of vocalic reduction in languages. The present study investigates whether these rhythmic measurements react differently to the two major Catalan dialects as a result of their difference in vowel reduction. On the one hand, Eastern Catalan reduces its vowel system in unstressed syllables. On the other hand, Western Catalan does not apparently undergo this process of vowel reduction. Rhythm measurements (%V, ΔC, ΔV, nPIV, and rPVI) were carried out in read speech from 7 speakers of Western and 4 speakers of Eastern Catalan. The results reveal that no significant difference in rhythmic measurements exists between the two Catalan dialects. Both Eastern and Western Catalan are shown to be classified as syllable-timed as regards the results obtained for %V and ΔC, and as intermediate—in between syllable-timed and stress-timed—as far as nPVI and rPVI are concerned. It will be discussed whether contemporary rhythm measures can capture vowel reduction processes or to what extent vowel reduction is actually qualitatively different in Eastern and Western Catalan.
Introduction

Vowel reduction is a feature that affects durational variability of vowels and/or vocalic intervals, which in turn is believed to affect speech rhythm (Ramus et al, 1999, Grabe & Low, 2002). Typical stress-timed languages tend to undergo vowel reduction. On the contrary, syllable-timed languages do not have this feature. Catalan is a romance language that is said to undergo vowel reduction, but it has all the other typical characteristics of a syllable-timed language. That is the reason why the rhythm of this language has not yet been clearly categorized and has been a matter of controversy in the literature (Nespor, 1990, Grabe & Low, 2002, Ramus et al, 1999).

At the same time, Catalan can be subdivided into two main dialects, which are claimed to differ in vowel reduction. According to Carbonell & Lлистерри (1999), Eastern Catalan (group within which the standard accent would be included) undergoes a process of vowel reduction whereas Western Catalan does not. The present paper investigates the effect of the dialectal difference in vowel reduction on speech rhythm. Speech rhythm was measured by recently proposed measures based on durational characteristics of consonantal and vocalic interval durations such as %V, ∆C, nPVI, rPVI, etc. (Ramus et al., 1999, Grabe & Low, 2002, further explanations below). In particular, the measures %V and nPVI and ∆V have been argued to be affected by vowel reduction. These measures should therefore be expected to show different speech rhythm results for Eastern and Western Catalan as an effect of the differences in vowel reduction. An acoustic analysis of vocalic and consonantal intervals of the two Catalan dialects will be carried out with the endeavour to shed some light on the nature of the dialectal variation of Catalan vowel reduction and its effect on Catalan speech rhythm.
1.1. Overview of the rhythm class hypothesis.

The rhythm class hypothesis has been traditionally based on the idea that languages can be classified into two main categories as regards their linguistic rhythm. Pike (1945) called these two classes “stress-timed” languages, for languages such as English and German, and “syllable-timed” languages, to refer to languages such as Spanish or French. This classification was especially held by Pike (1945) and Abercrombie (1965, 1967) and was categorical: languages could solely be either syllable-timed or stress-timed. Their categorization would depend on which features recurred isochronously, i.e. they happened at equal intervals of time. According to this view, in stress-timed languages, stresses would be isochronously spaced, whereas in syllable-timed languages syllable durations would be considered to be isochronous. This dichotomy based on isochrony was soon to be challenged by subsequent authors who gave strong evidence against both a categorical classification of rhythm and the idea of isochrony.

Research carried out by many authors, such as Roach (1983) and Dauer (1983) provides strong evidence against the concept of isochrony (see Grabe & Low (2002) for review). Their studies confirm that a) interstress intervals do not have a regular duration in either stress or syllable-timed languages and that b) the duration of syllables is not constant in either of these language types. As Roach states:

The results reported here give no support to the idea that one could assign a language to one of the two categories on the basis of measurement of time intervals in speech. Consequently one is obliged to conclude that the basis for the distinction is auditory and subjective – a language is syllable-timed if it sounds syllable-timed. (1983:77)
In other words, isochrony seems more related to perception than to the acoustic signal and consequently, the difference between languages such as English and Spanish does not rely on interstress intervals or syllable durations.

The duality established by Abercrombie and Pike by which languages could only belong to one of the two types—either stress-timed or syllable-timed—was also questioned when further languages were analysed. A third type, mora-timed rhythm, was added by several authors including Ladefoged (1975), where morae, which are units of syllable weight, are the units that establish the timing. Japanese is the language that typically exemplifies this rhythm class.

Besides, Dasher & Bolinger (1983) suggested that the impression of a difference between stress-timed and syllable-timed languages might be caused by specific phonological properties intrinsic in languages and not by any endeavour on the part of the speaker towards equalizing interstress intervals or syllable durations. Dauer (1983) went a step further by actually enumerating these linguistic properties, of which the most important are syllable structure and vowel reduction.

As regards syllable structure, we find that stress-timed languages allow a greater variety of syllable types: in English, for example, a vowel can be closed by up to four consonants (the syllable template for English would be \(C_0,3VC_{0,4}\)). On the contrary, syllable-timed languages have a very limited amount of allowed syllable structures, as in Spanish, where only two consonants can occupy the coda position (its syllable template is \(C_{0,2}VC_{0,2}\)). Stress-timed languages also show a considerable tendency to stress heavy syllables and keep the light syllables unstressed. Thus, “syllable structure and stress are more likely to reinforce each other in a stress-timed than in a syllable-timed language. (Dauer, 1983: 56)”

Vowel reduction is another feature that differentiates stress-timed from syllable-timed languages. In stress-timed languages, the unstressed vowels tend to be noticeably
shorter than stressed vowels and that may show up as a reduction of the phonetic vowel space and a subsequent neutralization of the vowel phonemes. English, for example, reduces a high percentage of its vowels—very often to the same vowel schwa—in unstressed position, whereas in a typical syllable-timed language such as Spanish, all vowels remain unchanged independently of their stress. This phenomenon emphasizes the difference between stressed and unstressed syllables in stress-timed languages.

