A comparative account of the suprasegmental and rhythmic features of British English dialects

Emmanuel Ferragne, François Pellegrino

Laboratoire Dynamique Du Langage (UMR CNRS 5596)
14 avenue Berthelot – 69363 LYON CEDEX 07
Emmanuel.Ferragne@univ-lyon2.fr
François.Pellegrino@univ-lyon2.fr

ABSTRACT

This research seeks to establish an inventory of the suprasegmental acoustic cues that are relevant to the automatic typology and identification of the dialects of British English. Using evidence from traditional dialectology suggesting that the dialects of the British Isles exhibit differences at the suprasegmental level – and, in particular, in terms of *rhythm* – we apply procedures that have been successful for inter-language purposes. This preliminary report focuses on durational features and vowel reduction (centralization). We show that the dialects of the Celtic countries (especially Ireland) are singled out on the basis of their durational features. The overall pattern for vowel reduction reveals a difference across genders, not dialects.

1. INTRODUCTION

While arguments for carrying out research in the field of automatic *language* identification can quite easily be found, the layman may perceive *dialect* identification and the modelling of dialectal pronunciation as no more than just another linguist's – or engineer's – game without real-world applications. This probably stems from the fact that some people – involuntarily – have so coarse a view of communication acts that they generally accept that once the obstacle of mutual intelligibility has been overcome (e.g. in multilingual contexts), there is no reason why one should bother to undertake more fine-grained analysis. However, it is indisputable that knowledge of dialect variation improves the performance of speech recognition systems. And it may sometimes be desirable to generate dialect speech synthesis, for instance, for the sake of user-friendliness. Besides, phonetic studies of dialects also have forensic applications [5].

2. A BRIEF HISTORICAL OVERVIEW

Pike [19] coined the terms *stress-timed* and *syllable-timed* while inventing a new system for teaching the intonation of English to Latin-Americans in the 1940s; ever since then, a wealth of studies have been devoted to trying and capture acoustic evidence in support of the impression that the world's languages belong to either of two rhythm classes. Some twenty years later, Abercrombie's [1] more in-depth account of the phenomenon provided new impetus for multilingual comparisons, but it would be inaccurate to state that concerns about rhythm in phonetics only date back to the middle of twentieth century.

As far as English is concerned, many grammars and treatises on poetry from the 16th century onwards [8], [20] have addressed the issue of what we now call *rhythm*. Although most of them concentrate on verse and therefore provide the reader with highly prescriptive accounts while trying to force the Greek and Latin models onto the English tongue, the idea that English rhythm is best described as an alternation of strong and weak – or long and short – syllables clearly appeared during this period. Notable among these writers is Steele [23], who can to a certain extent be said to have introduced and developed the notion of isochrony: stresses tend to recur at regular intervals.

Nowadays, several studies (e.g [2]) have proved that objective isochrony simply does not exist. Yet, given that in English – a prototypical stress-timed language – the duration of root vowels tend to shrink as the number of appended suffixes increases, we may hypothesize – for want of any better reason why this phenomenon should occur – that isochrony is actually desired on the perceptual level. Current research focuses on varying syllable complexity and vowel (durational) reduction as correlates of speech rhythm. The procedures that have been used so far – and will be employed in this study, with slight improvements – are discussed below.

3. DURATION

3.1 Background and hypothesis

Duration modelling has been shown to improve the accuracy of language ID systems [22]. And it is duration that has often been thought to be the most relevant correlate of perceived speech rhythm, although there is undoubtedly more to rhythm than mere duration. The metrics popularized by [21] and [10], and used in a multilingual framework, yielded results that were consistent with linguistic typologies (i.e. languages belonging to the same rhythm class tend to cluster together), which suggests that these metrics do capture part of speech rhythm. They actually measure the features that had been found to be responsible for a difference in "phonic impression" between German and

English, on the one hand, and Spanish and French on the other by [3], i.e syllable structure and vowel reduction. [21] used the percentage of vocalic duration (%V) and the standard deviation of consonantal intervals (ΔC) over a whole utterance: a low %V and a high ΔC indicate that the language under study is stress-timed. The Pairwise Variability Index (PVI, [10]) measures the average difference in duration between two successive intervals of the same type (vocalic or consonantal). A high vocalic PVI means that the duration of successive vowels varies greatly (often due to vowel reduction and contrastive vowel length [phonological quantity]) and a high consonantal PVI indicates that syllabic structures are of varying complexity, which, in combination, suggest that the language is stress-timed.

