

Building a prosodic profile of European Portuguese varieties: the challenge of mapping intonation and rhythm

Abstract

In the present paper we explore a methodology to map prosodic variation in Portuguese, namely intonation and rhythm, which goes beyond the traditional approaches used to represent segmental, lexical or syntactic variation. To find the most adequate mapping method for intonation and rhythm, we tested spatial interaction models for the representation of nuclear contours, and spatial interpolation methods for rhythmic distinctions across varieties. Our results show a non-contiguous distribution of prosodic features, thus not matching the regional areas previously defined on the basis of segmental, lexical or syntactic variation. These results, together with those of previous studies across varieties of other languages, provide growing evidence that the distribution of prosodic features tends to be independent of geography, unlike non-prosodic variation.

Keywords: prosodic variation, intonation, rhythm, probabilistic geographical mapping, European Portuguese

1. Introduction

Dialectology has met a methodological (r)evolution since the traditional approach of isoglosses to represent the geographical distribution of

linguistic variation (e.g., Cintra, 1971 for European Portuguese; Chambers & Trudgill, 1980/1998 for English). Many methods have been developed for comparing varieties, by measuring the degree of similarity and difference between them. Among these methods, there has been an increased use of quantificational approaches, combined with new techniques to represent the relations between varieties (Nerbonne, 2003; Heeringa, 2004; Goebel, 2006, 2007; *inter alia*). Nevertheless, several limitations of these new methods and techniques were identified, even when the method/technique chosen is the most adequate for the type of data (sample dimension, amount and type of variables, *inter alia*) involved. Quantificational approaches measure the relation between varieties already analyzed, using the description of the observed linguistic behavior of each variety. Although aiming to capture the relations between varieties in a realistic way, these methods are constrained by the amount of analyzed data, and thus limited by the description of the observed results. Consequently, unstudied locations, both close to and far from previously studied locations, are not considered by most of these methods, which do not allow the prediction of linguistic behavior at locations not yet analyzed.

In the present research we propose the use of more innovative methods in dialectology, in the sense that they allow the prediction of relations between locations for which there is data available and locations that have not been studied – the spatial interpolation methods and spatial interaction models. We thus aim to define a methodology to map prosodic

variation in European Portuguese (EP), which goes beyond the traditional approaches used to represent segmental or syntactic variation in this language. We tested the use of these innovative methods with two of the four prosodic aspects under analysis within the project *Interactive Atlas of the Prosody of Portuguese* (<http://labfon.lettras.ulisboa.pt/InAPoP/>) – namely, intonation and rhythm. The geographical distribution of these prosodic aspects leads to a global overview of intonational and rhythmic properties in EP, which still needs to be validated, but already provides an important contribution for building a prosodic profile of EP varieties.

In the next section, we introduce the challenges involved in mapping. We summarize some of the most important methodologies used to represent the relations between varieties, from the traditional approaches to the more recent quantificational approaches (section 2.1), and spatial models (section 2.2), and we mention the identified pros and cons of each methodology. In section 3, we describe the most known geographical representations for segmental and syntactic variation in European Portuguese, and the mapping methods to be used for the representation of prosodic variation are defined. After the description of the data used (section 4), we present our findings (section 5). A first proposal of the geographical representation of these results is presented for intonational variation (section 5.1) and rhythmic variation (section 5.2). Finally, in section 6, we sum up the main similarities

and differences found across EP varieties, thus contributing to the understanding of their prosodic profiles.

2. The challenge of mapping

The multiple perspectives and methods adopted for the design of spatial models lead to the assumption that these models are subjective in the sense that they incorporate a specific way, among others, to approach reality (Rocha & Morgado, 2007). This applies to any reality that may be represented, linguistic variation included.

2.1. Mapping linguistic variation

According to Goebel (2006, 2007), Maguire & McMahon (2011), *inter alia*, mapping linguistic variation is not a trivial task. Among multiple obstacles, the following questions arise: (i) how to quantify relations between dialects, (ii) how many features are needed to define a dialectal area, (iii) how to delimit isoglosses when two non-contiguous varieties share similar features. In addition to these difficulties, the amount of data also constrains its cartographic representation in the sense that large amounts of data are needed to propose areas of linguistic variation or to draw isoglosses (Nerbonne, 2003).

The traditional approach to represent the geographical distribution of linguistic variation is based on the proportional relation between

geographical distance and linguistic difference, argued by Chambers & Trudgill (1980/1998). According to this perspective, geographically closer varieties are linguistically similar, whereas geographically distant varieties are linguistically different, a fact related with the notion of geolinguistic continuum. This approach consists of the definition of dialectal areas by determining the geographical location of linguistic features and by drawing the correspondent isoglosses (Kessler, 1995).

However, Kessler (1995) and Maguire & McMahon (2011) consider that isoglosses impose some limitations on the representation of relations between varieties. The authors point out some weaknesses of this traditional approach: (i) varieties separated by two or more isoglosses are not necessarily different; (ii) randomly distributed features can also be important for determining similarities and differences across varieties; (iii) we cannot assume that features apparently distributed randomly have no structure in their distribution; (iv) varieties which are non-contiguous, but which share the same properties (for historical reasons, for instance) are nevertheless represented as being different areas.

Several quantificational methods, primarily developed for historical linguistics, have been used to calculate the distance between varieties. Among the categorical approaches, the dialectometry method was developed for the comparison of varieties of a given language (Séguy, 1973; Goebel, 1997, 2006, 2007). It uses comparable data from dialect surveys by assigning a specific score to similar/different answers. The percentage of

matching answers corresponds to the degree of similarity between two varieties, and the distance between them is obtained by subtracting the similarity from 100%. However, dialectometry is not the best method to deal with non-categorical (or gradient) data (Maguire & McMahon, 2011). For this type of data, the Levenshtein distance is the most adequate method (Nerbonne, Heeringa & Kleiweg, 1999; Nerbonne, 2003; Heeringa, 2004). Commonly used to compare phonetic and phonological properties across varieties, the Levenshtein distance is based on the presupposition that it is possible to convert any string of phonetic segments into any other using a set of processes (deletions, insertions, substitutions, *inter alia*), and the amount of operations needed corresponds to the cost (or the distance) between strings. However, one of the limitations of this method is the fact that the process of conversion of any segment to another may have the same cost, independently of the nature of the segments involved (Nerbonne et al., 1999; Heeringa, 2004).

An alternative technique to determine and represent the proximity/distance between varieties consists in using spatial analysis tools, described below. However, as for the methods presented above, we have to be aware of their (dis)advantages.

2.2. Models of spatial interaction and interpolation: an innovative proposal to map variation

According to Chasco (1997), spatial models were initially based on two different methods depending on the perspective followed: the descriptive/deterministic approach or the explicative/stochastic approach. Although characterized by the use of less complex techniques, deterministic models were based on fixed assumptions about the reality represented, and thus criticized for their inflexibility (Chorley & Haggett, 1967). Instead, explicative/stochastic models make use of several variables to analyze the reality, being more complex and flexible.