Dauer (1987) claims that the way these linguistic properties combine with one another is what creates the feeling of the existence of different types of rhythm. She also proposes a different view of the rhythm classification, which totally differs from that given by Abercrombie and Pike. She brings in a conception of linguistic rhythm as a continuum, with stress-timed and syllable-timed rhythms at either end. According to this view, then, languages could be more stress-timed or more syllable-timed depending on their balance of these phonological features. For example, stress-timed languages would typically have both a very complex syllable structure and vowel reduction, whereas a “less stress-timed” language would only have, say, one of these features.

Nespor (1990) supported this idea arguing for the existence of what she called “intermediate languages”, namely Catalan and Polish. These languages would be situated in an intermediate position within this continuum because they have some properties that typically belong to both rhythm types. Catalan has a syllable structure that is more similar to that of a syllable-timed language than to that of a stress-timed language (its syllable template being C_{0-2}VC_{0-3}) but it is claimed to have vowel reduction, which is a feature that typically belongs to stress-timed languages. On the other hand, Polish does not show vowel reduction, but it has a very complex syllable structure, like a stress-timed language.
1.2. Typology of rhythm as the result of phonetic properties of languages

This idea that the impression of a difference between two (or three) types of rhythm may be the consequence of the sum of some phonological properties of languages has been further developed by some recent studies, especially Ramus et al. (1999, 2003) and Grabe & Low (2002). These approaches effectively separate languages into the traditional rhythm classes by means of measurable phonetic properties that can be found in the speech signal. These properties are in turn a direct effect of the phonological properties we have seen before –mainly syllable structure and vowel reduction.

Ramus et al. (1999) base their description on a hypothesis about how children perceive speech. According to the authors, it has been shown that the infant perception of speech is focused on vowels –because they are more salient-, and that they perceive speech as “a succession of vowels of variable durations and intensities, alternating with periods of unanalyzed noise (i.e. consonants)” (Ramus et al, 1999: 270). The perception of the different types of rhythm by infants can then be explained by means of the segmentation of speech into vocalic and intervocalic (i.e. consonantal) intervals. From this segmentation, they derive three variables: 1) %V, which is the proportion of vocalic intervals within the sentence; 2) ΔV, the standard deviation of the duration of vocalic intervals; and 3) ΔC, the standard deviation of the duration of consonantal intervals. A graph locating their results on different languages over the (%V, ΔC) plane turns out to fit best with the standard rhythm typology, as can be seen in Figure 1.
According to this distribution, English, Dutch and Polish appear to be stress-timed languages while Spanish, Italian, French and Catalan would be syllable-timed languages. Japanese, which is separated from the rest of languages, is the one classified as mora-timed. It has been subsequently demonstrated that listeners actually make use of these acoustic cues to divide these languages into the different rhythmic classes (see Ramus et al., 1999, 2003).

A conclusion that derives from the distribution of the languages is that %V and \( \Delta C \) seem to be directly related to syllabic structure. A high \( \Delta C \), as in the case of stress-timed languages, reflects a greater variability in the duration of the syllables, what in turn results in a lower proportion of vocalic intervals—a low %V. \( \Delta V \), however, does not seem to be so related to rhythm as the other two measures. According to Ramus et al. (1999), it reflects all the possible phenomena that can affect vocalic variability, namely, vowel reduction, contrastive vowel length, long vowels, and vowel lengthening in specific contexts. The authors explain that

Only vowel reduction and contrastive vowel length have been described as factors influencing rhythm (Dauer, 1987), but the present analysis suggests that the other factors may also play a role. In our measurements, \( \Delta V \) reflects the
sum of all phenomena. As a possible consequence, the \( \Delta V \) scale seems less related
to the usual rhythm classes. (Ramus et al., 1999: 275)

Their conclusion is that, although this scale stills reflects phonological properties of
languages, it is not clear to what extent it reflects anything about rhythm perception.

Another influential study based on the segmentation of speech into vocalic and
intervocalic intervals is that carried out by Grabe & Low (2002). Their study is based on
the Pairwise Variability Index, an index which expresses the average differences between
consecutive vocalic and intervocalic intervals. On the one hand, they compute the raw
Pairwise Variability Index (rPVI), which is given in the following equation:

\[
    rPVI = \frac{1}{m-1} \sum_{k=1}^{m-1} |d_k - d_{k+1}|,
\]

where \( m \) is the number of intervals and \( d \) is the duration of the \( k \)th interval. A high rPVI
means a high variability in successive intervocalic intervals, and therefore, a rather
complex syllable structure. Then stress-timed languages should have a high rPVI as the
result of their having many possible types of syllable structures. Syllable-timed
languages, on the contrary, have a limited number of allowed syllable structures, which
means a low variability and hence a low rPVI.

The second index they use is the normalized Pairwise Variability Index (nPVI),
whose equation is the following:

\[
    nPVI = 100 \times \left[ \frac{\sum_{k=1}^{m-1} \frac{d_k - d_{k+1}}{(d_k + d_{k+1})/2}}{m - 1} \right]
\]

Contrary to %V, \( \Delta C \) and \( \Delta V \), which are speech rate dependent, nPVI is normalised for
speech rate (see Dellwo, 2006 for a working normalization procedure of \( \Delta C \) and \( \Delta V \)).
Grabe & Low compute a normalised PVI for vocalic intervals because vowels are
stretched or compressed depending on speech rate. On the contrary, a raw PVI is more
appropriate for intervocalic intervals because these intervals contain many segments and
that is the primary characteristic of syllabic structure. A normalisation of intervocalic intervals would then obliterate the differences in syllabic structure among languages, which is one of the fundamental properties that distinguish stress-timed and syllable-timed languages.

Grabe & Low’s results of the data on the different languages are plotted in Figure 2:

Figure 2: distribution of languages over the (rPVI, nPVI) plane. From Grabe & Low (2002).