Although normalization procedures for speech rate [1] have been proposed in [10], little was known, until very recently, about the robustness of these metrics under various speech rate conditions. One of the weaknesses of ΔC lies in the fact that it ignores the temporal organization of speech. Suppose a sentence begins very slowly and ends at a very fast tempo: ΔC will be high, suggesting that the language is stress-timed, even if it is not, whereas consonantal PVI will capture the sequential information and yield more suitable results. Earlier studies (reviewed in [12]) suggest that when speech rate increases, consonant duration is relatively less reduced than vowel duration; we may therefore infer that, for instance, %V would be lower with increased speech rate. In addition, under fast speech rate, the duration of stressed syllables is comparatively less reduced than that of unstressed syllables, which means, for English, that stress-timing may be more conspicuous at higher tempo. [4] tested whether tempo had an effect on %V and ΔC under five tempo conditions ranging from very slow to very fast. The general pattern for English suggests that ΔC is far more affected by speech rate than %V. Besides, contrary to what has just been said, %V and speech rate were positively correlated and stress-timing – assuming that %V and ΔC are appropriate metrics – is less marked at high tempo.

In 1982, [24] noted that the dialects of English possessed distinctive rhythmic patterns and that empirical work was awaited to shed light on this matter. His description contains several observations that led us to believe that our metrics might well capture rhythmic variation in the British Isles. Some dialects in the Celtic countries are known to make limited use – if any – of phonological vowel length. However, note that, as the result of the Scottish Vowel Length Rule (or Aitken's law), vowels are lengthened before /r/, voiced fricatives and morpheme boundaries.

[1] "speech rate" and "tempo" are used as synonyms in this paper.

3.2 Method

Material We investigate the so-called "sailor passage" of the Accents of the British Isles (ABI)[a] corpus. The corpus comprises recordings of about 20 speakers (10 male, 10 female) from 14 regions [b] throughout the British Isles; i.e. 284 speakers in all. The passage is a read text which was designed to elicit dialectal variation. It contains approximately 430 syllables, so that makes over 120,000 syllables for all dialects.

Segmentation The speech signal was automatically segmented into vowels, consonants, and pauses (see [17] for a thorough description of the algorithms). Whenever two or more segments of the same type occurred adjacently, they were merged into one single vocalic or consonantal interval. One excerpt containing approximately 40 syllables was also manually segmented into vocalic and consonantal intervals for every speaker in order to compare manual and automatic segmentation.

Quite a few borderline cases occur in English and it often fell to the transcriber arbitrarily to decide where to place boundaries. For instance, in many accents postvocalic /l/ is velarized (as in Standard English, but not in the two accents of Ireland in our corpus) – or changed into a vowel – and it is therefore rather difficult to tell where the preceding vowel stops and where the /l/ begins, as in the word *tools*. When sharp changes in amplitude or in the formant structure could be observed, then a boundary was inserted. But the formants trajectories often altered smoothly and so did the amplitude; in such cases, a boundary was placed at midpoint between /t/ and /s/. Whenever syllabic consonants were found – i.e. not in all dialects – as in *stabLe* and *coNditioN*, they were treated as vowels. Rhoticity also posed problems: the realization of orthographic word-final <r> across dialects ranges from nothing to a full apical approximant with many degrees of r-colouredness between these polarities. Since a decision as to where the vowel stops and were the /r/ begins and whether a full approximant or a simply r-coloured vowel occurs is hard to make, word-final /r/ were merged with the preceding vowel to make a vocalic interval except in cases where no doubt was possible as to the location of the boundary.

Moreover, some artefacts were deliberately added during manual segmentation: it so happened that some syllabic nuclei were realized as friction noise (e.g. *insTRUments*): in order to mark the existence of a syllable here (for subsequent estimation of speech rate) and to avoid an unusually long consonantal interval, a vocalic interval was inserted. These decisions are expected to add discrepancies between the manual and the automatic procedure.

