

Rhythm in central-southern varieties of European Portuguese: production and perception

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Abstract

This paper describes the rhythmic properties of two central-southern varieties of European Portuguese (Ale and Alg), following similar methodologies of previous production and perception studies of rhythm in Portuguese. The analysis of production data showed that Ale presents a mixed rhythmic nature, whereas Alg is clearly stress-timed. The use of different *corpora* did not affect the main results. Perceptual experiments with listeners from the Standard variety (SEP) showed that central-southern varieties are discriminated from SEP, even when F0 is not preserved in the signal. In contrast with SEP-Alg (where different rhythmic properties were found in the acoustic analysis), the discrimination between SEP-Ale (where similar rhythmic properties were found in the acoustic data) was unexpected. Speech rate is raised as a possible cue that listeners may use for discrimination, a hypothesis to be pursued in future research.

Keywords: rhythm, production, perception, varieties of European Portuguese.

Palavras-chave: ritmo, produção, percepção, variedades do Português Europeu.

1. Introduction

1.1. Rhythm in language

In the traditional view of rhythm in language (Lloyd James, 1940; Pike, 1945; Abercrombie, 1967; Ladefoged, 1975; *inter alia*), languages fall into one of three rhythmic classes, depending on the type of isochrony (i.e. a pattern of similar durations) observed: (i) syllable-timed (isochrony between syllables), (ii) stress-timed (isochrony between interstress intervals), and (iii) mora-timed (isochrony at the level of the mora). Several phonetic and acoustic studies were developed in order to provide evidence for each type of isochrony. However, this was hardly found in the speech signal. Although the empirical basis for the isochrony view was not successfully shown, the difference between rhythmic properties of languages was not put into question.

In alternative to the isochrony view, a new approach emerged that considers rhythmic distinctions among languages as a consequence of different phonological and phonetic properties, such as syllable structure, vowel reduction and correlates of stress (Dasher & Bolinger, 1982; Dauer, 1983). According to this approach, syllable-timed languages present a lower variety of syllable types than stress-timed languages and do not display vowel reduction (that is why syllables tend to be more similar than in stress-timed languages, giving the illusion¹ of syllable-based isochrony). With this approach, a new debate emerged: whereas some languages were clearly assigned to one type of rhythm (e.g., English and Dutch as stress-timed, Spanish and Italian as syllable-timed, Japanese and Tamil as mora-timed), others have been considered mixed or intermediate languages (Catalan, Brazilian Portuguese, Polish) (Dauer, 1987; Nespó, 1990). Within this approach, languages could be seen as organized in rhythmic classes or along a rhythmic continuum. However, the hypothetical organization of

¹ We took this term from studies that refer to isochrony as an illusion or impression caused by different phonological properties of each language (e.g., Nespó, Shukla & Mehler, 2011).

languages along a rhythmic continuum does not provide an explanation for the results obtained in several perception studies (Frota & Vigário, 2001; Frota, Vigário & Martins, 2002a, b). Indeed, perceptual experiments both with adults (Ramus & Mehler, 1999; Ramus, Dupoux & Mehler, 2003) and newborns (Mehler et al., 1996; Nazzi, Bertoncini & Mehler, 1998) showed discrimination between languages belonging to different rhythmic classes, but not between those of the same class, and give evidence for the encoding of rhythmic differences in the speech signal (sentences were low-pass filtered, i.e. segmental information is reduced, but prosodic information is preserved). This would lead us to the prediction that listeners would not be able to distinguish between varieties of the same language, if they have the same rhythm. Ghazali, Hamdi & Barkat (2002) showed that although Arabic dialects were consistently described as stress-timed, listeners were able to distinguish speakers from North Africa from those of the Middle East. Complex syllables and reduced vowels in the Western dialects, as well as longer vowels in the Eastern dialects, seem to explain the perceived differences between these Arabic varieties. Thus, three main questions arise: which properties in the signal are responsible for the observed discrimination between languages belonging to different rhythmic classes (either in the traditional or the phonetic/phonological properties approach)? How are mixed or intermediate languages perceived? To what extent varieties of the same language may show distinct rhythms?

Several studies have been developed in order to answer similar questions. For example, Frota & Vigário (2001) and Frota, Vigário & Martins (2002a, b) addressed the first two questions with respect to Portuguese within the context of cross-linguistic differences in rhythm. The analysis of dialectal variation in rhythm was the focus of various studies (e.g., Ghazali, Hamdi & Barkat, 2002 for Arabic varieties; O'Rourke, 2008 for Spanish varieties; Russo & Barry, 2008 or Giordano & D'Ana, 2010 for Italian varieties). Also relevant to the rhythmic characterization of different languages is the work on L2 learning that considers the possible transfer or use of rhythmic properties from L1 to L2 (e.g., Mok & Dellwo, 2008; Kireva, 2013; Robles-Puente, 2013).

1.2. The correlates of rhythm: different proposals, different measures

Many properties of the speech signal have been measured in the attempt to identify reliable acoustic correlates of rhythmic distinctions: (i) the proportion of vocalic intervals (%V) and the variability of vocalic (ΔV) and consonantal (ΔC) intervals within the sentence (Ramus, Nespors & Mehler, 1999), (ii) the normalised measures $\Delta\%V$ and $\Delta\%C$ to compensate for durational differences (Frota & Vigário, 2001), (iii) the durational variability in successive vocalic and consonantal intervals, using *Pairwise Variability Indices* (PVI) (Grabe & Low, 2002), (iv) the varcos (varcoV and varcoC), proposed in order to normalise the interaction between deltas and speech rate (Dellwo & Wagner, 2003), and, more recently, (v) the Control and Compensation Index (CCI), which measures the level of compression allowed in a language, i.e. how much the segments can be lengthened or shortened according to the context (Bertinetto & Bertini, 2008).

According to Ramus, Nespors & Mehler (1999), %V, ΔV and ΔC reflect differences in the syllable structure of languages. In this sense, stress-timed languages present a low %V and a higher ΔC than syllable-timed languages. For Grabe & Low (2002), and in contrast with Ramus, Nespors & Mehler's measures, PVIs capture the variability of successive pairs of vocalic and consonantal intervals. The raw Pairwise Variability Index (rPVI) is not normalised for speech rate and is usually used for the consonantal intervals, while the normalised Pairwise Variability Index (nPVI) is used for the vocalic intervals since the authors argue that vocalic intervals are more prone to the influence of speech rate. In this sense, stress-timed languages present a higher nPVI than syllable-timed languages. Similar results are expected when applying Varcos as rhythmic measures, i.e. stress-timed languages show higher values of both VarcoC and VarcoV than syllable-timed languages. The CCI is a modification of the rPVI, since the duration of each vocalic or consonantal interval is divided by the number of phonological segments included in it. Following this formula, Bertinetto & Bertini (2008) consider that 'controlling languages' allow for a low level of compression (and correspond to languages traditionally classified as syllable-timed languages), while 'compensating languages' allow for a high level of compression (and thus correspond to the traditionally called stress-timed languages). Other measures have been proposed, based for instance on the measure of sonority (Galves et al., 2002), but this method is considered as being less precise (Nespors, Shukla & Mehler, 2011).