In an intermediate position, spatial interaction models were developed by combining both deterministic and stochastic techniques. These methods are based on Reilly's Gravity Law (1931) and the adapted gravity model developed by Huff (1963) is one of the most well-known. This model analyzes and predicts patterns of spatial interaction (Haynes & Fotheringham, 1984), and allows the generation of areas of influence/attractiveness of a given spatial point. Initially developed as a tool for the GeoMarketing, this model has been adapted for other research fields, and the technological advances have allowed its inclusion in specialized softwares. Other models, criticized for their extreme complexity and difficult implementation (Cliquet 2006), were proposed as being better than the Huff model, in the sense that their algorithm includes several explicative variables, such as logistic models (McFadden, 1974, 1977; Fotheringham, 1983; Fotheringham & O'Kelly, 1989; *inter alia*) and spatial dynamic models (Tardiff, 1979; Heckman, 1981; Leonardi, 1983; *inter alia*).

Spatial interaction models differ from spatial interpolation methods. Interpolation is defined as the process of estimating values of a given variable for geographical points without information, by using a known scattered set of points. There are two main types of spatial interpolation methods: deterministic and geostatistic. Deterministic methods are based on mathematical functions used to calculate unknown values with a weighted average of the values available at the known points. This is the basis of the *Inverse Distance Weight (IDW)* and *Radial Basis Functions (RBF)* methods. Geostatistic methods combine mathematical, but also statistical, methods in order to calculate values for the unknown points and they also provide probabilistic estimates of the quality of the interpolation, based on the spatial correlation between the geographical points considered in the analysis. The most frequently used geostatistic methods are the *Kriging* and the *Co-Kriging*, usually applied to large samples.

Besides the nature of the formula that is the basis of each method, it is important to mention that spatial interpolation methods are also distinguished by the amount of data used. From this perspective, these methods may be implemented locally or globally. Local methods, such as the deterministic methods *IDW* or *RBF*, are applied to a small set of points, belonging to a more extended spatial area considered in the analysis, whereas global methods, such as the polynomials, are applied to the whole set of points considered in the analysis (Burrough & McDonnell, 1998; Johnston, Ver Hoef, Krivoruchko & Lucas, 2001).

The *IDW* is one of the most used local deterministic methods and it has several advantages, such as the simple mathematical concept of its base, its algorithm is well known, and it is easily understood/interpreted. It is also considered a robust method, since it faithfully uses the known values of the sample and it does not estimate higher or lower values than the sample's range.

3. Mapping linguistic variation in European Portuguese

In European Portuguese, the most known geographical representations of segmental and syntactic variation follow the traditional approach of defining dialectal areas on the basis of isoglosses. The proposal for the classification of EP dialects on the basis of segmental variation (Cintra, 1971), adapted by Segura & Saramago (2001), as illustrated in Figure 1, describes a split between two major linguistic areas corresponding to northern varieties (in blue) and central-southern varieties (in brown and white). Northern varieties are separated into two regions by the isogloss of the phonetic realization of sibilants: the area in light blue is characterized by the maintenance of four sibilants (the fricative [s], its sonorant [z], and the correspondent apical-alveolar realizations); the dark blue area is characterized by the reduction of the system of four sibilants to the two apical-alveolar realizations (Cintra, 1971: 102). Central-southern varieties are also separated into two regions by the isogloss of the phonetic

realization of the diphthong <ei>: it is produced as [ej] in the Littoral-Centre (in brown), but reduced to [e] in the Interior Centre and South (in white) (Cintra, 1971: 102).

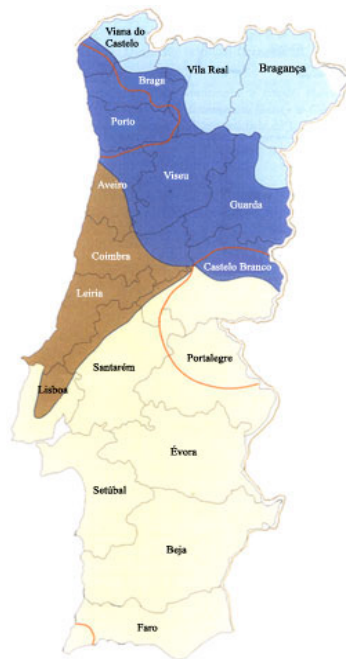


Figure 1. European Portuguese dialects based on phonetic and phonological phenomena, according to Cintra (1971), adapted by Segura & Saramago (2001). The red thinner line signals regions with peculiar linguistic features.

The geographical representation of syntactic variation in EP is illustrated in Figure 2. Carrilho & Pereira (2011, 2012), based on previous studies describing a geographical distribution of some non-standard syntactic structures (Martins, 2003; Pereira, 2003; Magro, 2007; Lobo, 2008; *inter alia*), proposed isoglosses for each of them. The authors concluded that the geographical distribution of these syntactic structures

matches the dialectal areas determined on the basis of phonetic and phonological segmental phenomena. Namely, non-standard syntactic structures with inflected gerunds and with <*estar* + gerund> were found in the Interior Centre and South area of Cintra (1971).

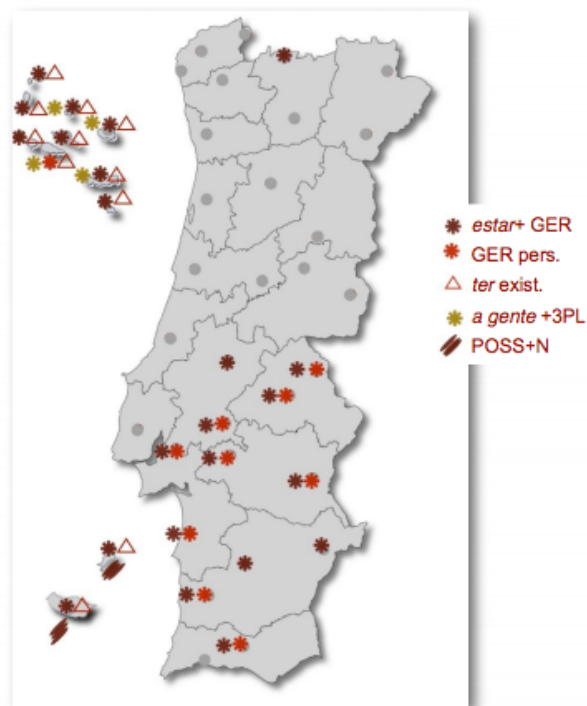


Figure 2. Geographical distribution of non-standard syntactic structures in European Portuguese (periphrastic construction with *estar* + gerund; inflected gerund; constructions with the existential *ter*; constructions with *a gente* + verb in the 3rd person of plural; pronominal possessive not preceded by determinant) (Carrilho & Pereira, 2012).