Women tended to have clearer enunciation than men in all dialects resulting in more difficulties for the segmentation of male subjects due to heavy coarticulation (see [11] for an overview of some sociolinguistic elements).

Computation The following indices were computed:

meanV: mean duration of vocalic intervals

meanC: mean duration of consonantal intervals

%V: percentage of vocalic duration over the whole passage

ΔC: standard deviation of consonantal interval duration

ΔV: standard deviation of vocalic interval duration

varcoC: ΔC expressed as a fraction of mean consonantal interval duration

varcoV: ΔV expressed as a fraction of mean vocalic interval duration

mean_rpviv: mean difference in duration between all pairs of consecutive vocalic intervals (the <r> stands for "raw")

mean_npviv: same as above except that the duration difference for each pair is divided by the sum of the duration of the two vocalic intervals (the <n> stands for "normalized")

$$mean\_npviv = \sum_{i=1}^{n-1} \frac{1}{n-1} \times \frac{|d_i - d_{i+1}|}{d_i + d_{i+1}}$$

med_rpviv and med_npviv: same as previous two, except that the median, instead of the mean, is used

the consonantal counterparts of the PVI measures just mentioned were also computed

SR: speech rate in syllables per second.

3.3 Results

In order to check to what extent the values obtained with manual segmentation (dependent variable) can be predicted by automatic segmentation (predictor), a series of linear regression analyses were performed. The results are summarized in Table 1. The automatic procedure fails to predict the values for the following metrics: ΔV, varcoV, mean_npviv, and med_npviv. The best prediction is achieved for speech rate. Given that most scores for manual segmentation are poorly predicted by automatic segmentation, all the results discussed below are based on hand segmentation.

[4] found that the same *objective* speech rate in syllables per second may correspond to different *intended* speech rates depending on the language. We can perhaps expect that speech rate is sociolinguistically conditioned and may therefore constitute a discriminant feature. To test the hypothesis whether SR is dialect specific – in which case normalization might erase important information – a non-parametric one-way analysis of variance (Kruskal-Wallis) was computed to compare mean SR across dialects. The results suggest that tempo may be dialect-specific (*KW* = 59.17; *df* = 283; $p < 0.001$).

TABLE 1 – *Results of the regression between values from automatic (independent variable) and manual (dependent variable) segmentation.*

metric	r squared	F ratio	p value
meanV	0.087	26.52	0.00001
%V	0.023	6.7	0.01
ΔV	0.008	2.15	*0.14*
varcoV	0.008	2.19	*0.14*
meanC	0.26	96.75	0.00001
ΔC	0.156	54.2	0.00001
varcoC	0.046	13.3	0.0003
mean_rpviv	0.025	7.24	0.0075
mean_rpvic	0.15	50.61	0.00001
mean_npviv	0.0001	0.04	*0.84*
mean_npvic	0.023	6.67	0.01
med_rpviv	0.056	17.18	0.00001
med_rpvic	0.095	29.39	0.00001
med_npviv	0.0003	0.09	*0.76*
med_npvic	0.024	7.04	0.008
speech rate	0.315	128.39	0.00001

A Kruskal-Wallis one-way analysis of variance was used to test hypothetical differences for the other parameters. Except for med_npviv, all *p* values fall below 0.001. The greatest value for the Kruskall-Wallis statistic is reached with ΔV. Post hoc Dunnett T3 tests were then performed. In order be consistent with our hypotheses, we focus on vocalic durational features. Table 2 shows a matrix where pairs of dialects that achieve statistical difference for each parameter can be identified. For the metrics that have a *raw* and a *normalized* version, only the one with the higher Kruskall-Wallis value was considered. Figure 1 plots the means and confidence interval bars for the mean at the 99% level for each dialect on the ΔV dimension (i.e. the most discriminatory one). *Uls* is clearly singled out; its distribution only overlaps that of *roi*. It is noticeable that the dialects of the Celtic countries (except for Wales) exhibit the lowest values.