Perceptual studies are considered as the strongest evidence in favour of rhythm classes, and the proportion of vocalic intervals is considered as an important predictor of language discrimination (Ramus, Nespors & Mehler, 1999; Frota, Vigário & Martins, 2002a, b; Ramus, Dupoux & Mehler, 2003). For other authors, Varco V together with %V (White & Mattys, 2007; White et al., 2007) are predictive of listeners' discrimination within

and between languages. By contrast, the PVI, although shown as a better indicator of rhythmicity, leads to conclusions that go against perceptual evidence: e.g., Japanese is considered as more syllable-timed (Grabe & Low, 2002). Recently, many studies have been developed with the major goal of comparing the results obtained with different rhythmic measures. Ramus (2002) calculated PVI scores for Ramus, Nespor & Mehler's (1999) data and concluded that results are largely equivalent. Thus, the author argues that a controlled *corpus* is needed to measure rhythm. Loukina et al. (2009) compared 15 different measures in 5 languages (Southern British English, Greek, Russian, French and Taiwanese Mandarin). They found that vocalic measurements are more successful in distinguishing languages of different rhythm properties than the consonantal measurements. The use of different *corpora* or speech styles is also under discussion in much recent work. Giordano & D'Anna (2010) compared three different speech styles (read speech, pre-planned speech – TV news –, and spontaneous speech – task-oriented dialogues) and 15 regional varieties of Italian, by using %V, ΔV , ΔC and nPVI/rPVI metrics. The authors show that there is a wide-ranging variation of duration values in different speech styles and across the observed Italian varieties. Arvaniti (2009, 2012a) and Arvaniti & Ross (2010) also compare ΔC , %V, PVIs and Varcos in English, German, Greek, Italian, Korean and Spanish, considering three different elicitation methods (spontaneous speech, story reading and sentences reading). The authors show that rhythmic classifications are not consistent across metrics, that they are sensitive to different elicitation methods, and that inter-speaker variation is substantial. These results lead the authors to the suggestion that cross-linguistic differences captured by metrics are not robust. It has also been suggested that there is an interplay between the rhythmic structure and the intonational properties of the language, which cannot be captured by the rhythmic measures used. Frota, Vigário & Martins (2002a, b) have shown, for example, that European and Brazilian Portuguese are only discriminated when intonation is present. This suggests that the discrimination between languages may be related with the interaction of components of prosody which impact on rhythm. Prieto et al. (2012) examined three languages (English, Spanish and Catalan) and concluded that the rhythmic class distinctions found (English *versus* Spanish/Catalan) correlate with differences in the way these languages instantiate the durational marking of prosodic heads and pre-final lengthening at prosodic boundaries. Other prosodic cues such as speech rate were also pointed out as being important cues for rhythm distinctions, that have not been detected earlier because they were eliminated from the signal or manipulated (Arvaniti, 2012b; White, Mattys & Wiget, 2012). Dellwo (2010) also concluded that speech rate has an effect on the acoustic correlates of speech rhythm.

2. Rhythmic properties of Portuguese

Little is known about the rhythmic properties of Portuguese. In this section we provide a summary of the main findings of previous studies on rhythm in European and Brazilian Portuguese varieties, based on the comparable methodological procedures. Frota & Vigário (2000, 2001) were the pioneering work in the identification of the rhythmic properties of Portuguese and their physical correlates. For Brazilian Portuguese (BP), earlier studies of rhythm were inconclusive, since the phonetic inspection of the duration of interstress intervals did not reveal whether BP was stress- or syllable-timed (Major, 1981; Massini-Cagliari, 1992). Moraes & Leite (1992) concluded that BP presents a mixed rhythm, although intra- and inter-speaker variability have been observed in the data. Frota & Vigário (2000, 2001) have analysed rhythm in Brazilian Portuguese (BP) and in Standard European Portuguese (SEP), on the basis of Ramus, Nespor & Mehler's measures, and have explored the relation between these measures and the phonological properties of the two varieties of Portuguese. Additionally to %V and ΔC , the authors suggested two normalised measures to deal with the interaction between durational variability and speech rate – $\Delta\%V$ and $\Delta\%C$ – and concluded that %V and $\Delta\%C$ support the rhythmic distinction between SEP and BP. A cross-comparison analysis between SEP and BP and the eight languages considered by Ramus, Nespor & Mehler (1999) showed that SEP clusters with stress-timed languages in the ΔC dimension and with syllable-timed languages in the %V dimension, while BP is closer to syllable-timed languages in the ΔC dimension and to mora-timed languages in the %V dimension.² Crucially, both SEP and BP present a mixed rhythm (not intermediate rhythm), which gives support to the rhythm classes approach. These results were related to vowel reduction and deletion in SEP (and the consequent increase of consonantal sequences of variable duration) and vowel epenthesis in BP (thus breaking consonant clusters and promoting CV sequences).

² A similar result was obtained in Castro & Teixeira (2004) with data from Oporto.

Frota, Vigário & Martins (2002a, b) applied perceptual experiments in order to examine how the results obtained from production data (Frota & Vigário, 2001) relate with perception. The results showed that EP and BP are distinguished only when the F0 contour is preserved, suggesting that durational properties *per se* may not be enough to discriminate between languages/varieties, even when they are acoustically different. However, it still remains to be shown whether the sensitivity to intonation is a general property of the European Portuguese native speakers' phonological system, or a specific property of the SEP-BP distinction. The results also showed that SEP is discriminated from Dutch, a typical stress-timed language, showing that the most important dimension for perception is %V and not consonantal variability.

Still unexplored is the rhythmic characterization of varieties of European Portuguese, which is the main goal of the present study. The rhythmic properties of two central-southern varieties (Ale – Beja district –, and Alg – Faro district) were inspected on the basis of production (section 3.1) and perception (section 3.2) experiments. First, an acoustic analysis considering two different metrics and different read *corpora* is presented. Secondly, perception experiments with participants from the Standard variety perceiving manipulated sentences (with and without F0) produced by speakers from the Interior Centre and South are described. Besides testing discrimination between varieties of European Portuguese, we also want to test whether F0 helps listeners in the discrimination task and whether this cue is equally used by listeners from different varieties. Finally, section 4 offers a summary of the main findings and discusses the contribution of this preliminary study of rhythmic properties across varieties of EP for the debate on the rhythmic organization of languages (and varieties). Some avenues for future research are also pointed out.

3. Rhythm across European Portuguese varieties: the central-southern varieties

3.1. Production

The present research aims to explore the rhythmic properties of the central-southern varieties of EP under analysis. Our main goals are: (i) to observe whether the rhythmic measures that Frota & Vigário (2001) considered relevant to distinguish between SEP and BP also contribute for the characterization of the central-southern varieties, previously shown to be different from SEP in terms of intonational contours, phrasing patterns and pitch accent distribution (Cruz, 2013; Cruz & Frota, 2011, 2013a, 2013b; Frota et al., in press); (ii) to observe whether the use of different *corpora* across varieties leads to different results from the use of a common *corpus*; (iii) to observe whether the use of different acoustic measures (Varcos were also calculated³) leads to different results from the ones obtained by means of Ramus, Nespors & Mehler's (1999) metrics; (iv) to add to the debate on the organization of languages/varieties into rhythmic classes or along a rhythm continuum. In order to contribute to the analysis of rhythm across EP varieties, we have analysed two sets of production data. The data is part of the full set of speech materials collected within the *Interactive Atlas of the Prosody of Portuguese* project (*InAPoP* web platform available at <http://www.fl.ul.pt/laboratoriofonetica/InAPoP/>, Frota & Cruz, coord., 2012-2015).