The PVI measures show a distinction between traditionally stress-timed languages such as Dutch, German and English and some of the typical syllable-timed languages such as French and Spanish, similarly to Ramus et al. (1999). However, Catalan and Polish appear, supporting Nespor’s (1990) idea, as somewhat intermediate languages, whereas Ramus et al.’s (1999) measures clearly classify Catalan as a syllable-timed language and Polish as a stress-timed language.
1.3. Catalan and rhythm

1.3.1. Introduction to Catalan

Catalan is a romance language spoken in four different European states by approximately 7 million people. The Spanish areas where it is most broadly used and is official are the autonomous community of Catalonia, the Valencian Community and the Balearic Islands. Apart from these communities, it is also spoken in the eastern part of Aragon, which is the nearest area to Catalonia. Catalan is also the main official language of the Principality of Andorra. Moreover, it is spoken in Rousillon (Rosselló), in the south of France, as it was one of the historical counties of what used to be –until 1931- the Principality of Catalonia. Finally, Catalan is spoken by a minority of the population of the city of Alghero (l’Alguer), in the Italian isle of Sardinia, as a consequence of the invasion of Catalan colonists in the 16th century.

Catalan has usually been divided into two main dialects, Eastern and Western Catalan. Although this paper is only centred on these two major dialects, each dialect can be subdivided into further sub–dialects, which may differ slightly between each other in their pronunciation. A map of the different dialects and sub-dialects of Catalan can be seen in Figure 3.

---

1 From: http://commons.wikimedia.org/wiki/Image:Dialectal_map_of_Catalan_Language.png
Both Eastern and Western Catalan have a stressed vowel system of seven vowels: [i] [e] [ɛ] [a] [ɔ] [o] and [u]. However, Catalan has vowel reduction and it is their unstressed vowel systems what has been claimed to be the fundamental difference between the two main dialects. Carbonell & Llisterrri (1999) categorically state that Eastern Catalan undergoes vowel reduction while Western Catalan does not:

The two main dialects differ noticeably in the treatment of unstressed vowels: while Western Catalan does not show vowel reduction processes in unstressed syllables, in Eastern Catalan dialects /e/, /e/ and /u/ merge into schwa [ə] and /o/ and /ɔ/ merge into [u] in unstressed positions, while /i/ and /u/ retain their quality. (1999: 63)

Catalan has two weak vowels [i, u] which when accompanying a strong vowel, may become the semivowels [j, w] to form a diphthong. There are two kinds of diphthongs depending on the position of the weak and strong vowels within the syllable. Falling diphthongs (decreixents) are formed when the weak vowel follows the strong vowel, in which case, the weak vowel is considered to be a semivowel2. Examples of these are:

mai [maj] “never”
nou [nɔw] “new”

Two weak vowels together are considered to be a falling diphthong, where the first vowel behaves as the vowel, and the second one as the semivowel, as in

ciutat [ciw’tat] “city”
buit [bujt] “empty”

The second type of diphthong is the rising diphthong (creixent), which is formed by a weak vowel preceding a strong vowel word-initially or between vowels, or by the weak

---

2 Literature on Catalan phonetics normally distinguish semivowels (weak vowels that follow strong vowels) from semiconsonants (weak vowels that precede strong vowels). Semivowels tend to be transcribed as [i, u] in Catalan literature, whereas semiconsonants are transcribed as [j w]. In this paper only the symbols [j w] will be used for both semivowels and semiconsonants.
vowel [u] situated between [g] or [k] and a strong vowel. In this type of diphthongs, the weak vowel works as a semiconsonant:

- *iode* [jɔdə] “iodine” (Eastern Catalan pronunciation)
- *creuar* [crə'wa] “to cross” (Eastern Catalan pronunciation)
- *guany* [gwan] “profit”

When the weak vowels are situated between a consonant and a strong vowel, it is not considered as a diphthong, but as a hiatus, and therefore both vowels function as the nucleus of two different syllables, as in:

- *camió* [kəmio] “lorry”
- *suor* [su'o] “sweat”

### 1.3.2. Catalan and the literature on rhythm.

As previously mentioned, authors do not agree on the rhythmic status of Catalan. Firstly, Nespor (1990) qualified Catalan as an intermediate language. According to her description, Catalan “has 12 most common syllable types that are constituted by a minimum of 1 and a maximum of 6 segments” (1990: 164). This would make Catalan depart a little bit from the syllable-timed languages like Italian, Greek or Spanish which have a simpler syllabic structure and would make it approximate to stress-timed languages such as Dutch and English, which would have a much more complex syllable structure. In addition to this, Catalan undergoes a process of vowel reduction, by which some of its vowels are automatically centralised in unstressed position, which is a feature typically associated with stress-timed languages. Apart from this, Catalan also has a rule by which one of two adjacent vowels is deleted under certain conditions, which is typical of syllable-timed languages. Therefore Catalan, having certain features distinctive of stress-timed languages and some other characteristics in common with syllable-timed
languages, would be situated somewhat in the middle of the rhythm continuum suggested by Dauer (1983).

Ramus et al. (1999), on the contrary, classify Catalan as a syllable-timed language as regards their results on %V, ΔC and ΔV. Additionally, according to the perceptual studies carried out by Ramus et al. (2003), Catalan is indistinguishable from Spanish as regards rhythm, which confirms their rhythmic similarity in spite of their difference in vowel quality and vowel reduction. The conclusion they reach regarding their data on ΔV—which captures the variability of the duration of vocalic intervals caused by vowel reduction—is the following:

…ΔV does not separate Catalan from syllable-timed languages, suggesting that vowel reduction in Catalan does not quantitatively impact on this variable. This is consistent with our perceptual results which suggest that vowel reduction in Catalan is not enough to make it depart from syllable-timing. (2003:5)

Under this perspective, then, Catalan should be considered a syllable-timed language and not an intermediate language, in spite of its vowel reduction.