TABLE 2 – *Post hoc Dunnett T3(significance level: 0.01; x: meanV; Δ: ΔV; %: %V; p: mean_rpviv).*

	brm	crn	ean	eyk	gla	ilo	lan	lvp	ncl	nwa	roi	shl	sse	uls
brm											Δ			Δ p
crn				p			%							Δ
ean											Δ p			Δ p
eyk		p									x Δ p	p		x % Δ p
gla											p			Δ p
ilo											x Δ p	Δ		x % Δ p
lan		%									x Δ			x Δ p
lvp											x Δ p			x % Δ p
ncl											x Δ p	Δ		x Δ p
nwa											Δ p			Δ p
roi	Δ		Δ p	x Δ p	p	x Δ p	x Δ	x Δ p	x Δ p	Δ p				
shl				p		Δ								Δ
sse														Δ
uls	Δ p	Δ	% Δ p	x Δ p	% Δ p	x % Δ p	x % Δ p	x Δ p	x % Δ p	Δ p		Δ	Δ	

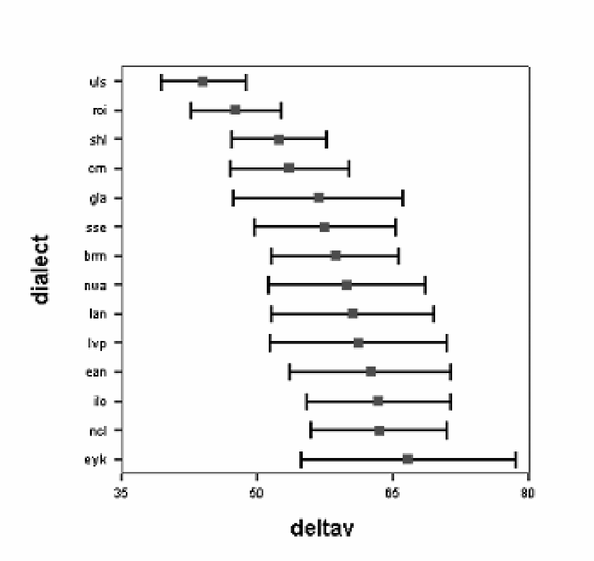

FIGURE. 1 – *ΔV: mean and 99% confidence interval of the mean for each dialect (see endnote).*

4. VOWEL REDUCTION

4.1 Background and hypothesis

In phonological, generativist parlance, vowel reduction occurs when an underlying vocalic phoneme surfaces as a mid-central vowel, mainly because it appears in an unstressed syllable. Physical correlates of this phenomenon are centralization on an F1/F2 plane and durational reduction. There is evidence that not all British dialects use vowel reduction in the same way: for instance, some Scottish dialects are known to retain full vowels in some unstressed prefixes, which gives an impression of "unusual accentuation" for the Southern British ear [9]. [24] reports the same phenomenon in some Northern English dialects. Similarly, Welsh English tends to avoid centralization of unstressed vowels in word-final checked syllables. This can be termed resistance to phonological vowel reduction. But in addition to this, even when a vowel undergoes phonological reduction, it is realized, in some Scottish dialects, as a less central phone than in some other British dialects ([24], commA and lettER lexical sets). We therefore predict that our Scottish dialects should exhibit a relatively low concentration of vowels around the centroid on an F1/F2 plane. [13] carried out the same type of study to highlight the rhythmic differences between Taiwan English and American English. Her vowels were manually labelled as stressed and unstressed. Her results show that the dispersion of phonologically reducible vowels in Taiwan English overlap that of unreduced vowels whereas unreduced vowels in American English are more peripheral.

Gauging these differences with unlabelled data is particularly difficult since we must rely on a crude measure of overall "centrality" in the vowel space and several spurious factors come into play. Probably the most conspicuous one is phonetic vowel reduction – i.e. centralization that is not brought about by phonological reduction – which occurs when the articulators fail to reach the target they would have reached, had the word been uttered as a citation form. This may be due to free idiosyncratic variation or speaking style. Early literature on the subject (reviewed in [15]) seems to indicate that, in English, phonetic vowel reduction correlates with degree of stress, speech rate, and consonantal context. Quite unexpectedly, [7], in a study on American English, found that tempo had no centralizing effect on individual formant trajectories; however an increase in tempo caused the vowel space to shrink by 30 %. Surprisingly, some vowels in his study moved further away from the central point in the fast tempo condition.