3.1.1. Data set 1 – Global comparison

The *corpus* of Ramus, Nespors & Mehler (1999), adapted by Frota & Vigário (2001) to Portuguese, was included in the *InAPoP* data set and used in the present research: 54 sentences with different lengths in number of syllables (from 15 to 21 syllables, 8 sentences per length condition) were read twice, in random order, by 3 speakers per variety (Ale and Alg), aged between 20-45 years of age. Two renditions of one speaker per variety, naturally produced, were considered in this preliminary analysis. A total of 216 sentences (54x2x2) were analyzed in *Praat* (Boersma & Weenink, 2007). Vocalic and consonantal intervals were delimited on the basis of both auditory and acoustic cues, following standard criteria of segmentation (Turk, Nakai & Sugahara, 2006; Frota & Vigário, 2001) – see Figure 1. Duration measures were then automatically extracted with *Correlatore* 2.1 (Mairano, 2009) and manually cross-checked. Results from Ale and Alg were compared with the overall results obtained for SEP and BP (Frota & Vigário, 2000, 2001), which comprise the analysis of three different *corpora*: (i) an EP *corpus* analysed with the purpose of establishing the prosodic and intonational structure of the data (*MAVig corpus*, from Vigário, 1998), (ii) a comparative EP/BP *corpus* developed within the Project

³ Since PVI metrics were shown not to provide consistent results between production and perception, these were excluded from the present analysis.

Rhythmic Patterns, Parameter Setting, and Language Change (Fapesp, Brazil) (*20F corpus*), and (iii) the comparative EP/BP *corpus* corresponding to the translation of the multi-language *corpus* used in Ramus, Nespor & Mehler (1999) (*Rm corpus*).

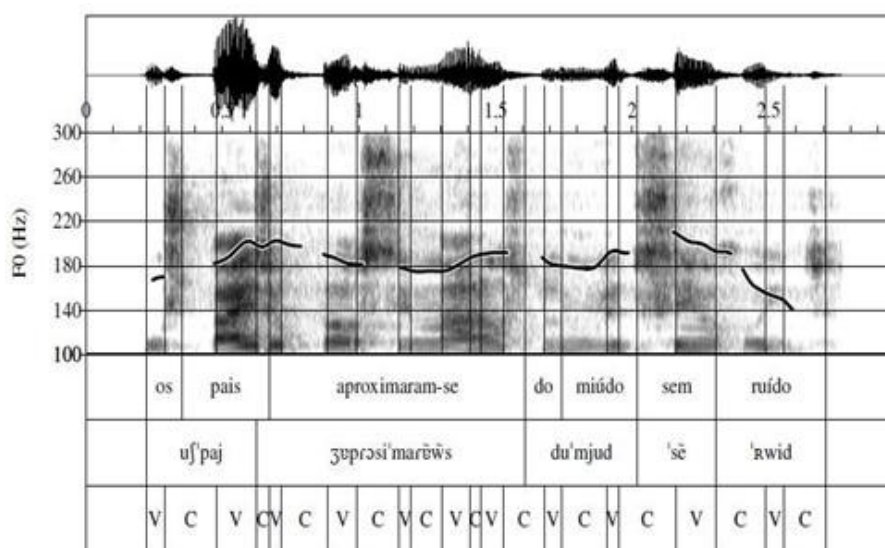


Figure 1 - Segmentation of vocalic and consonantal intervals, following the criteria from Turk, Nakai & Sugahara (2006) and Frota & Vigário (2001). ‘Os pais aproximaram-se do miúdo sem ruído’. (The parents approach the kid silently.).

Frota & Vigário (2000, 2001) showed that %V and Δ%C are the crucial acoustic correlates of the rhythmic distinction between SEP and BP. We thus decided to report the same metrics for Ale and Alg. However, ΔC is also useful if we want to establish a comparison between central-southern varieties of EP and the eight languages analyzed by Ramus, Nespor & Mehler (1999), as Frota & Vigário (2001) did for SEP and BP.

Our preliminary results, given in Table 1 below, show that both Ale and Alg present (i) higher scores of ΔC than SEP (64,2 in Ale and 73,9 in Alg, *contra* 54,6 in SEP) and higher scores of % ΔC, thus clustering with stress-timed languages in this dimension, and (ii) lower scores of %V than SEP (44% in Ale and 37,3% in Alg, *contra* 48% in SEP), suggesting a more stress-timed nature. The same conclusion can be extracted from the comparison between central-southern varieties and BP.

	%V	Δ%C	ΔC
Alg	37,3 (0,51)	4,1 (0,21)	73,9 (2,49)
Ale	44,0 (0,60)	3,6 (0,25)	64,2 (2,72)
SEP	48,0 (0,71)	2,4 (0,12)	54,6 (2,06)
BP	55,6 (1,05)	1,6 (0,07)	43,5 (2,69)

Table 1 - Three averaged acoustic measures across Portuguese varieties and their respective standard errors. Global results for SEP and BP from Frota & Vigário (2001). Gray colour signals new data.

A more detailed inspection within central-southern varieties shows that the %V dimension seems to distinguish between Ale and Alg, since Alg presents the lowest proportion of vocalic intervals (37% *contra* 44% in Ale, which is closer to SEP). Alg also shows the highest consonantal interval variability. These results suggest that Ale is a mixed variety (as SEP), being syllable-timed in the %V dimension and stress-timed in the Δ%C/ ΔC dimension, whereas Alg is a stress-timed variety in both dimensions.

However, these preliminary results are based on the acoustic analysis of data produced by only one speaker per variety. Furthermore, we are comparing different *corpora* in Alg/Ale and in SEP. In order to avoid possible effects of these factors, we decided to conduct a second analysis on data from more speakers per variety and

selecting exactly the same sentences used in the *Rm corpus* adapted for Portuguese by Frota & Vigário (2001). Additionally, we have considered other metrics (Varcos) in order to observe whether the use of different metrics has an impact on the results obtained, as reported for other languages by Arvaniti (2009, 2012a) and Arvaniti & Ross (2010).

3.1.2. Data set 2 – Selective comparison

We used the same *corpus* as in Ramus, Nespors & Mehler (1999), adapted for Portuguese by Frota & Vigário (2001). From this *corpus*, a selection was made, comprising sentences with 15 to 19 syllables (thus excluding sentences with 20 and 21 syllables long). Only one sentence per length condition was selected, matching the data analysed by Frota & Vigário (2001) (the *Rm corpus*) and by Ramus, Nespors & Mehler (1999). Thus, a total of 5 sentences read twice, in random order, by 3 speakers per variety, aged between 20-45 years of age, were analyzed. The 60 sentences (5x2x3x2) were segmented in *Praat*, according to the annotation and segmentation criteria already mentioned in section 3.1.1. The results obtained were then compared with the results for SEP and BP (Frota & Vigário, 2001) and with the results for the eight languages analysed by Ramus, Nespors & Mehler (1999), on the basis of a similar set of data.

First, we examined whether there was an effect of speaker in the data. A MANOVA was run with *speaker* as a factor, with three levels for each variety (speaker 1, speaker 2, and speaker 3) and %V, ΔC and $\Delta\%C$ as dependent variables.⁴ The analysis showed no effect of speaker either in Ale or Alg, similarly to previous results for SEP and BP (Frota & Vigário, 2001) (Ale: for %V, $F(2,12)=1.12$, $p=.358$; for ΔC , $F(2,12)=0.78$, $p=.478$; for $\Delta\%C$, $F(2,12)=0.29$, $p=.750$. Alg: for %V, $F(2,12)=3.13$, $p=.081$; for ΔC , $F(2,12)=0.33$, $p=.727$; for $\Delta\%C$, $F(2,12)=1.17$, $p=.343$).