In opposition to that, Grabe & Low’s (2002) analysis ratify Nespor’s (1990) observation as regards the differences between Catalan and Spanish vowel qualities. Their findings (see Figure 2) show a detachment of Catalan from Spanish in the nPVI axis. However, Catalan also appears near French in the same axis, also a syllable-timed language which does not have vowel reduction. In relation to this, the authors explain how a study carried out by Low et al. (2000) found significant differences in the way vowels are reduced in Singapore English and British English. These differences have been considered to affect their respective rhythm. Grabe & Low (2002) conclude by saying that

These findings suggest that we may be able to account for our vocalic nPVI data from French, Spanish and Catalan on the basis


1.4. **Rationale**

In the light of the existence of a considerable difference in vowel reduction between the two main Catalan dialects, Grabe & Low’s suggestion (see section 1.3.2.) seems an invitation for further investigation on this matter. As we have previously seen, rhythm measures are thought to react to vowel reduction and this difference in vowel reduction between the two dialects could very possibly have an influence on their rhythm, up to the point that both dialects could be separated in the linguistic rhythm continuum by the lack or presence of a vowel reduction process. If this was the case, Western Catalan could likely be classified as a syllable-timed language due to its lack of vowel reduction while Eastern Catalan could be categorized as an intermediate or even a stress-timed language as a result of its vowel reduction.

The aim of the present study is precisely to test this hypothesis. It consists of an examination of a set of recordings from two groups of speakers of the two main dialects of Catalan. The analysis of the data is mainly centred on the two major approaches to rhythm measures that have been previously examined: on the one hand, Ramus et al.’s (1999) %V, ΔV and ΔC, and on the other hand Grabe & Low’s (2002) nPVI and rPVI.

1.5. **Hypothesis**

The hypothesis of the present paper, as aforementioned, is based on the previous idea that Eastern and Western Catalan differ qualitatively in vowel reduction, and that this difference is likely to have an influence on their rhythm. According to this hypothesis, it was conjectured that the two dialects should differ acoustically in vowel durational characteristics –as a consequence of their qualitative difference in vowel reduction-, while their consonant complexity should remain equivalent.
The material collected was compared with other languages included in the Bonntempo corpus, a speech database created for the study of speech rhythm in connection with speech rate (see Dellwo et al., 2004). The languages included are English, German, Italian, French and Czech. English and German have been traditionally classified as stress-timed languages and Italian and French are considered to be syllable-timed. Czech’s rhythm, however, was demonstrated to be difficult to classify using contemporary rhythm measures (see Dankovicová & Dellwo, 2007). For the purpose of the present study, Catalan will only be compared to the languages in the database that have been widely defined as either syllable-timed – Italian and French- or stress-timed – English and German.

1.5.1. Expectations on Vowel Complexity

Vowel reduction is a feature that typically characterizes stress-timed languages (see section 1.1.), and German and English, as stress-timed languages, both undergo a process of vowel reduction. For this reason, it was hypothesized for measures that are thought to react to this feature (%V, ΔV, nPVI) that Eastern Catalan, which is the dialect that apparently has vowel reduction, would reveal results not significantly different from English and German. On the contrary, Western Catalan, the dialect which is claimed not to undergo this process, was expected to have similar values for %V, ΔV and nPVI as the syllable-timed languages – French and Italian- because syllable-timed languages do not normally undergo vowel reduction processes.

1.5.2. Expectations on Consonant Complexity

The difference between Eastern and Western Catalan seems to rely solely on their variation in vowel reduction. As a result, it was expected to obtain equivalent values between the two dialects as regards ΔC and rPVI, the measures that react to variability in
syllable structure. Catalan syllable structure is in principle much more similar to that of typical syllable-timed languages than to that of stress-timed languages, having a syllable template like C_{0-2}VC_{0-3}, which implies a rather simple syllabic structure. This is the reason why it was hypothesized that both dialects would overlap with the syllable-timed languages in the corpus –French and Italian- in their ΔC and rPVI values.

2. Experimental Methodology

2.1. Data Collection

The data was collected in two areas of Catalonia, each of them representative of one main dialect: a village called *La Pobla de Massaluca*, in the county of Terra Alta –in the south of Catalonia- as representative of Western Catalan. The data on Eastern Catalan were gathered in Barcelona. The location of both places can be seen in Figure 4. The speakers were recorded reading a text consisting of seven sentences (see Appendix) at an average pace - the subjects were told to read the text as if they were explaining a story and they had plenty of time to read it before recording them. The data collected were to be compared with the data from other languages included in the Bonntempo corpus (see Dellwo et al., 2004).
2.2. Subjects

Seven native speakers of Western Catalan and seven native speakers of Eastern Catalan –male and female with an age range from 20 to 40 years old- were recorded (and labelled) for the experiment. Only speakers that were born and still lived in the place where the data were collected were chosen in order to have as few influences from other languages or accents as possible. Because the labelling process was very time consuming, three of the Eastern Catalan speakers were not finished when the data analysis of the current project was carried out. For this reason the present results for Eastern Catalan are only based on 4 speakers. However, the total number of speakers and the total number of consonantal and vocalic interval processed for each Catalan dialect in the present study is drastically higher than in key studies on speech rhythm (Ramus et al., 1999, Grabe & Low, 2002).

2.3. Method

The analysis of the data was carried out by means of the software Praat (http://www.praat.org) by the author, who is a native speaker of Catalan. The labelling was done in a similar way as the data on the other languages within the Bonntempo corpus (Dellwo et al., 2004). The text was firstly segmented into syllables and secondly into vocalic and intervocalic intervals. Syllables were separated according to Catalan syllabification rules (see Recasens, 1991:147-154) by which CV structures were maintained when possible. For example, in VCV sequences, the consonant in the middle was syllabified as the onset of the following vowel and sequences such as VC-CV were only created whenever the two consonants were not a possible onset in the language.