Prosodic variation in EP is a fairly recent topic of research. The first discussion of dialectal variation in EP intonation appears in Vigário & Frota

(2003). Since then, other studies were developed on prosodic phrasing, pitch accents and nuclear contour types and pitch accent distribution across EP varieties (Cruz & Frota, 2011; Frota, 2002; Frota & Vigário, 2007; Frota et al., 2015). For rhythm, until recently only the Standard EP variety and the Brazilian variety spoken in S. Paulo were compared (Frota & Vigário, 2000, 2001; Frota, Vigário & Martins, 2002a, b). These results have been recently extended by the analysis of rhythmic variation within EP, namely in central-southern varieties (Cruz, 2013; Cruz & Frota, 2014).

Our main goal consists of defining a methodology to map prosodic variation in EP in two of the dimensions investigated within the *InAPoP* project – intonation and rhythm – each presenting different challenges. For the representation of intonation, the following aspects were considered: (i) the mapping of the dominant nuclear contour might not provide sufficient information about each variety in the sense that two varieties may present the same dominant contour, but different alternative contours, with different weights; (ii) a given nuclear contour may be the dominant one in one variety and the alternative one in another variety (geographically contiguous or not); (iii) the fact that some varieties may present one single nuclear contour to convey a specific sentence type or pragmatic meaning and other varieties may present a wide range of alternatives could reflect the relationship between varieties (in contact and/or non-contiguous). The representation of rhythm presents a different challenge. According to Ramus, Nespor & Mehler (1999) and Frota & Vigário (2001), the rhythmic characterization of

languages/varieties is given by the combination of arguably independent parameters such as the proportion of vocalic intervals (%V), and the variability of the duration of consonantal intervals (ΔC or $\Delta \%C$). The difficulty lies in the cartographic representation of the combination of more than one quantitative variable (for further details on these variables, see sections 4 and 5.2). In addition to these challenges, so far we only have analyzed data from 7 from a total of 36 possible locations in the continent.

Based on the main goals and in order to face the challenges previously presented, we developed a methodology, through Geographical Information Systems software, using spatial interaction models and spatial interpolation methods in distinct ways: (i) spatial interaction models for the representation of nuclear contours (dominant and alternative) across varieties, and (ii) spatial interpolation methods for the representation of rhythmic distinctions across varieties, by combining two different quantitative variables.

Spatial interaction models seem most suited to be applied to the representation of intonation since we are dealing with quantitative data – percentage of occurrence of a given type of nuclear contour. Thus, on the basis of a few selected geographical points, these methods generate spheres of influence of a given contour type, allowing us to predict how much a given contour type can spread to adjacent points. Among all the existing spatial interaction models, we decided to use the Huff model, as it is one of the most commonly used in the Geography field (Cliquet, 2006) due to its

easier implementation and since it is available in the GIS software (ArcMap 10.2).

Differently, spatial interpolation methods seem most suited to be applied to the representation of rhythmic properties. By using a known scattered set of points expressing rhythmic properties, spatial interpolation methods allow the prediction of rhythmic classification of unknown geographical points. Among the spatial interpolation methods available in the GIS software, we selected the *Inverse Distance Weight (IDW)* for the following reasons: (i) it is a local deterministic method, thus adequate for small samples, belonging to a more extended spatial area considered for analysis; (ii) it is a robust method, thus a good estimator; (iii) it is usually applied to data geographically distributed in an irregular way, which is the case of our data, since the seven urban areas analyzed are not homogeneously distributed in the Portuguese territory (e.g., the northeastern districts – Bragança and Guarda –, as well as the coastal districts between Oporto and Lisbon form geographical gaps which certainly have an impact on the predictions made by the method).

4. Materials

Our data was selected from the database of the *InAPoP* project, available at the project's webplatform (Frota & Cruz, coords., 2012-2015). For the present study, seven urban areas were selected, each corresponding to a

continental district of Portugal, as illustrated in Figure 3: Braga (Bra) – Braga district, Ermesinde (Por) – Oporto district, Lisbon (SEP) – Lisbon district, Castelo Branco (CtB) – Castelo Branco district, Évora (Eva) – Évora district, Castro Verde (Ale) – Beja district, and Albufeira (Alg) – Faro district. Only the data produced by three female speakers per region, aged between 20-45 years old, were considered for analysis.



Figure 3 – Urban areas covered in the present study.

We have focused on two dimensions of prosodic variation: intonation and rhythm. For intonation, we analyzed both the dominant and the alternative nuclear contours of information-seeking yes-no questions. Therefore, the type and weight (in percentage of occurrence) of the dominant and the alternative nuclear contours were considered for the cartographic representation. We selected data from two different tasks, in

order to compare the geographical distribution of the nuclear contours of neutral yes-no questions across speech styles – the reading task (scripted speech based on a controlled corpus designed for intonational analysis) and the DCT (semi-spontaneous speech – Félix-Brasdefer, 2010). We analyzed a total of 609 sentences: 420 sentences produced in the reading task (10 sentences x 2 renditions x 3 speakers x 7 regions), and 189 sentences produced in the DCT (3x3x3x7). The analytical framework followed here is the Autosegmental Metrical (AM) theory of intonational phonology (Pierrehumbert, 1980; Beckman & Pierrehumbert, 1986; Pierrehumbert & Beckman, 1988; Gussenhoven, 2004; Jun, 2005, 2014; Ladd, 2008), and we used the ToBI labeling system for Portuguese (Frota, 2000, 2014; Frota, Oliveira, Cruz & Vigário, 2015).

For the cartographic representation of rhythmic variation in EP, we analyzed two different corpora, both obtained by means of a reading task: the corpus of Ramus, Nespor & Mehler (1999), adapted by Frota & Vigário (2001) to Portuguese (210 sentences – 5 sentences x 2 renditions x 3 speakers x 7 regions), and the comparative corpus used in Frota & Vigário (2001) for European and Brazilian varieties of Portuguese (840 sentences – 20x2x3x7). We analyzed a total of 1050 sentences, using *Praat* (Boersma & Weenink, 2007). Vocalic and consonantal intervals were delimited on the basis of both auditory and acoustic cues, following standard criteria of segmentation (Frota & Vigário, 2001; Turk, Nakai & Sugahara, 2006). Data were then automatically extracted with *Correlatore* 2.1 (Mairano, 2009) and

manually cross-checked, and our analysis is based on the three acoustic measures that allow a comparison between our results and those of the eight languages analyzed by Ramus, Nespor & Mehler (1999) and of the varieties of Portuguese (Standard EP and BP) previously analyzed following a similar methodology (Frota & Vigário, 2000, 2001): the proportion of vocalic intervals (%V), the variability of consonantal intervals (ΔC), and the normalized measure of the variability of consonantal intervals ($\Delta\%C$).

In the next section, the main results obtained for intonation and rhythm across regions are presented, together with our proposal of geographical mapping of intonational and rhythmic variation in EP.

5. Results

5.1. Intonation

We first present the results of the dominant nuclear contours of information-seeking yes-no questions, followed by those of the alternative contour, for each speech style. Following this, we put forward our attempt to geographically represent our main results.