In Table 2, the results from the acoustic analysis are reported. They show that both Ale and Alg present higher scores of ΔC and $\Delta\%C$ than SEP, thus clustering with stress-timed languages in this dimension (as in the results from data set 1). However, differently from that observed in data set 1, Ale presents higher scores of %V than Alg and SEP (46,0% in Ale *contra* 38,6% in Alg and 44,9% in SEP). The same relation across varieties applies when considering the normalized measure $\Delta\%V$.

	%V	$\Delta\%V$	ΔC	$\Delta\%C$
Alg	38,6 (1,80)	1,6 (0,22)	61,7 (3,06)	2,9 (0,24)
Ale	46,0 (1,72)	2,3 (0,44)	57,0 (3,03)	2,8 (0,34)
SEP	44,9 (2,50)	1,9 (0,14)	54,7 (4,23)	2,3 (0,23)
BP	53,2 (2,18)	2,3 (0,20)	55,7 (5,75)	1,7 (0,15)

Table 2 - Averaged acoustic measures across Portuguese varieties and their respective standard errors: same *corpus* across varieties. Results for SEP and BP from Frota & Vigário (2001). Gray colour signals new data.

As in data set 1 (Figure 2, left panel), the results from the acoustic analysis performed on data set 2 show that Ale stays close to SEP in the %V dimension, thus being syllable-timed like SEP, while %V in Alg points to stress-timing (Figure 2, right panel). In the $\Delta\%C$ dimension the two southern varieties are stress-timed like SEP.

⁴ Here and elsewhere, Normality and Levene's Tests were run. MANOVAs and ANOVAs were used whenever the necessary criteria were met. Otherwise, non-parametric tests were applied. A confidence level of 99% was used in all statistical analyses, and thus results with a significance level below .01 ($p \leq .01$) were considered significant.

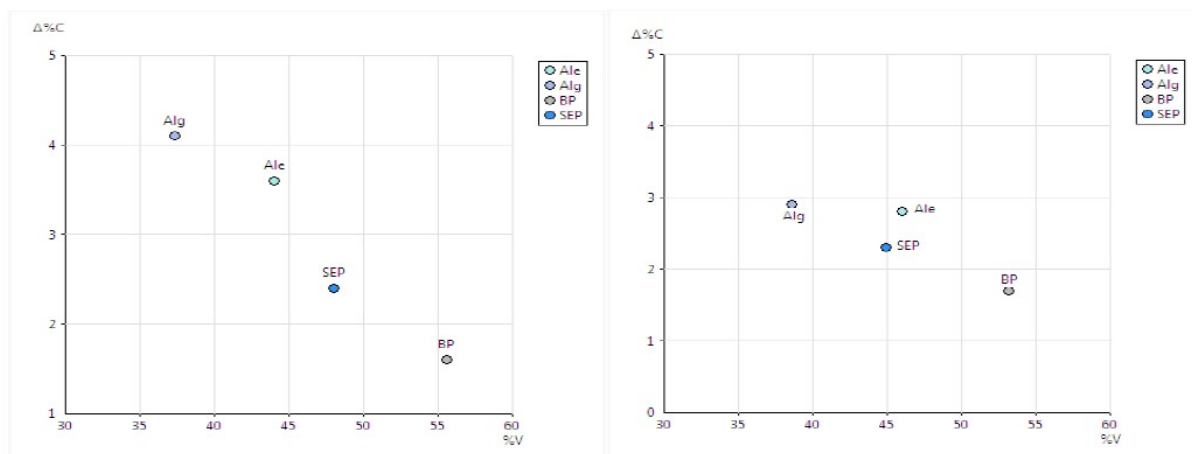


Figure 2 - $\Delta\%C$ vs. $\%V$ for Portuguese varieties. Data for SEP and BP from Frota & Vigário (2001). Left panel: whole adapted *corpus* for Portuguese (data set 1). Right panel: selected sentences for a cross-linguistic analysis (data set 2).

Although we have selected a specific set of data for analysis (the *Rm corpus* previously used in Frota & Vigário, 2001), we conclude that the use of different *corpora* did not impact on the overall results. This is confirmed by the MANOVAs run with *corpus* as a factor, with two levels for each variety (global, selected) and $\%V$, ΔC and $\Delta\%C$ as dependent variables. The results show no effect of *corpus* either in Ale or Alg (Ale: for $\%V$, $F(1,2)=0.33$, $p=.626$; for ΔC , $F(1,2)=1.73$, $p=.319$; for $\Delta\%C$, $F(1,2)=4.44$, $p=.170$. Alg: for $\%V$, $F(1,2)=0.52$, $p=.840$; for ΔC , $F(1,2)=10.87$, $p=.081$; for $\Delta\%C$, $F(1,2)=5.62$, $p=.141$). Nevertheless, the syllable-timed nature of Ale comes out more clearly in the analysis based on data set 2, where a similar set of materials across all the varieties of Portuguese was used.

We may conclude that Ale and Alg behave as stress-timed varieties in the $\Delta\%C$ dimension and that the $\%V$ dimension allows us to distinguish the two central-southern varieties – stress-timing in Alg, but syllable-timing in Ale, as in SEP. Thus, Ale seems to display a mixed rhythm, similarly to SEP, while Alg seems clearly a stress-timed variety.

The acoustic analysis based on Varcos measures (Table 3) shows that SEP presents higher scores than Ale and Alg, thus showing a higher variability of the duration of both vocalic and consonantal intervals than Ale and Alg.

	Varco V	Varco C
Alg	39,3 (2,84)	45,0 (2,67)
Ale	40,8 (2,56)	45,8 (2,32)
SEP	52,0 (4,00)	47,3 (4,00)

Table 3 – Varcos: Averaged acoustic measures across European Portuguese varieties and their respective standard errors (same *corpus*).

The two central-southern varieties seem not to be rhythmically distinguished when we consider Varcos, in contrast with the distinction found between Ale and Alg when Ramus, Nespor & Mehler’s/Frota & Vigário’s metrics are considered. Thus, the $\%V$ and $\Delta(\%)C/V$ metrics and the Varcos metrics provide a different insight into the data. Furthermore, according to the Varcos measures, SEP presents a higher consonantal and vocalic interval variability than the central-southern varieties. However, according to the $\Delta(\%)C/V$ metrics, the two central-southern varieties present a higher consonantal interval variability than SEP. Furthermore, variability is much higher in the Varco measures. These different findings according to the two types of metrics are schematized in (1) *versus* (2), below.

- (1) %V and $\Delta(\%)C/V$ metrics
 Ale > %V, $\Delta\%V$ than SEP
 Alg < %V, $\Delta\%V$ than SEP
 Ale/Alg > ΔC , $\Delta\%C$ than SEP
- (2) Varcos metrics
 Ale/Alg < Varco V than SEP
 Ale/Alg < Varco C than SEP

Statistical analysis of both types of acoustic measures showed that neither of them significantly sets EP varieties apart. Similarly to the analysis performed in Frota & Vigário (2001), a MANOVA was run with *variety* as a factor with three levels (SEP, Ale, and Alg), and %V, $\Delta\%V$, $\Delta\%C$, Varco V, and Varco C as dependent variables. Differently from the results obtained for EP *versus* BP, in which %V and $\Delta\%C$ were shown to distinguish between the two Portuguese varieties (Frota & Vigário, 2001), our analysis showed no effect of *variety* for each of the acoustic measures observed, i.e. there were no significant differences across the three EP varieties (%V: $F(2,12)=2.26$, $p=.147$; $\Delta\%V$: $F(2,12)=0.42$, $p=.671$; $\Delta\%C$: $F(2,12)=0.70$, $p=.516$; Varco V: $F(2,12)=2.24$, $p=.149$; Varco C: $F(2,12)=0.65$, $p=.938$).