Intervals were segmented following the procedures suggested in Ramus et al. (1999) and Grabe & Low (2002). Vocalic intervals were regarded as what was comprised between the onset and the offset of a vowel (or vowels) and included monophthongs,
diphthongs, hiatus, and all vocalic segments from different words that became adjacent due to coarticulation. Glides, therefore, being part of diphthongs, were included within the vocalic intervals. An example of segmentation and labelling of the word *ciutats* [siw'tats] -which comprises a falling diphthong- spoken by an Eastern and Western Catalan speaker, can be seen in Figures 12 and 13 in the Appendix. Intervocalic intervals were regarded as what was situated between the offset and the onset of a vowel. It could be worth mentioning a particular case of vocalic element which was not included within the vocalic intervals, which is the svarabhakti element. This is a vocalic element that very often appears between a sequence of obstruent and liquid (in any order). In Catalan, the svarabhakti element very often appears together with the rhotic consonants [r r]. In the segmentation performed in this study, these vocalic elements were regarded as part of the consonant, and therefore included within the intervocalic intervals. An example of svarabhakti element in the word “Berga” ['berɣə] can be found in Figure 14 in the Appendix.

Rhythm measures were calculated from the measurements derived from the labelling according to the formulae presented above. The statistical analysis software employed was SPSS. The measures extracted were %V, ΔV and ΔC following Ramus et al. (1999) and nPVI and rPVI following Grabe & Low (2002). From the measures derived, box plots were computed (see Figures 5, 6, 7, 8 and 9), which show the distribution of each of the dependent variables -%V, nPVI, ΔV, ΔC, and rPVI respectively- for all the languages in the Bonntempo corpus. By including Eastern and Western Catalan in the Bonntempo corpus, a comparison between the two dialects of Catalan and the rest of languages could be carried out. Afterwards, an analysis of variance (ANOVA) on the data was calculated with all the dependent variables, which showed an overall significant difference. Subsequent Post Hoc tests (see Tables 1 and 2)
were executed in order to establish where the significant differences between the languages were.

3. Results

3.1. Vowel Complexity

Figure 5 shows our results for the %V of all the languages comprised in the Bonntempo corpus, including Eastern and Western Catalan. Figure 6 shows the results for nPVI. It is obvious that, as regards vowel complexity, both plots differ considerably. In Figure 6 both Eastern and Western Catalan appear grouped together with Italian and French, syllable-timed languages, all of them having a high %V. On the contrary, as seen in Figure 6, both Eastern and Western Catalan appear considerably nearer the stress-timed languages –German and English- than the syllable-timed languages, as regards the nPVI values.

![Figure 5. Box plot comparing results from %V for all languages](image)

Cc = Czech  
Ce = Eastern Catalan  
Cw = Western Catalan  
Dd = German  
Ee = English  
Ff = French  
Li = Italian.
What is true for both figures is that both Eastern and Western Catalan have the same values. This is confirmed by the Post Hoc Tests which show no statistical significance for the %V and nPVI values respectively –see table 1 and 2. This would mean that, independently of whether Catalan is a syllable-timed or a stress-timed language, both dialects are rhythmically equal at a vocalic level. Therefore, from now on, whenever we speak about Catalan, both dialects will be referred to, unless specified.

<table>
<thead>
<tr>
<th>(I) language</th>
<th>(J) language</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>Ce</td>
<td>Ce</td>
<td>1.5822</td>
<td>1.41257</td>
<td>.919</td>
<td>-2.7808</td>
</tr>
<tr>
<td></td>
<td>Cw</td>
<td>-3320</td>
<td>1.47735</td>
<td>1.000</td>
<td>-4.8827</td>
</tr>
<tr>
<td></td>
<td>Dd</td>
<td>4.0878</td>
<td>1.32279</td>
<td>.050</td>
<td>.0022</td>
</tr>
<tr>
<td></td>
<td>Ee</td>
<td>5.6808</td>
<td>1.47335</td>
<td>.006</td>
<td>1.1301</td>
</tr>
<tr>
<td></td>
<td>Ff</td>
<td>-.9204</td>
<td>1.51734</td>
<td>.996</td>
<td>-5.6070</td>
</tr>
<tr>
<td></td>
<td>Ii</td>
<td>-1.7504</td>
<td>1.79534</td>
<td>.957</td>
<td>-7.2956</td>
</tr>
<tr>
<td>Cw</td>
<td>Ce</td>
<td>1.9141</td>
<td>1.18462</td>
<td>.673</td>
<td>-1.7448</td>
</tr>
<tr>
<td></td>
<td>Cw</td>
<td>.3320</td>
<td>1.47335</td>
<td>1.000</td>
<td>-4.2187</td>
</tr>
<tr>
<td></td>
<td>Dd</td>
<td>4.4198</td>
<td>1.07598</td>
<td>.003</td>
<td>1.0965</td>
</tr>
<tr>
<td></td>
<td>Ee</td>
<td>6.0128</td>
<td>1.25648</td>
<td>.000</td>
<td>2.1320</td>
</tr>
<tr>
<td></td>
<td>Ff</td>
<td>-.5885</td>
<td>1.30778</td>
<td>.999</td>
<td>-4.6278</td>
</tr>
<tr>
<td></td>
<td>Ii</td>
<td>-1.4184</td>
<td>1.62210</td>
<td>.975</td>
<td>-6.4286</td>
</tr>
</tbody>
</table>

Table 1. Post hoc multiple comparisons for %V values. (Statistically significant values are highlighted)
As regards the %V values –see Table 1-, the Post Hoc Tests illustrate a significant difference between Catalan and the stress-timed languages. The significant difference between Catalan and English is p<0.000 for Western Catalan and p<0.006 for Eastern Catalan. The difference between Catalan and German is p<0.003 for Western Catalan and p<0.050 for Eastern Catalan. At the same time, they show no significant difference between Catalan and the syllable-timed languages French and Italian. Therefore, it can be undoubtedly concluded that, according to %V values, both Catalan dialects should be classified as syllable-timed, confirming Ramus et al.’s (1999, 2003) claims.