The analysis of the most frequent nuclear contour of yes-no questions produced in the reading task shows that low/falling nuclei and rising tonal boundaries dominate, as illustrated in Figure 4 and Figure 5.

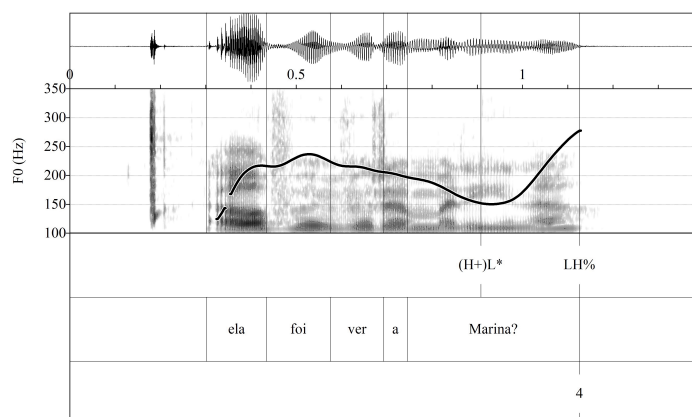


Figure 4. Reading task – yes-no question produced in Bra. *Ela foi ver a Marina?* ‘Has she gone to see Marina?’.

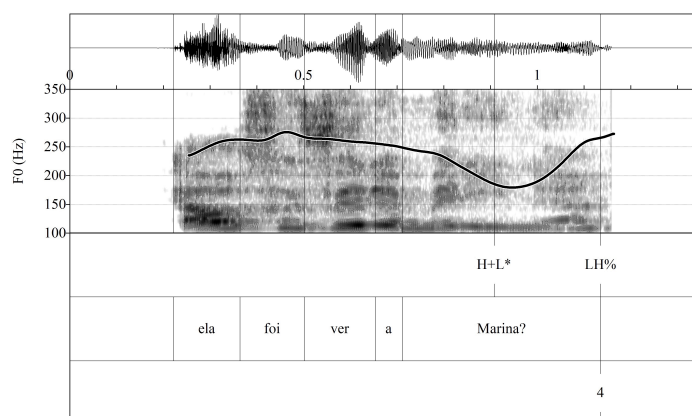


Figure 5. Reading task – yes-no question produced in SEP. *Ela foi ver a Marina?* ‘Has she gone to see Marina?’.

However, as reported in Table 1, this is not the most frequent nuclear configuration in three non-contiguous regions: Por, in the North; CtB in the Centre-South; Alg, in the South.

Urban area	Dominant contour	% of occurrence	Alternative contour	% of occurrence
Bra	(H+)L* LH% †	55%	H+L* LH%	21%
Por	L*+H H%	60%	L*+H HL%	27%
CtB	L+H* L%	42%	L* H%	22%
SEP	H+L* LH%	83%	L*+H H%	7%
Eva	(H+)L* LH% ‡	28%	(H+)L* L%	28%
Ale	L* H%	60%	H+L* LH%	20%
Alg	L*+H H%	79%	L*+H HL%	21%

Table 1. Reading task – dominant and alternative nuclear contour

types of information-seeking yes-no questions and their percentage of occurrence across EP urban areas.

† The parentheses on nuclear pitch accent (H+)L* means that the pre-stressed syllable may be already falling. These cases were quantified apart from those where the H tone is realized on the pre-stressed syllable and the falling movement occurs in the stressed syllable, annotated with H+L*, without parentheses. However, both realizations are considered variants of the same nuclear accent (H+L*).

‡ (H+)L* LH% was considered the most frequent nuclear contour although the observed percentage of occurrence was low (28%). In Eva neutral yes-no questions were mainly produced with a falling-rising nuclear configuration (41%). However, in 28% of the sentences the falling movement starts before the stressed syllable, whereas in the other cases (13%) the falling movement occurs in the stressed syllable (H+L* LH%). As we mentioned in the note †, these differences in pitch alignment were quantified separately. However, they represent variants of the same nuclear falling pitch accent. Importantly, we also found 28% of all-falling nuclear contours – (H+)L* L% or L* L% - in Eva.

In Por and Alg, an all-rising nuclear contour (L*+H H%) was found, whereas in CtB a rising-falling pattern dominates (L+H* L%). Also important, the rising nuclear pitch accent exhibits a different alignment of the high tone across these three regions: in Por and Alg, the pitch is initially

low in the stressed syllable and then rises into the post-stressed syllable (Figure 6), whereas in CtB the rising contour starts in the pre-stressed syllable and the peak is attained in the stressed syllable (Figure 7).

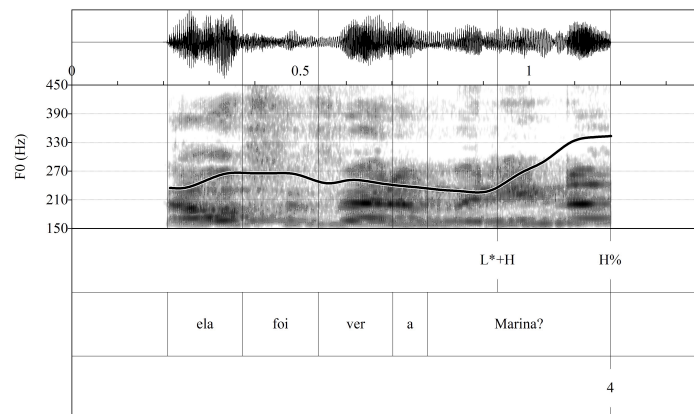


Figure 6. Reading task – yes-no question produced in Alg. *Ela foi ver a Marina?* ‘Has she gone to see Marina?’.

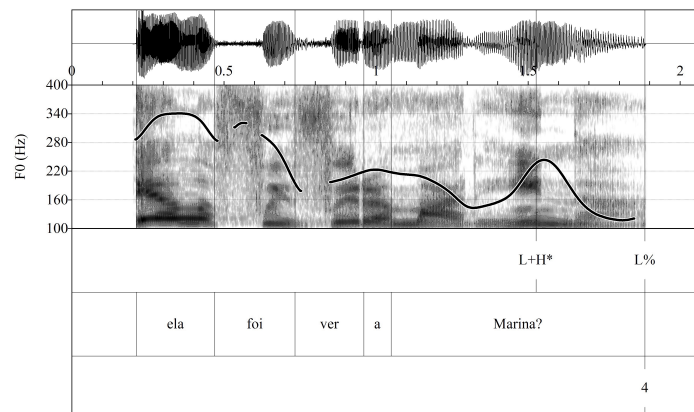


Figure 7. Reading task – yes-no question produced in CtB. *Ela foi ver a Marina?* ‘Has she gone to see Marina?’.

Most regions studied present more than one alternative contour (except SEP and Alg). The most frequent alternative contour was considered for the mapping of intonational variation (given the need to balance the amount of relevant information pictured and readability).

As shown in Table 1 above, in most regions the whole pitch configuration changes from the dominant to the alternative contour (in grey), following different directions: from a rising-falling to an all-rising nuclear contour in CtB; from a falling-rising to an all-rising contour in SEP; from a falling-rising to an all-falling contour in Eva; from an all-rising to a falling-rising contour in Ale.