The statistical results point to the preliminary conclusion that Ale and Alg belong to the same rhythmic class as SEP, in contrast with our previous descriptive observations on the basis of the acoustic analysis and the $\Delta(\%)C/V$ metrics. In order to further inspect possible rhythmic differences, the integration of Ale and Alg in the traditional rhythm classes was tested through an ANOVA for each of the acoustic parameters %V, ΔC , with rhythm class as a factor with three levels: syllable-timed, stress-timed, and mora-timed. Following Frota & Vigário (2001), in this analysis the data from the eight languages in Ramus, Nespór & Mehler (1999) and from SEP and BP was used together with the present findings on Ale and Alg.

According to our preliminary conclusion that Ale and Alg belong to the same rhythm class as SEP in the %V dimension, we classified the two central-southern varieties as syllable-timed in this dimension. A significant effect was found for %V, which means that there are at least two rhythm classes that are significantly different (%V: $F(2,9)=23.16$, $p=.000$). However, post hoc tests (Scheffé) showed that syllable-timed and stress-timed languages did not differ significantly (%V: $p=.237$ for syllable-timed vs. stress-timed, *contra* $p=.001$ for syllable-timed vs. mora-timed, and $p=.000$ for stress-timed vs. mora-timed), suggesting that at least one of the two central-southern varieties is not syllable-timed in the %V dimension. On the basis of the acoustic analysis that showed that Ale is close to SEP in %V, whereas Alg presents a lower score of %V than SEP, we now classified Alg as stress-timed in the %V dimension. Again we found a significant effect for %V (%V: $F(2,9)=75.65$, $p=.000$), but now post hoc tests (Scheffé) showed that all rhythm classes differ significantly (%V: $p=.002$ for syllable-timed vs. stress-timed, $p=.000$ for syllable-timed vs. mora-timed, and $p=.000$ for stress-timed vs. mora-timed). In sum, we may conclude that the %V dimension successfully classifies the EP varieties under analysis as follows: (i) SEP: syllable-timed, (ii) Ale: syllable-timed, (iii) Alg: stress-timed.

For the ΔC dimension, a similar path was followed. Based on the preliminary conclusion that Ale and Alg do not differ significantly from SEP, and given the results obtained from the acoustic analysis (higher scores of consonantal interval variability in Ale and Alg than in SEP), we classified the central-southern varieties as stress-timed in the ΔC dimension. The ANOVA shows a significant effect of ΔC , (ΔC : $F(2,9)=25.18$, $p=.000$). We thus conclude that in the ΔC dimension all the EP varieties under analysis are stress-timed.

To summarize, the comparison between Portuguese varieties and the eight languages analysed by Ramus, Nespór & Mehler (1999) confirms the proposed rhythmic classification of Ale and Alg, and it is compatible with an organization of Portuguese varieties in rhythm classes (as suggested by Frota & Vigário, 2001 and Frota, Vigário & Martins, 2002a, b), and not along a continuum (Figure 3).

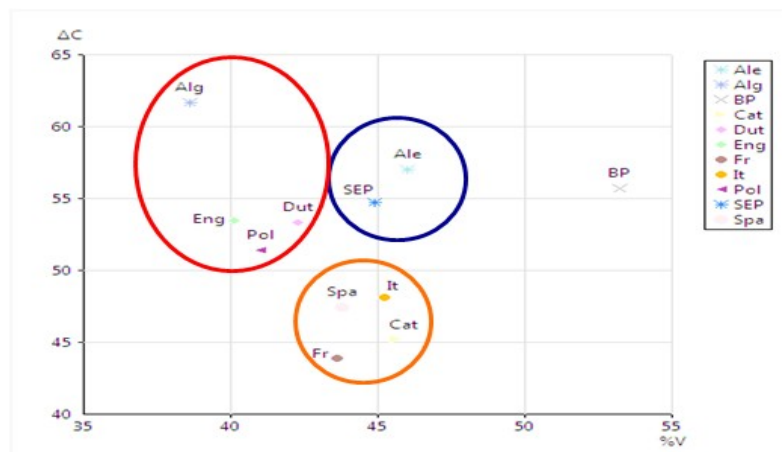


Figure 3 - ΔC vs. $\%V$ for Portuguese varieties (data set 2), and the 8 languages from Ramus, Nespor & Mehler (1999), extending Figure 8 from Frota & Vigário (2001). A red circle groups stress-timed languages/varieties; an orange circle groups syllable-timed languages/varieties; a blue circle groups mixed EP varieties.

To conclude, the acoustic analysis performed showed that depending on the acoustic measures used ($\%V$, ΔC , ΔV , $\Delta\%C$, $\Delta\%V$ or Varcos), Ale and Alg seem to present different rhythmic properties, in line with previous studies showing that the use of different metrics does not provide consistent results (Arvaniti, 2009, 2012a; Arvaniti & Ross, 2010). However, the use of different *corpora* did not affect the main results. Furthermore, the fact that the rhythmic metrics do not provide a statistically significant result in the distinction of SEP, Ale and Alg, does not mean that EP varieties are integrated in the same rhythm class. Indeed, the comparison with other languages revealed that EP varieties cannot be integrated in the same rhythm class. Thus, as suggested by Frota, Vigário & Martins (2002a, b), the contrast with a wider range of languages/varieties is needed in order to evaluate the rhythmic distance between languages and varieties. If EP varieties are not significantly different, we expect that Ale, Alg and SEP are not discriminated in perception studies. If, by contrast, they show significantly different rhythmic properties, we expect discrimination. In particular, given the results obtained, we expect that Alg is discriminated from Ale and from SEP, but Ale and SEP are not discriminated.

In order to test these predictions, we ran perception experiments.

3.2. Perception

We followed the methodological procedures of previous perception studies for Portuguese (Frota, Vigário & Martins, 2002a, b). The discrimination experiments in Frota, Vigário & Martins (2002a, b) had two goals: (i) to test whether SEP and BP were discriminated on the basis of prosodic information, both timing information only and timing plus F0 information and (ii) to investigate the perceptual weighting of $\%V$ and ΔC , and the perceptual distance between SEP, BP and typical stress-timed and syllable-timed languages. The importance of intonation for language discrimination was also inspected. The results showed that adult participants were able to discriminate SEP from BP on the basis of filtered sentences when intonation is preserved (Experiment 1). Experiment 2 showed that SEP and BP are both discriminated from Dutch, thus providing evidence for the perceptual relevance of $\%V$ over ΔC . Additionally, when contrasted with Dutch, SEP and BP are no longer discriminated, suggesting that the distance between SEP and Dutch is bigger than the distance between the two Portuguese varieties (as it was confirmed by perceptual distance values measured with d' – Kaplan, MacMillan & Creelman, 1978).

In the present study, we aim to test whether adult native speakers of SEP are able to distinguish their native variety from each of the two central-southern varieties. In addition, we want to measure the perceptual distance between SEP, Ale, and Alg, by calculating d' scores. Following Frota, Vigário & Martins (2002a, b), we also tested whether intonation is an important cue to discriminate SEP from central-southern varieties, as it is in the case of the SEP/BP distinction.