As fornPVI –see Table 2-, things are not that straightforward. Whereas the data show no significant difference between Catalan and German, a stress-timed language-, at the same time, there is no significant difference between Catalan and the syllable-timed languages French and Italian. We can infer from these data that, as regards the vocalic rhythmic measures, Catalan is somewhat stress-timed, since it is detached from the syllable-timed languages, but, in the continuum that Dauer (1983) suggests, it would not
be so stress-timed as German. Therefore, it could be considered as an intermediate language, as Nespor (1990) formerly described.

As we argued before (section 1.2.), it is not clear to what extend $\Delta V$ is related to speech rhythm perception. However, since it is supposed to reflect vowel reduction –among many other phonological properties- we decided to also compute $\Delta V$, to see how it reacted to the difference in vowel reduction between Eastern and Western Catalan. These are plotted in Figure 7.

![Figure 7. Box plot comparing results from $\Delta V$ for all languages.](image)

As it can be seen from the descriptive data, there is no apparent difference between Eastern and Western Catalan. And what is more, there seems not to be any difference between any of the other languages, which certainly differ in vowel reduction. These impressions are confirmed by the subsequent ANOVA test that was carried out, which is not significant. No Post Hoc test was therefore performed due to the lack of statistical significance in the ANOVA test. If $\Delta V$ captures vowel reduction –or any other phonological feature related to vocalic complexity- as it is thought to do, there should be at least some kind of difference reflected between English and German –languages with a high vowel variability that undergo vowel reduction- and Italian and French –which do
not have much vocalic variability and do not undergo vowel reduction. Our results calls into question not only the idea that $\Delta V$ is related to rhythm classes, as Ramus et al. (1999) argue, but also the very same idea that $\Delta V$ reflects vowel reduction. What is certain is that, as far as Ramus et al.’s (1999) results and the results shown in this study are concerned, $\Delta V$ cannot be regarded as a rhythm measure, and therefore will not be dealt with from this point on.

3.2. Consonant Complexity

Figures 8 and 9 present the data on $\Delta C$ and rPVI respectively. In both figures, the distribution of the languages is fairly similar: both Eastern and Western Catalan appear quite detached from German, which has a very complex syllabic structure, and at the same time, both dialects somehow overlap with the rest of the languages – both with English, which is a stress-timed language, and with the syllable-timed languages French and Italian.

Figure 8. Box plot comparing results from $\Delta C$ for all languages.
The Post Hoc Tests –Table 3 and 4- actually ratify this in that, apart from not finding any significant difference between Eastern and Western Catalan as expected, Catalan only shows a significant difference with German (p<0.000), whereas it is not significantly different from any of the other languages.

<table>
<thead>
<tr>
<th>(I) language</th>
<th>(J) language</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cc</td>
<td>-1.8327</td>
<td>.50285</td>
<td>.012</td>
<td>[-3.3858, -0.2795]</td>
</tr>
<tr>
<td></td>
<td>Cw</td>
<td>-.7290</td>
<td>.52449</td>
<td>.804</td>
<td>[-2.3490, .8910]</td>
</tr>
<tr>
<td></td>
<td>Dd</td>
<td>-3.0912</td>
<td>.47089</td>
<td>.000</td>
<td>[-4.5457, -1.6368]</td>
</tr>
<tr>
<td></td>
<td>Ee</td>
<td>-1.5782</td>
<td>.52449</td>
<td>.061</td>
<td>[-3.1982, .0418]</td>
</tr>
<tr>
<td></td>
<td>Ff</td>
<td>.1213</td>
<td>.54015</td>
<td>1.000</td>
<td>[-1.5471, 1.7896]</td>
</tr>
<tr>
<td></td>
<td>Ii</td>
<td>-.1651</td>
<td>.63911</td>
<td>1.000</td>
<td>[-2.1391, 1.8090]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cc</td>
<td>-1.1037</td>
<td>.42171</td>
<td>.146</td>
<td>[-2.4062, .1988]</td>
</tr>
<tr>
<td></td>
<td>Ce</td>
<td>.7290</td>
<td>.52449</td>
<td>.804</td>
<td>[-.8910, 2.3490]</td>
</tr>
<tr>
<td></td>
<td>Dd</td>
<td>-2.3623</td>
<td>.38303</td>
<td>.000</td>
<td>[-3.5453, -1.1792]</td>
</tr>
<tr>
<td></td>
<td>Ee</td>
<td>-.8492</td>
<td>.44729</td>
<td>.492</td>
<td>[-2.2308, .5323]</td>
</tr>
<tr>
<td></td>
<td>Ff</td>
<td>.8503</td>
<td>.46555</td>
<td>.538</td>
<td>[-.5877, 2.2882]</td>
</tr>
<tr>
<td></td>
<td>Ii</td>
<td>.5639</td>
<td>.57744</td>
<td>.956</td>
<td>[-1.2196, 2.3475]</td>
</tr>
</tbody>
</table>

Table 3. Post hoc multiple comparisons for ΔC values.
Table 4. Post hoc multiple comparisons for rPVI values.

Figure 10 and 11 show the distribution of the different languages over the (%V, ΔC) plane and over the (nPVI, rPVI) respectively.
In Figure 10, we can see, in agreement with Ramus et al. (1999, 2003), that—as regards %V and \( \Delta C \) values, both dialects of Catalan are grouped together with the syllable-timed languages –Italian and French-, while the stress-timed languages are far away.

In Figure 11, both Catalan dialects appear as intermediate languages since they are detached from both syllable-timed and stress-timed languages. These results agree with Grabe & Low’s (2002) results considering Catalan to be intermediate.