Interestingly, geographically non-contiguous (and considerably distant) regions present similar intonational behaviors: (i) Bra and Ale show the same type of alternative contour, which corresponds to the dominant nuclear contour of the Standard variety of EP; (ii) Por and Alg present the same dominant (all-rising) and alternative (rising-falling) contours. Final falls, which had only appeared as part of the dominant nuclear configuration in one region, emerge as alternative contours in three (non-contiguous) regions.

In the DCT, information-seeking yes-no questions were mainly produced with the same dominant nuclear contour found in the reading task, i.e. low/falling nuclei and rising tonal boundaries, as illustrated in Figure 8 and Figure 9, which show similar nuclear patterns to Figures 4 and 5, respectively.

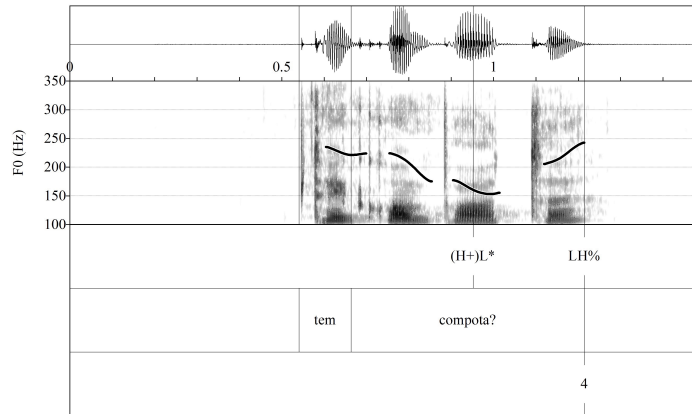


Figure 8. DCT – yes-no question produced in Bra. *Tem compota?* ‘Do you have jam?’.

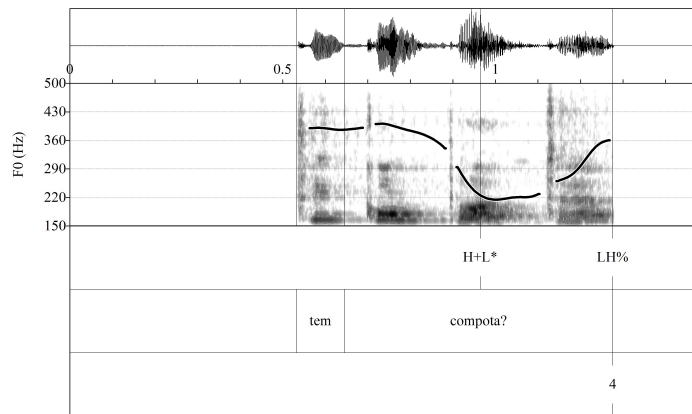


Figure 9. DCT – yes-no question produced in SEP. *Tem compota?* ‘Do you have jam?’.

Also, similarly to the results found in the reading task, in the DCT Por, CtB and Alg do not show the falling-rising pattern that dominates in the other regions (Table 2). In the two non-contiguous regions of Por and Alg,

the nuclear contour L*+H H% dominates, i.e. the same all-rising tune found in the reading task (see Table 1).

Urban area	Dominant contour	% of occurrence	Alternative contour	% of occurrence
Bra	(H+)L* LH%	64%	H+L* LH%	36%
Por	L*+H H%	60%	L*+H HL%	20%
CtB	H*+L L%	56%	H+L* LH%	25%
SEP	H+L* LH%	83%	H+L* L%	17%
Eva	(H+)L* LH%	26% †	H+L* LH%	21%
Ale	L* H%	67%	H+L* LH%	33%
Alg	L*+H H%	56%	H+L* L%	33%

Table 2. DCT – dominant and alternative nuclear contour types of information-seeking yes-no questions and their percentage of occurrence across EP urban areas.

† In Eva, we considered this tune as the dominant one since it is used across all speakers. We also found the nuclear contour characteristic from the Standard variety of EP (H+L* LH%), with a similar percentage of occurrence (21%), but only in two speakers. The all-falling nuclear contour found in the reading task also occurs in the DCT (H+L* L% or L* L%).

CtB is the only region where a difference across speech styles was found: in the DCT, the dominant nuclear contour of yes-no questions corresponds to a falling movement where the peak is realized in the stressed syllable and the pitch falls into the post-stressed syllable, followed by a low boundary tone (H*+L L%), as illustrated in Figure 10, which is different from the rising movement from the pre-stressed syllable into the stressed one, followed by a low boundary tone (L+H* L%) found in the reading task, as illustrated in Figure 7 above.

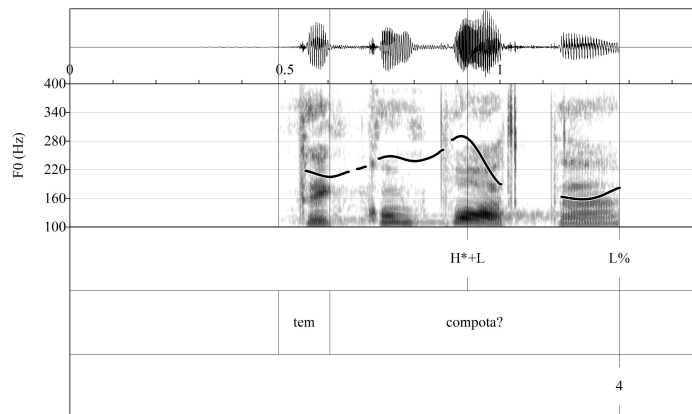


Figure 10. DCT – yes-no question produced in CtB. *Tem compota?* ‘Do you have jam?’.

As in the reading task, in the DCT we found more than one alternative contour in the production of information-seeking yes-no questions, with the exception of Bra, SEP and Ale (see Table 2 above, in grey). In Bra and Ale, the most frequent alternative contour is the same as the dominant contour observed in SEP (H+L* LH%). Interestingly, this is the most frequent alternative contour in the majority of the urban areas considered – Bra, CtB, Eva and Ale –, differently from the reading task, where only in Bra and Ale we found the main contour of SEP used as the alternative contour. This difference may be explained by the methodological nature of each task and its behavioral impact: in the reading task, the speaker reads the written sentences as they appear on a computer display, whereas in the DCT there is an interaction between the speaker and the interviewer, the latter being a native of the SEP variety. Therefore, in the DCT there may be a tendency to

accommodate the intonation to the interlocutor, although further work is needed in order to confirm this hypothesis and to understand the factors that may promote this switch from the native to the standard variety (Viaplana, 2002).