3.2.1. Method

Two perception experiments were run. Sentences used in both experiments were selected from the production data in data set 2 (section 3.1.2). We selected two sentences per speaker, which were representative of each variety in terms of the acoustic parameters %V and $\Delta\%C$. The two sentences contained 15 and 17 syllables respectively. The same two sentences were selected for two speakers per variety. Thus, four sentences were included per variety, in a total of 12 sentences (2x2x3). Stimuli for SEP were taken from Frota, Vigário & Martins (2002a, b).

All sentences were low-pass filtered at 400Hz and amplified in order to minimize quality differences between audio recordings. Two versions of each sentence were created: (i) low-pass filtered (with F0 contour preserved – ‘+F0’); (ii) low-pass filtered with flat F0 contour (‘-F0’).

Since we have two conditions per variety (+F0; -F0) and the discrimination is being tested between SEP and two other varieties (Ale, Alg), four AX discrimination tasks were run (SEP-Ale +F0; SEP-Ale -F0; SEP-Alg +F0; SEP-Alg -F0). Each task contained 8 pairs with stimuli from the same variety and 16 pairs combining stimuli from two different varieties (SEP-Ale or SEP-Alg). The stimuli in each pair were always uttered by two different speakers. All pairs were randomly presented three times. Thus, each task included a total of 24 trials (8x3) with stimuli from the same variety, and 48 trials (16x3) with stimuli from two different varieties.

The AX discrimination tasks were performed by 40 participants, all SEP native speakers, mainly university students, with a mean age of 27. A group of 20 subjects performed the two AX discrimination tasks with stimuli preserving the F0 contour (SEP-Ale +F0; SEP-Alg +F0), while another group of 20 subjects performed the two AX discrimination tasks containing stimuli with a flat F0 contour (SEP-Ale -F0; SEP-Alg -F0). Within groups, the presentation of the two tasks was counter-balanced, i.e. half of the subjects started the experiment by contrasting SEP-Ale, and the other half started the experiment by contrasting SEP-Alg.

Following Frota, Vigário & Martins (2002a, b) method, all participants were told that they would be listening to acoustically modified sentences of different exotic languages: Urdu and Punjabi in the SEP-Ale contrast, and Fonti and Lingala in the SEP-Alg contrast. Each task was preceded by a training phase, including acoustic modified sentences with a different length from the one considered for the stimuli in the test phase: 16 and 18 syllables per sentence. The training phase consisted of 4 steps, again following Frota, Vigário & Martins (2002a, b) methodology: (1) a set of sentences from Urdu/Fonti (SEP/SEP) or a set of sentences from Punjabi/Lingala (Ale/Alg), (2) a set of AX pairs where X is the same as A, (3) a set of AX pairs where X is different from A, and (4) a set of AX pairs of both types presented in random order. In this last step, subjects were asked to answer after each pair, by clicking on ‘D’ if sentences are different (‘D’ stands for the Portuguese word ‘diferente’ or on ‘I’ if sentences are the same (‘I’ stands for the Portuguese word ‘igual’). Feedback was given only for incorrect answers, and only during the training phase. Subjects were asked to answer as quickly as possible, as reaction time (RT) was also a measure considered for the analysis. Both the training phase and the test phase lasted about 15 minutes per experiment, thus 30 minutes per participant.

In order to avoid including data from subjects that were not able to perform discrimination tasks with degraded stimuli, we decided to apply a rejection criterion (similar to Frota, Vigário & Martins, 2002a, b). We thus excluded and replaced subjects that were not able to identify sentences belonging to the same variety as being the SAME above chance level. According to this criterion, a total of 12 participants were excluded: eight in the condition ‘-F0’, four in the condition ‘+F0’.

3.2.2. Results

To observe whether native speakers of SEP were able to discriminate their variety from Ale and from Alg, we calculated the average percent scores of ‘different’ responses to DIFFERENT pairs (i.e. success in discrimination). Additionally, we followed Signal Detection Theory (SDT) which provides a model for calculating the sensitivity (d' measure) to differences between stimuli (Kaplan, MacMillan & Creelman, 1978; Boley & Lester, 2009). ‘Different’ responses to DIFFERENT pairs were used as hit rate and the ‘different’ responses to the SAME pairs were considered as false alarms. Mean reaction times (RTs) were also computed. The results of pairs used as hit rate are summarized in Table 4.

	SEP vs. Ale		SEP vs. Alg	
	+F0	-F0	+F0	-F0
Percent scores	71	73	65	65
RTs (ms.)	600	485	549	544
d' -scores	2.72	2.81	2.16	2.16

Table 4 – Hit rate for SEP *versus* Ale and SEP *versus* Alg: mean percent scores of discrimination, mean reaction times (RTs) and d' scores.

The results show that SEP participants were able to discriminate their native variety from both Ale and Alg. Interestingly, this result contradicts the absence of significant acoustic differences across the three EP varieties. Furthermore, on the basis of the integration of Ale and Alg in the rhythm classes, discussed above, these results are unexpected. If Ale is a mixed variety and if Alg is a stress-timed variety, then we would expect high percent scores for the discrimination between SEP and Alg, and we would expect absence of discrimination between SEP and Ale, or a shorter perceptual distance between SEP and Ale than between SEP and Alg. However, our results don't go in this direction: both central-southern varieties were discriminated from SEP and with slightly higher percent scores of discriminated pairs in Ale than in Alg. This means that the distance between SEP and Ale seems to be bigger than the distance between SEP and Alg, which is reflected in d' -scores: the distance between SEP and Alg is overall smaller ($d'=2.16$) than the distance between SEP and Ale ($d'=2.77$).

Since we have two groups of subjects (2x20), performing the same two discrimination tasks (SEP *versus* Ale, and SEP *versus* Alg), but differing in the presence/absence of the F0 contour, two dependent t -tests were run with the discrimination percent scores for both Ale and Alg as paired variables in each dependent t -test (+F0 and -F0). The analysis shows that independently of F0 condition, discrimination scores obtained in the SEP *versus* Ale experiment do not differ significantly from the discrimination scores obtained in the SEP *versus* Alg experiment performed by the same group of subjects (+F0: $t(19)=1.32$, $p=.203$; -F0: $t(19)=1.42$, $p=.173$).

Reaction times (RTs) were also inspected within subjects, for both the +F0 and -F0 conditions. Two Wilcoxon signed-rank tests were run, with mean RT in Ale and mean RT in Alg as paired variables. Similarly to the percent scores, this analysis shows that independently of the F0 condition, mean RTs of responses in the SEP *versus* Ale experiment did not differ significantly from the mean RTs obtained in the SEP *versus* Alg experiment performed by the same group of subjects (+F0: $Z=-.52$, $p=.601$; -F0: $Z=-.64$, $p=.526$).

In sum, SEP participants were able to discriminate their native variety from Ale and from Alg and the discrimination rates in the two tasks were similar for both within subjects, which suggests that the ability to discriminate the three varieties is not significantly different.

To inspect whether intonation was a relevant cue for rhythm, we run two independent-samples t -test, with *F0 condition* as a grouping variable (+F0, -F0), and with the discrimination percent scores for both Ale and Alg as paired variables in each independent-samples t -test (+F0 Ale *versus* -F0 Ale; +F0 Alg *versus* -F0 Alg). The analysis revealed that the presence/absence of F0 seems to be irrelevant for the discrimination between SEP and Ale and between SEP and Alg. Indeed, the discrimination scores obtained in the SEP *versus* Ale experiment preserving the F0 contour do not differ significantly from the discrimination scores obtained in the SEP *versus* Ale experiment with a flat F0 contour. The same applies to the SEP *versus* Alg experiments (+F0 Ale *versus* -F0 Ale: $t(38)=-.37$, $p=.714$; +F0 Alg *versus* -F0 Alg: $t(38)=-.04$, $p=.968$). These results are illustrated in Figure 4, by means of a clustered boxplot, which gives a general overview of the statistical analysis described above.