### 4. Discussion

The first hypothesis of this paper was that Eastern and Western Catalan would have different values in rhythmic measures influenced by vowel reduction (%V, nPVI, \( \Delta V \)). This hypothesis has been clearly proved wrong as confirmed by the results in section 3.1. The data on the two vocalic rhythm measures -%V and nPVI- have shown no statistically significant difference at all between the two dialects either in the descriptive data or in the inferential statistics. Both Catalan dialects are alike in terms of their vowel and consonant complexity and as a consequence, their rhythm—insofar as it can be
characterised by the rhythm measures calculated in this experimental study- is not significantly different.

Vowel reduction in Catalan, though, is not a very straightforward matter in the literature, since it is slightly contradictory. Carbonell & Llisterri (1999) categorically state in the IPA handbook (1999) that Western Catalan does not have vowel reduction whereas Eastern Catalan does. However, other authors, such as Recasens (1991) or Mascaró (2002) explain that all dialects in Catalan do show a vowel reduction process, although it may be different in every accent. According to these authors, in Western Catalan, the mid vowels /e/, /e/ and /o/, /ɔ/ merge into /e/ and /o/ in unstressed positions, as in the following examples:

Set [set] “seven” \(\rightarrow\) setè [se'te] “seventh”

Sol [sol] “sun” \(\rightarrow\) solet [so'let] “little sun”

The stressed and unstressed vowel systems of the two main dialects –without forgetting that these systems may vary in some sub-dialects- can be seen in Table 5 and 6:

<table>
<thead>
<tr>
<th>Eastern Catalan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stressed system</strong></td>
</tr>
<tr>
<td>/i/</td>
</tr>
<tr>
<td>/e/</td>
</tr>
<tr>
<td>/e/</td>
</tr>
<tr>
<td>/o/</td>
</tr>
<tr>
<td>/ɔ/</td>
</tr>
<tr>
<td>/u/</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Table 5: Eastern Catalan stressed and unstressed vowel systems.
Table 6: Western Catalan stressed and unstressed vowel systems.

<table>
<thead>
<tr>
<th>Stressed system</th>
<th>Unstressed system</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>/a/</td>
<td>[a]</td>
<td>pa [pa] “bread” → panet [paɾet] “little bread”</td>
</tr>
<tr>
<td>/u/</td>
<td>[u]</td>
<td>truc [ɾuk] “call” → trucar [ɾuɾkaɾ] “to call”</td>
</tr>
</tbody>
</table>

As it can be seen, Eastern Catalan only allows three vowels in unstressed position, [i], [ɔ] and [u], while vowel reduction in Western Catalan only entails the merging of [ɛ] and [ɛ] into [e] and that of [o] and [ɔ] into [ɔ] whereas all the other vowel phonemes remain equal. Flemming (submitted) refers to this latter type of vowel reduction, where the contrasts between close-mid and open-mid vowels are eliminated, as a “more moderate reduction” (2005:3). In any case, there seem to exist two different kinds of vowel reduction involved in the two main dialects of Catalan. Herrick (2004), following Crosswhite (1999) and Flemming (submitted), distinguishes between two different vowel reduction processes. On the one hand, as a consequence of the shortening of vowels in unstressed positions, and of the subsequent F1 formant undershoot for low vowels, the floor of the vowel space may be raised causing the overall vowel space to shrink, what would be referred to as phonetic vowel reduction. On the other hand, in this reduced vowel space, neighbouring vowels are more easily confused, what leads to the neutralisation of some phonemic contrasts, i.e. phonological vowel reduction. This seems to be the case in Eastern Catalan. The vowel space is shrunken in unstressed position (phonetic vowel reduction) and as a consequence, phonemes are centralised and
neutralised (phonological vowel reduction). However, Western Catalan seems a different story. Some phonemes are neutralised, but the vowel space is not shrunken and the vowels remain peripheral. Thus it could be stated that both dialects differ on their respective vowel reduction processes: Eastern Catalan both reduces the vowel space and neutralises some of its contrastive unstressed vowels, while Western Catalan only neutralises some of its vowels, which keep being peripheral instead of being centralised.

Although the literature is confusing and misleading about this issue, we can extract from the previous argumentation that there actually exists a difference in vowel reduction between Eastern and Western Catalan. Whether this difference is categorical, as Carbonell & Llistérri (1999) state, gradual, as Recasens (1991) and Mascaró (2002) argue, or simply different in kind, is not an issue for research in this paper. This difference, though, is not reflected in any of the vocalic rhythm measures calculated in this experiment (%V and nPVI), and the key for this matter could be on these rhythm measures in question. If we consider that both dialects have different vowel reduction processes, but their rhythm measures do not reflect any difference whatsoever, it could be the case that vowel reduction in Catalan did not affect vowel quantity –i.e. duration. Therefore, the rhythm measures would not have been able to detect any differences between the two dialects.

Another likely explanation could be that vowel reduction in Catalan does not affect speech rhythm. Ramus et al. (2003) state, as mentioned before, that vowel reduction in Catalan is not enough to make it separate from the syllable-timed languages. It could be possible that vowel reduction in Catalan might not have any impact on the overall rhythm of the language. That would mean that we would be dealing with two different types of vowel reduction. On the one hand, a type of vowel reduction that would affect speech rhythm, such as the one found in German or English. This type of vowel reduction would be reflected in rhythm measures and these would capture any kind of
variation in vocalic reduction that may occur in the language, as in the case of the
difference in vowel reduction in Singapore and British English which is captured by
rhythm measures (Low et al, 2000 cited by Grabe & Low, 2002). On the other hand, we
would be dealing with a second kind of vowel reduction that would not affect speech
rhythm, as in the case of Catalan. If these two types of vowel reduction existed, that
would explain why no difference in vowel reduction between the two dialects of Catalan
was reflected on the rhythm measures calculated in this study.