Our data also shows that in Por a rising-falling contour, and in SEP and Alg an all-falling contour may be used in the production of yes-no questions. As in the reading task, final falls emerge more frequently in alternative contours than in the dominant contours across regions. Por and Alg are thus the only exceptions to the production of the dominant contour of SEP as the alternative one. Interestingly, these regions present the same dominant contour in the DCT as in the reading task – an all-rising contour ($L^*+H\ H\%$) –, but only Por shows the same alternative contour in the DCT ($L^*+H\ HL\%$): only the boundary tone changes in Por, from a high boundary tone ($H\%$) in the dominant contour to a falling boundary tone ($HL\%$) in the alternative contour; in Alg, the whole pitch configuration changes, from a rising nuclear pitch accent (L^*+H) and a high boundary tone ($H\%$) in the dominant contour to a falling nuclear pitch accent ($H+L^*$) and a low boundary tone ($L\%$) in the alternative contour.

The results obtained from the analysis of both the dominant and alternative contours found in information-seeking yes-no questions in the seven regions were represented in two maps – one for the reading task (Figure 11) and the other for the DCT (Figure 12) – by using the Huff model as the spatial interaction method. These maps contain information about

four aspects: (i) the type of the dominant nuclear contour, given by color coding (grey color means low/falling pitch accents; orange and yellow code rising pitch accents); (ii) the sphere of influence of each dominant nuclear contour type, which is generated on the basis of the percentage of occurrence of each contour type; (iii) the type of alternative contour, given by the type/direction of stripes; (iv) and the weight of each alternative contour type, given by the weight of the stripes (lighter stripes represent a frequency of occurrence up to 25%; darker stripes represent a frequency of occurrence above 25%).

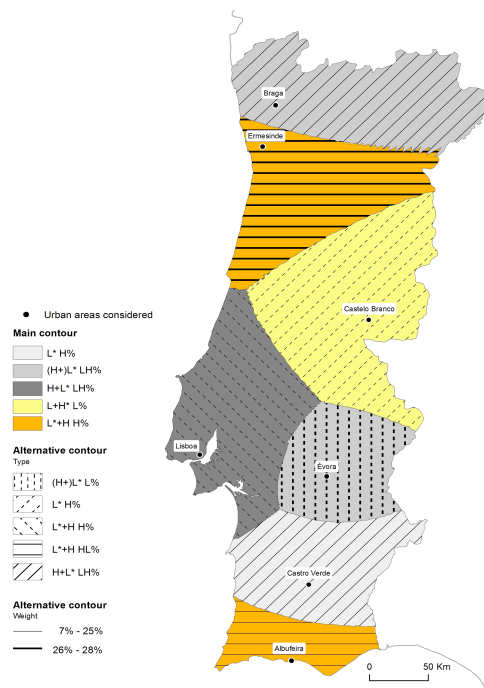


Figure 11. Reading task – geographic distribution of the dominant and the alternative nuclear contours of yes-no questions. Spatial interaction method used: Huff model.

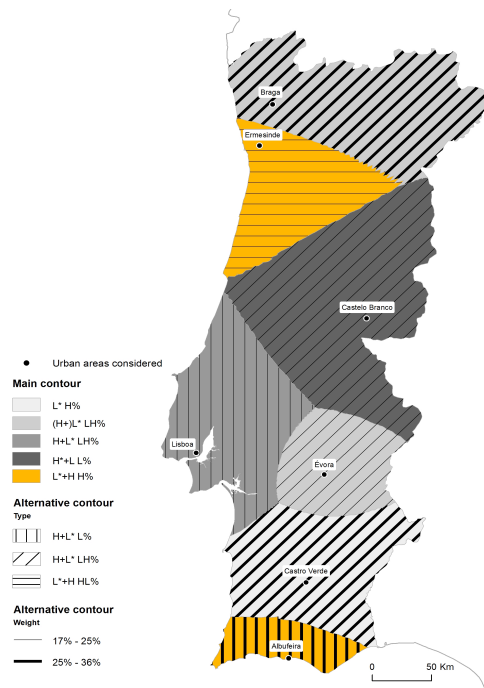


Figure 12. DCT – geographic distribution of the dominant and the alternative nuclear contours of yes-no questions. Spatial interaction method used: Huff model.

Figures 11 and 12 depict the mapping of all the information described above and provide a preliminary prosodic profile of a specific intonational property – the tunes of information-seeking yes-no questions used throughout the country, on the basis of 7 studied urban regions. By comparing the two maps, we can clearly identify a set of intonational similarities. First, the spheres of influence of the main contour for each region are similar across speech styles. Only a small difference in the spheres of influence of the dominant contours produced in Bra and Alg is observed, being larger in Bra and shorter in Alg in the DCT, when

compared to the correspondent spheres of influence predicted in the reading task. Second, grey colors dominate across speech styles, representing the low/falling nuclei followed by rising boundaries as the dominant nuclear contour. Por and Alg show all-rising contours in both speech styles, represented in orange. Third, in Bra, Por and Ale, the most frequent alternative contour is the same across speech styles (H+L* LH% in Bra and Ale; L*+H HL% in Por), although with different weights. Forth, only few differences were found across speech styles: (i) CtB is the only region presenting a difference in the type of dominant nuclear contour across speech styles; (ii) the nuclear contour of SEP (H+L* LH%) is the most used alternative contour in the DCT, but not in the reading task. Importantly, Figures 11 and 12 clearly show that intonational variation has a non-contiguous nature.

5.2. *Rhythm*

A comparative analysis between SEP and BP and the eight languages studied in Ramus, Nespor & Mehler (1999) lead Frota & Vigário (2000, 2001) to the conclusion that the SEP variety clusters with stress-timed languages in the ΔC dimension and with syllable-timed languages in the %V dimension, whereas BP is closer to syllable-timed languages in the ΔC dimension and to mora-timed languages in the %V dimension, thus presenting a mixed rhythm. The authors added that these results are clearly

related to phonetic-phonological phenomena, such as vowel reduction in SEP (and the consequent increase of consonantal sequences of variable duration) and vowel epenthesis in BP (which breaks consonant clusters and promotes CV sequences). Perceptual experiments were carried out in order to confirm the results obtained from production data (Frota, Vigário & Martins, 2002a, b). Among the perception results, we highlight the fact that SEP is discriminated from Dutch, a typical stress-timed language, showing that the most important dimension for the perception of rhythm is %V and not consonantal variability.

Adding to the knowledge of rhythmic variation in EP, Cruz (2013) and Cruz & Frota (2014) analyzed the rhythmic properties of two central-southern varieties (Ale and Alg). Following the methods of Frota & Vigário (2000, 2001), and Frota, Vigário & Martins, 2002a, b), the authors concluded that Ale presents a mixed rhythm, as in SEP, clustering with stress-timed languages in the ΔC dimension and with syllable-timed languages in the %V dimension, whereas Alg presents stronger stress-timing properties. Additionally, Cruz (2013) and Cruz & Frota (2014) suggested that EP exhibits more stress-timed properties towards the southern varieties. However, the authors highlighted that more EP varieties need to be studied, especially northern varieties, to establish whether this drift towards stress-timing in the South is supported or not.