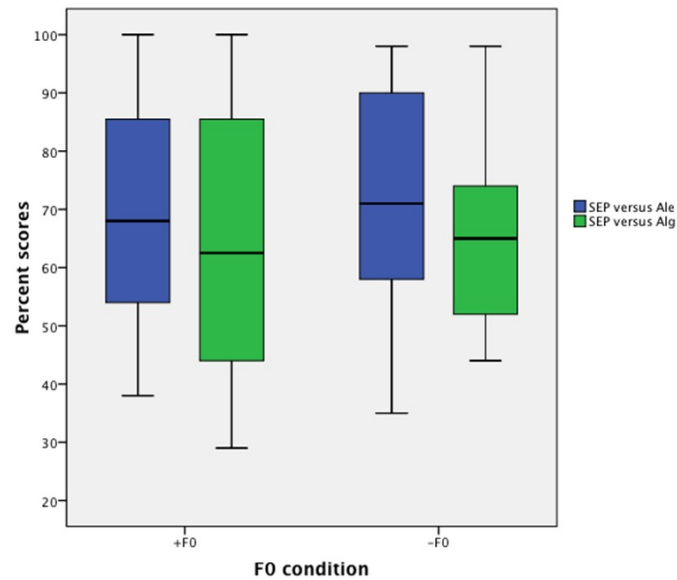


Figure 4 – Boxplot of the discrimination scores in the tasks SEP *versus* Ale and SEP *versus* Alg (within-subjects), clustered by F0 condition (between-subjects). The black horizontal line represents the median.

Reaction times (RTs) were also compared across the two F0 conditions. A Mann-Whitney U test was run, with *F0 condition* as a grouping variable (+F0, -F0), and with the mean RTs in SEP *versus* Ale tasks as test variables. The analysis reveals that mean RTs did not differ significantly depending on the presence/absence of F0 in the signal (+F0 Ale *versus* -F0 Ale: $Z=-.87, p=.387$). The same was observed for the mean RTs in SEP *versus* Alg tasks (Figure 5). Since this variable presents a normal distribution ($D(40)=.130, p=.087$), an independent-samples *t*-test was run, with *F0 condition* as a grouping variable (+F0, -F0), and with the mean RTs in SEP *versus* Alg tasks as test variables (+F0 Alg *versus* -F0 Alg: $t(38)=-.07, p=.948$).

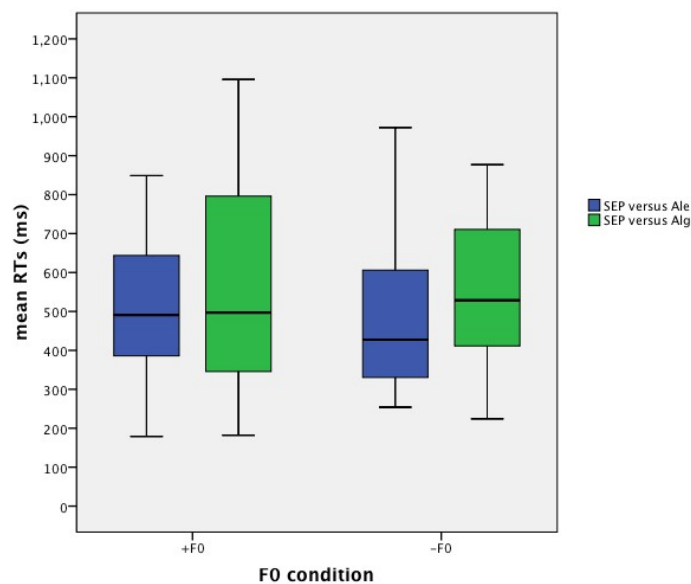


Figure 5 - Boxplot of mean Reaction Times (RTs) in milliseconds (ms) in the tasks SEP *versus* Ale and SEP *versus* Alg (within-subjects), clustered by F0 condition (between-subjects). The black horizontal line represents the median.

As mean RTs were similar whether F0 is preserved or not, the results show that F0 does not play a relevant role in the discrimination between SEP and Ale and between SEP and Alg.

Our results partially confirmed our initial predictions on the basis of the production data: SEP and Alg were discriminated, as expected, but contrary to expectations SEP and Ale were also discriminated. The latter finding suggests that some other property in the signal is being interpreted by SEP participants as a cue to distinguish their variety from Ale. We already know that this cue cannot be based on duration because there is a mismatch between production and perception results (SEP and Ale were both considered as mixed varieties, on the basis of acoustic analysis of duration). Additionally, the perception experiments revealed that F0 was also not being used as a cue, since SEP participants were able to discriminate their variety from Ale (and Alg), independently of the presence/absence of this cue in the signal.

We suggest that speech rate might be cueing the discrimination between SEP and Ale. To examine this possibility, we measured the average duration (in milliseconds) of the sentences used as stimuli (Table 5).

	Ale	Alg	SEP
15 syllables	2546	2343	2395
17 syllables	2924	2448	2347

Table 5 – Average duration (ms.) of sentences selected for the perceptual experiments.

The results indicated that the duration of the sentences from Ale was indeed longer than the duration of the sentences from SEP (and Alg). We then compared the ranges of duration of the sentences with 15 and 17 syllables for each variety. This is illustrated in Figure 6.

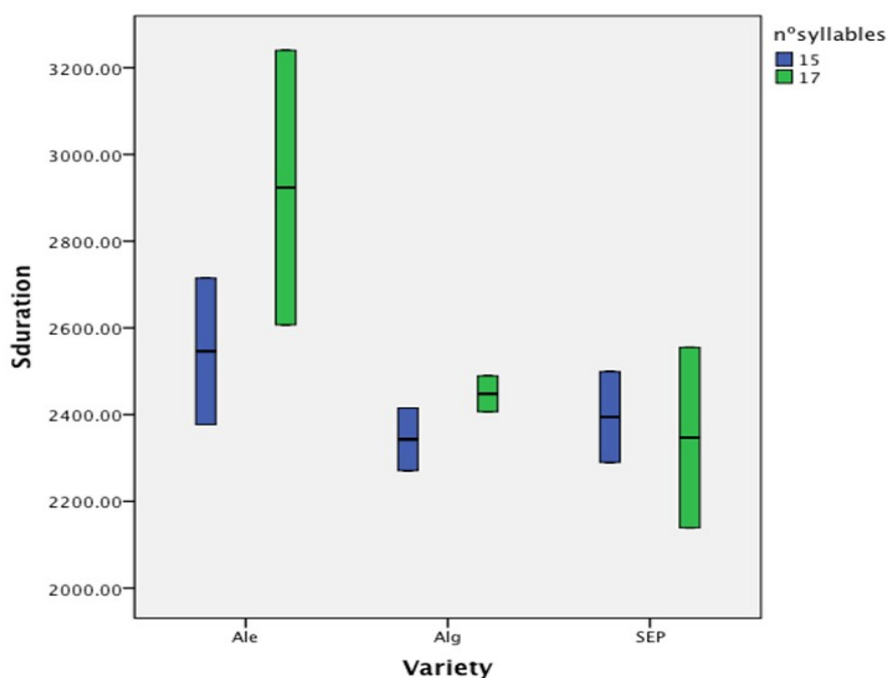


Figure 6 – Range of duration (ms.) of sentences across varieties by length in number of syllables.