A final issue that is worth mentioning is the rhythmic category of Catalan. Our
data do not shed any light on the question about how Catalan should be classified. The
results obtained in this paper are very different from each other. On the one hand, our
data on the %V and ΔC measures agree with Ramus et al. (1999) in that they group
Catalan with the rest of syllable-timed languages French and Italian. Thus, Catalan is
clearly classified as a syllable-timed language, whose vowel reduction appears not to
have any influence on its rhythm. On the other hand, our results on nPVI and rPVI situate
Catalan somewhat in the middle of the rhythmic continuum suggested by Dauer (1983) in
the same way that Grabe & Low (2002) do. Catalan appears at a half way point between
the syllable-timed languages French and Italian, and the stress-timed languages German
and English. Yet, what these results show is an important contradiction in the current
literature on linguistic rhythm. It is obvious that the key empirical evidence for the
traditional classification of linguistic rhythm relies on some phonetic properties that can
be found in the acoustic signal, namely the durations of the vocalic and intervocalic
intervals and their variability. This latest research approach has turned out to be a huge
step in the study of speech rhythm. However, there is not a clear agreement between
these two main current trends as far as languages that cannot be typically classified are
concerned. In this experimental study it has been shown, among other things, that the
measures of speech rhythm that are currently available are contradictory as far as Catalan
–a language which cannot be easily categorized- is concerned. The same data collected for the same language –Catalan- have two very different results depending on what measures are regarded. Data for %V and ΔC classify Catalan as a syllable-timed language whereas results for nPVI and rPVI characterize Catalan as an intermediate-language. There is, therefore, an obvious need for further research on speech rhythm measures in order to categorize the languages whose rhythm has not yet been clearly classified, such as the case of Catalan.

5. Conclusion

This paper has investigated the impact on Catalan rhythm of the different processes of vowel reduction undergone by its two main dialects. This has been carried out by means of the acoustic measures for speech rhythm provided by current research on the subject (Ramus et al., 1999, Grabe & Low, 2002), which focus on the division of the speech signal into vocalic and intervocalic intervals. Due to the difference in vowel reduction that exists between the two major dialects of Catalan, it was hypothesized that the measures for vocalic complexity would be different whereas the ones for consonantal complexity would be similar. The acoustic evidence that this experiment provides show that both vocalic and consonantal complexities are alike for the two dialects, which denies the initial hypothesis. It is clear that, as far as the rhythm measures calculated can capture speech rhythm, both dialects should be considered to have equivalent linguistic rhythm. However, the categorization of Catalan rhythm turns out not to be so straightforward, since the measures provided by the current research on speech rhythm are still contradictory as far as this language is concerned. More research is therefore needed on rhythm measures, on vowel reduction and its effect on rhythm, and on the degree in which rhythm measures can capture vowel reduction processes.
Acknowledgements

I would not be able to finish this work without expressing my immense gratitude to my tutor, Volker Dellwo, for his extremely valuable input and for all the time and effort that he has devoted to this piece of work. I would also like to thank Jill House for her helpful suggestions and amendments. Special thanks should also go to all the speakers who kindly let me record their speech, to Josefina Carrera for her comments on Catalan and all my teachers at UCL for sharing their knowledge with me and especially their passion for the intriguing field of Phonetics.
Appendix

Eastern Catalan Text

A l’endemà em vaig dirigir a Roses; és un viatge a la fi del món. Després de passar Berga, els boscos i les muntanyes es van tornar monòtons; passat Berga, les ciutats es van tornar avorrides i, prop de Villalba, el paisatge era pla i desolat. Si se’ls prohibís als dissidents viure al nostre país, probablement viurien el seu exili al Port de la Selva.

Bernhard Schlink (1994) Selbs Betrug: Diogenes (p. 242)

Translation: Núria Gavaldà-Ferré

Broad Transcription

/A l’endemà’ma òm ’badʒ dirigí’zi ò ’rəzəs | ’es um bi’adʒə ò lo ’fi dəl ’mon|

dəs’pres ò pə’sa ’beryə əlz ’bəskuz i løz mun’tənəz òz ’van tur’nə

mu’nətunds| pə’sat ’beryə læs siw’tats əz ’bən tur’nə əs’məridəz | i pəɾəp ə

bi’ələʃə əl pəj’zədə ərə ’pla i dəzu’lat| si søls pru’jə’s əls disil’dəns ’biwə

əl ’nostrə pa’is | pru,ɔbilə’men biw’rían əl ’seu ə’gzili al ’pɔɾ əl la ’selbə | /

Western Catalan text

A l’endemà me vaig dirigir a Roses; és un viatge a la fi del món. Després de passar Berga, los boscos i les muntanyes se van tornar monòtons; passat Berga, les ciutats se van tornar avorrides i, prop de Villalba, lo paisatge era pla i desolat. Si se’ls prohibís als dissidents viure al nostre país, probablement viurien lo seu exili al Port de la Selva.
The next day I went to Falmouth. It is a voyage to the end of the world; after Lincoln the hills and woods become monotonous, after Bristol the towns get boring and near Saintsbury the countryside becomes flat and desolate. If dissidents were banned in our country, they would be banned to the Portishead Bay.

Bernhard Schlink (1994) *Selbs Betrug: Diogenes* (p. 242)

Translation: Stacy Dellwo & Volker Dellwo
Labelling and Segmentation

Figure 12: Example of the segmentation and labelling of the word “ciutats” [siw'tats] spoken by an Eastern Catalan speaker.

Figure 13: Example of the segmentation and labelling of the word “ciutats” [siw'tats] spoken by a Western Catalan speaker.
Figure 14: Example of the word “Berga” [beryə] with an svarabhakti element between [r] and [y] (indicated by red rectangle)
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combined study of speech rhythm and rate. *Proceedings of the 8th ICSLP*, Jeju Island, Korea.