In the present research we used the data from Frota & Vigário (2000, 2001) for SEP and the data from Cruz (2013) and Cruz & Frota (2014) for

Ale and Alg. However, these analyses of Ale and Alg were only based on the corpus of Ramus, Nespó & Mehler (1999). The comparative corpus of Frota & Vigário (2001) was not analyzed for the two central-southern varieties. In order to provide a more geographically broad characterization of rhythmic variation in EP, thus complementing the results of previous studies and filling the gap in the characterization of rhythm in varieties spoken in the north of the country, we analyzed four new regions – Bra and Por in the northern varieties, CtB in the transition between the northern and the central-southern varieties, and Eva in the central-southern varieties, but geographically located above Ale, thus closer to SEP. We have also enriched the analysis of Ale and Alg, by including materials, from the comparative corpus used in Frota & Vigário (2001), for each region.

Following the methodology described in section 4, we calculated the average values of rhythmic variables for the two corpora (all materials included). Based on previous studies on the rhythmic properties of Portuguese, %V and $\Delta\%C$ were considered for the rhythmic classification of the seven urban regions analyzed. As reference values for this classification, we selected the %V value of Dutch (42,5), identified by Ramus, Nespó & Mehler (1999) as being a clear stress-timed language, and the $\Delta\%C$ value of SEP (2,6), also clearly pointing to stress-timing properties in the dimension of consonantal variability (Frota & Vigário, 2001; Frota, Vigário & Martins, 2002a, b). In this sense, higher values than 42,5 for %V mean syllable-timed varieties, whereas values around 42,5 and lower for

%V point to stress-timed varieties. As for $\Delta\%C$, lower values than 2,6 mean syllable-timing properties, whereas values around 2,6 or higher point to stress-timed varieties.

The results for EP varieties are given in Table 3. Based on both the %V and $\Delta\%C$ values, we concluded that four regions present mixed rhythmic properties (Bra, Por, SEP, and Ale) and three regions are more stress-timed.

Urban area	%V	$\Delta\%C$	Rhythm class
Bra	43,2	3,0	Mixed
Por	43,4	2,8	Mixed
CtB	39,9	2,8	Stress-timed
SEP	46,6	2,6	Mixed
Eva	40,1	2,8	Stress-timed
Ale	46,0	2,8	Mixed
Alg	38,6	2,9	Stress-timed

Table 3. Rhythmic properties of seven urban areas (average values of two corpora), based on the measures of %V and $\Delta\%C$ (Frota & Vigário, 2001).

Data for SEP were extracted from Frota & Vigário (2001).

The challenge of mapping rhythmic variation lies precisely in the difficulty of representing the articulation between two quantitative variables. Consequently, before running the spatial interpolation method selected – the *Inverse Distance Weight* method (see section 3) – an index was manually calculated in order to convert two independent variables into a single one. For the calculation of the index, which was obtained first by assigning a number below or above 1 to each absolute value of %V and $\Delta\%C$ and after

by calculating the product of the two numbers, the reference values for %V and $\Delta\%C$ were considered as equal to 1, and the relative weight of each variable on the rhythmic classification of each language/variety was encoded with %V having more weight than $\Delta\%C$ due to its larger range below and above 1. Then, the index obtained for each region was computed using the *IDW* method, providing the mapping illustrated in Figure 13. In Figure 13, rhythm classes are represented in a scale from syllable-timing properties (signaled by yellow color) to stress-timing properties (in blue). The greenish color shades are the intermediate zone in the color spectrum, thus covering regions that are neither clearly stress-timed nor clearly syllable-timed.

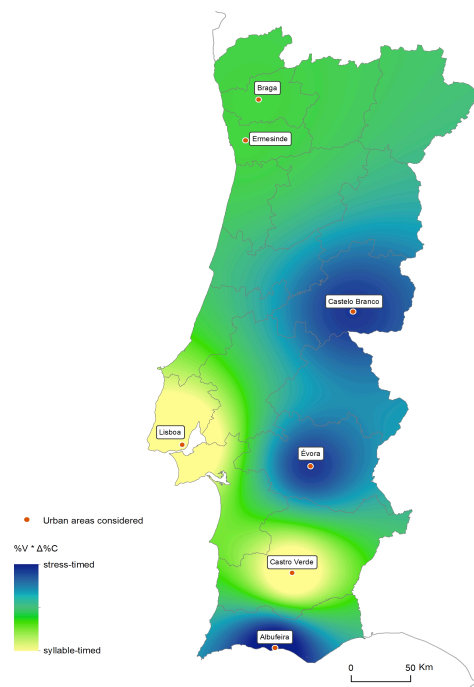


Figure 13. Rhythmic variation in European Portuguese, on the basis of two quantitative measures (%V and $\Delta\%C$) calculated for seven urban regions,

labeled in the map. Spatial interpolation method used: *Inverse Distance Weight* method.

From Figure 13 we can conclude that interior regions from the Centre-South are more stress-timed, whereas coastal regions from the north-centre display mixed rhythm properties. Moreover, the southern coast in the extreme South is stress-timed. In contrast, the Lisbon area, together with Ale, exhibits syllable-timing properties. Comparing Figure 13 with the results in Table 3, we can conclude that the representation of rhythm in Figure 13 is more fine-grained: Bra, Por, SEP and Ale were all classified as having mixed rhythmic properties in Table 3, but within these mixed varieties, two of them are clearly more syllable-timed (SEP and Ale, in yellow), whereas the other two are less syllable-timed (Bra and Por, in green).

These differences within mixed varieties become clear when we look at the values in Table 3. Although Por and Ale display the same value for $\Delta\%C$ (2,8), they differ in the $\%V$ dimension, with Por being less syllable-timed than Ale (43,4 *contra* 46,0, respectively). Inversely, SEP and Ale present different values in the $\Delta\%C$ (2,6 *contra* 2,8, respectively), but they are similar in the $\%V$ dimension (46,6 for SEP; 46,0 for Ale), and they are both considered syllable-timed varieties. This reflects the articulation between the two rhythmic variables as computed in the index, where more weight was given to $\%V$ similarly to previous studies, showing that the

proportion of vocalic intervals is more relevant than consonantal variability for the rhythmic characterization of Portuguese varieties (Frota, Vigário & Martins, 2002a, b). Building on this insight, it could be asked whether %V would not be sufficient for mapping rhythmic variation. Thus, we applied the *IDW* mapping method to %V values only, instead of using the index. The result is shown in Figure 14.

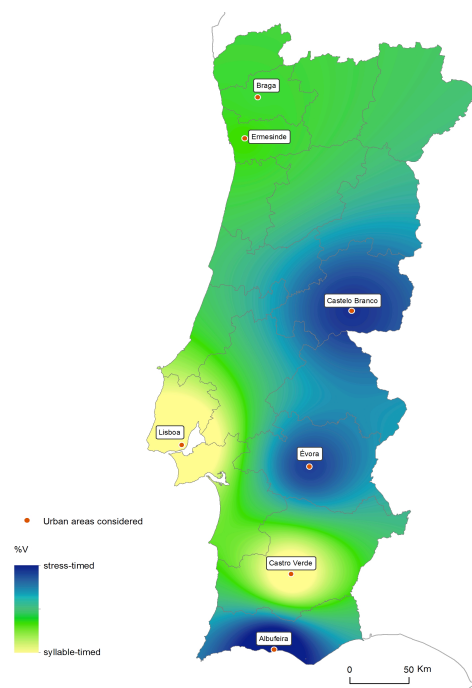


Figure 14. Rhythmic variation in European Portuguese, on the basis of one quantitative measure (%V) calculated for seven urban regions, labeled in the map. Spatial interpolation method used: *Inverse Distance Weight* method.