In Ale the sentences are longer than in Alg and in SEP: the lowest duration of sentences with 15 syllables in Ale is almost level with the highest duration of sentences with the same length in Alg and SEP. Similarly, the lowest duration of sentences with 17 syllables in Ale is even higher than the highest duration of sentences with the same length in Alg and SEP. This supports our suggestion that speech rate might explain the discrimination

between varieties with similar rhythmic properties (Ale and SEP), which could not be captured by the metrics used. However, it does not explain the discrimination between Alg and SEP, which may be accounted for by the acoustic differences revealed in the production data that point to a stress-timed nature of Alg and a mixed rhythmic nature of SEP. We thus hypothesize that participants from SEP used different cues in order to discriminate their native variety from each central-southern variety. We leave for future work a more detailed inspection of the effect of speech rate as a cue for the discrimination between languages/varieties.

4. Conclusion

Based on prior studies of rhythm across varieties (Ghazali, Hamdi & Barkat, 2002, for Arabic varieties; O'Rourke, 2008, for Spanish varieties; Giordano & D'Anna, 2010, for 15 varieties of Italian), as well as on the previous inspection of rhythm in Portuguese (Frota & Vigário, 2001), we established the following goals: (i) to observe whether the rhythmic measures that Frota & Vigário (2001) considered relevant to distinguish between SEP and BP also contribute for the characterization of central-southern varieties, previously shown to be different from SEP in terms of intonational contours, phrasing patterns and pitch accent distribution (Cruz, 2013; Cruz & Frota, 2011, 2013a, b; Frota et al., in press); (ii) to observe whether the use of different *corpora* across varieties leads to different results from the use of a common *corpus*; (iii) to observe whether the use of different acoustic measures leads to different results from the ones obtained by means of Ramus, Nespore & Mehler's (1999) metrics; (iv) to inspect whether rhythmic differences were perceived; and (v) to add to the debate on the organization of languages/varieties into rhythmic classes or along a rhythm continuum.

We concluded that, depending on the acoustic measures used (%V, ΔC , ΔV , $\Delta \%C$, $\Delta \%V$ or Varcos), Ale and Alg seem to present different rhythmic properties, in line with previous studies showing that the use of different metrics does not provide consistent results (Arvaniti, 2009, 2012a; Arvaniti & Ross, 2010). The use of different *corpora* was shown not to affect the main results. Crucially, the comparison with other languages revealed that EP varieties cannot be all integrated in the same rhythm class. Thus, as suggested by Frota, Vigário & Martins (2002a, b), the contrast with a wider range of languages/varieties is needed in order to evaluate the distance between them.

Based on previous perception studies (Frota, Vigário & Martins, 2002a, b), we ran several experiments to examine (i) whether native speakers of SEP were able to distinguish their native variety from each central-southern variety at a time, and (ii) what was the perceptual distance between SEP, Ale, and Alg, by calculating d' scores. Intonation was also considered as a possible cue for discrimination, as it was previously found to be relevant to discriminate SEP from BP. We concluded that: (i) SEP participants are able to discriminate their native variety from both Ale and Alg; (ii) although SEP and Alg present lower discrimination scores and lower d' -scores than SEP and Ale, suggesting that Alg is closer to SEP than Ale, statistical analysis of discrimination scores and mean Reaction Times shows that these differences were not significant; (iii) intonation did not play a significant role in discrimination.

The results from the acoustic analysis of rhythm suggested that the following aspects should be taken into account in an investigation of rhythmic properties. First, different acoustic measures should be used, and results should be interpreted in articulation with other phonological properties of the language/variety under analysis (along the lines of Dasher & Bolinger, 1982, and Dauer, 1983), and also in articulation with perception data.

Second, the fact that central-southern varieties were not found to be statistically different from each other, and from SEP, on the basis of the acoustic data does not necessarily mean that EP varieties are integrated in the same rhythm class or space. As suggested by Frota, Vigário & Martins (2002a, b), the contrast with a wider range of languages/varieties may be needed in order to evaluate perceptual distances and the relation between acoustic and perceptual differences may not be linear. Indeed, the comparison with other languages revealed that EP varieties cannot be integrated in the same rhythm class: in particular, while Ale may share the same rhythmic properties as SEP, Alg is clearly a more stress-timed variety.

Third, although several studies suggest that discrimination between languages may be related with the interaction of components of prosody which impact on rhythm (Frota, Vigário & Martins, 2002a, b; Prieto et al., 2012), we may conclude that rhythmic properties cannot be directly deduced from other prosodic aspects (such as pitch accent distribution or prosodic phrasing choices). Previous studies have shown that there is a correlation between pitch accent distribution and the dominant phrasing pattern in SEP (Vigário & Frota, 2003; Frota & Vigário, 2007), as this variety presents a sparse pitch accent distribution and longer phrases. The same

interdependence was observed in Ale (dense pitch accent distribution and short phrases), but not in Alg. This variety presents a dense pitch accent distribution (as Ale), but the preference for longer phrases (as SEP), thus showing a mixed pattern (Cruz & Frota, 2013a, b). However, this does not mean that Alg presents a mixed rhythmic nature. Actually, Alg is clearly stress-timed, while both Ale and SEP present mixed properties (syllable-timed in the %V dimension, and stress-timed in the ΔC dimension).

Finally, the present findings suggest that the relevance of intonation as a cue to rhythm is not generalised to all Portuguese varieties. Frota, Vigário & Martins (2002a, b) showed that when F0 was absent from the auditory stimuli, SEP and BP were not discriminated, unlike when F0 was preserved. Our findings on the perception of Ale and Alg as different from SEP suggest that intonation does not play a significant role in discrimination, although both Ale and Alg show a dense distribution of pitch accents, unlike SEP. It is thus possible that sensitivity to intonation is not a general property of Standard European Portuguese native speakers' perception of rhythm (as was suggested by Frota & Vigário, 2001), or that the intonational features that impact on the perception of rhythm go beyond pitch accent distribution. In addition, if it is not F0 (as shown by the perception results) nor the general durational properties captured by the metrics (as suggested by the acoustic analysis) that are behind the discrimination between SEP and Ale, then some other property in the signal is being used as a cue to rhythmic differences. A strong candidate is speech rate, which was found to be slower in Ale than in Alg or SEP. We leave for future work the inspection of speech rate, a component of prosody already pointed out as a possible cue for the discrimination of rhythm across languages/varieties (Arvaniti, 2012b; White, Mattys & Wiget, 2012; Prieto et al., 2012).

By and large, the current preliminary findings for production and perception taken together suggest that the rhythm of EP exhibits more stress-timed properties towards the Southern varieties, and that the varieties analysed exhibit rhythmic differences that are perceptually salient. Studies of more EP varieties are required, especially of Northern varieties, to establish whether the drift towards stress-timing from Lisbon to the South is supported or not. Other perception studies within EP varieties are also needed, as well as perception studies including typical stress-timed and/or syllable-timed languages in the experiment, additionally to EP varieties (as in Frota, Vigário & Martins, 2002a, b). Such studies would allow a better understanding of the rhythmic distance between the different EP varieties and between these and prototypical stress-timed and syllable-timed languages. These studies would also provide critical information for the debate on the organization of languages/varieties into rhythmic classes or along a rhythm continuum.

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