By comparing the maps in Figures 13 and 14, we can conclude that they are quite similar. %V does indeed seem sufficient to map rhythmic variation, as the geographical distribution of rhythmic properties throughout

the country is nearly the same for both known and unknown data points. However, we must emphasize that we have analyzed few geographical points and that, although the *IDW* is considered a robust method and the most adequate for small samples, more data is needed in order to test whether one rhythmic variable (%V) is enough to accurately account for rhythm similarities and differences across EP varieties.

In sum, we have shown that spatial interaction models and spatial interpolation methods are an important tool for prosodic variation (and linguistic variation in general), that allows a representation of the distribution of a given linguistic property, and provides a proposal towards the definition of dialectal areas. Differently from traditional methods, these models, being probabilistic, make predictions about the linguistic features of unstudied points, thus contributing to a global knowledge of different aspects (in the present case, intonation and rhythm) of linguistic variation. This is certainly one of the advantages of such methods, as exhaustive geographical coverage is usually not possible. Equally important is the fact that these predictions can be tested under the collection and analysis of additional data points. The innovative application of these models and methods to our data on intonational variation of information-seeking yes-no questions clearly points to a non-contiguous distribution of intonational features, which was not observed for segmental (Segura & Saramago, 2001) or syntactic (Carrilho & Pereira, 2011, 2012) variation. A similar result has

been found in other cross-variety studies, as in Savino (2012) for Italian varieties or Frota et al. (2015) for Brazilian Portuguese varieties. Thus recent studies provide growing evidence that the distribution of intonation features is independent of geography and usually does not match the regional areas defined on the basis of non-prosodic variation. Rhythmic variation, however, although still not strictly contiguous, seems to have a distribution closer to geography. This could be due to the nature of rhythmic features, which can be seen to reflect an array of phenomena, segmental phenomena included. However, it is too soon to draw any definitive conclusions on the possible differences between intonational and rhythmic variation, since to better understand the latter we need to include in our model additional data points, especially for the Center-Southern varieties area, and to develop a comparative study of the segmental facts that promote rhythmic differences (e.g., vowel reduction, vowel deletion, epenthesis), alongside the study of other prosodic features (such as pitch accent distribution or final lengthening).

6. Building a prosodic profile of European Portuguese varieties

With the main goal of mapping prosodic variation in EP, we analyzed the intonational and rhythmic properties of seven urban locations. In addition, for intonation two different speech styles were considered. The results from

these analyses fed the models of spatial interaction and interpolation used to obtain a mapping of prosodic variation in EP.

The prosodic profile of EP varieties, on the basis of our main findings on the intonation of information-seeking yes-no questions and the rhythmic properties obtained with the acoustic metrics of Ramus, Nespor & Mehler (1999) and of Frota & Vigário (2000, 2001) has the following features: (i) the dominant contour of yes-no questions is globally the same across regions and speech styles (low/falling nuclei followed by rising boundary tones); (ii) three regions (Por, CtB and Alg) do not show the falling-rising pattern that dominates in other regions, but either an all-rising pattern ($L^*+H\ H\%$, in Por and Alg) or a pattern with a final low tone ($L\%$, in CtB); (iii) the most frequent alternative contour corresponds to the dominant contour found in SEP ($H+L^* \ LH\%$); (iv) final falls emerge more frequently in alternative contours than in dominant contours, across regions and speech styles; (v) rhythmically, the Lisbon area, together with Ale, exhibits syllable-timing properties, the interior regions in the center-south are more stress-timed (with the prominent exception of Ale), coastal regions in the north-center are less stress-timed, and the southern coast in the extreme South is stress-timed. Importantly, prosodic features show a non-contiguous distribution and do not point to the regional areas previously defined on the basis of segmental or syntactic variation.

This prosodic profile is necessarily preliminary as a first attempt to map prosodic variation in EP and much further work needs to be done

before a fully accurate geographical representation of prosodic variation in EP can be achieved. In our view, the following avenues should be explored in future research. Additional data and more geo points need to be included in the models to test their predictions and assess their robustness. The predictions should be validated by means of mathematical/statistical methods (hit rate, error rate, standard deviation, sensitivity scores, measures of distance, *inter alia*), as well as by perception experiments (Maguire & McMahon, 2011), or by comparing the results obtained with different procedures (e.g., with the results from the traditional dialectological approach or even with the results from other quantificational approaches) (Heeringa, Nerbonne & Kleiweg, 2002; Heeringa, 2004). Moreover, we have to decide which and how many variables should be considered in the mapping process within each prosodic dimension. For this decision, we have to weigh the gains and losses of having (or not) different layers (e.g., dominant and alternative contours) for one single variable (intonation of yes-no questions). Among the several prosodic dimensions that characterize the prosodic system of a given language (namely, phrasing, intonation, rhythm and stress), we need to understand which one(s) is(are) the most relevant to characterize prosodic variation within the language. Last but not least, it is crucial to test the geographical representation of clusters of prosodic features, although it is already known that prosodic features may vary independently from one another (Hyman, 2012; Frota, Vigário, Galves, Gonzalez-Lopez & Abaurre, 2012).

The exploration of these lines of research will allow a thorough discussion of the non-contiguity of prosodic variation and of how it may relate to segmental, lexical or syntactic variation. Although much work still needs to be done, we believe that our main goal of mapping prosodic variation by testing the possibilities offered by GIS and spatial analysis tools was attained. We are now equipped with more powerful tools to analyze spatial data, and thus prepared to move forward into further explorations.

Acknowledgements

The present research was developed within the Project *InAPoP – Interactive Atlas of the Prosody of Portuguese* (PTDC/CLE-LIN/119787/2010), funded by Fundação para a Ciência e a Tecnologia/MCTES (PIDDAC). We are grateful to Joelma Castelo for a preliminary intonational analysis of yes-no questions in some of the regions covered, to Nuno Paulino and Nádia Barros for the data pre-processing, and to Marina Vigário for comments in different stages of this work. We thank the participants of the *First Workshop of the project Interactive Atlas of the Prosody of Portuguese*, held in Lisbon in 2013, where we first presented the use of GIS to map prosodic variation in EP. We also thank Celeste Rodrigues and all the participants of the *I International Symposium on Variation in Portuguese*, held in Braga in 2014, for their comments and suggestions on a first version of the present work.

Last but not least, we thank the anonymous reviewers for their comments and suggestions, and Joseph Butler for the final revision of the text.

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