Lexical incidence and the actual phonological inventory of a given dialect (e.g. the Northern use of /ʊ/ for /ʌ/ in words like <bus> creates more tokens of a vowel further from the centroid) [2] are factors that cannot really be controlled for when one automatically calculates distances from the centroid of the vowel space.

Another important factor is sociolinguistic variation: [16] found that lower-class social groups used a more retracted and lowered variant of the KIT vowel than their higher class counterparts in Glasgow. What is more, even with a socially well-balanced corpus (we unfortunately have no means of knowing this in the ABI database), the bias would very likely be dialect-dependent. However, given that unstressed vowels are far more frequent in English than stressed vowels, we can perhaps rely on a long-term frequency effect to play down the noise caused by variations in lexical incidence, phonemic inventory differences, and sociolinguistic variation affecting non schwa vowels.

4.2 Method

Segmentation For this part of the study, only the hand segmented portion of the corpus was used. In all, 11183 vocalic intervals were measured (39 per speaker on average).

Computation F1 and F2 values in Bark at temporal midpoint for all the vowels were obtained with the Praat software. Normalization for gender was achieved by subtracting 1 Bark from F1 and F2 in women [11]. For each speaker, we computed the position of the F1/F2 centroid and the unweighted Euclidean distance between each vowel and the centroid. Whenever the distance between a token and the centroid was above the 95^{th} percentile, the token was removed and new values for the centroid and the individual distances

[2] These symbols – as is often the case when we adopt a phonemic view – do not reflect actual realizations and are used as standard conventions by British phoneticians.

were calculated. Each distance in a given speaker was divided by the greatest distance observed for this speaker as a means to normalize for differences in vowel space size across speakers. Then the mean distance, the mean normalized distance, the standard deviation of normalized distances, and the skewness of normalized distances for each speaker were computed. The latter two will be interpreted as measures of centralization.

4.3 Results

A two-way ANOVA was computed with factors "gender" and "dialect" and the skewness of normalized distances as the independent variable. The results show that main effects for gender (F = 105.24, df = 1, p < 0.0001) and dialect (F = 2.93, df = 13, p < 0.001) are both significant. The two-way interaction (gender × dialect) is only significant at the 0.05 level (F = 1.85, df = 13). Post hoc Tukey tests show differences between *sse* and *eyk*, *gla*, *lan* at the 0.05 level. The distribution of normalized distances to the centroid for each vowel token is shown in Figure 2 and 3, for women and men respectively. The superimposed normal curve is meant to highlight the different skewness (men: 0.503; women: 1.108) across genders

The procedure was repeated with the standard deviation of normalized distances. Main effects for dialect and gender are significant (F = 3.374, df = 13, p < 0.0001; F = 10.87; p < 0.001, respectively). The gender × dialect interaction is non significant (F = 1.33, df = 13, p = 0.19). The only post hoc difference relevant to our hypothesis is between *sse* and *gla* (p < 0.05).

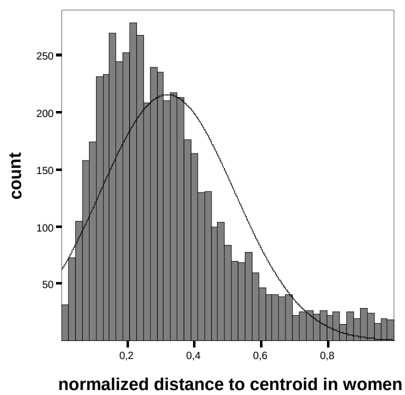

FIGURE 2 – *Distribution of normalized (fraction of greatest distance for each speaker) distance to centroid in women.*

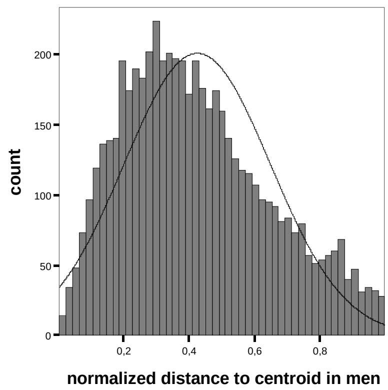

FIGURE 3 – *Distribution of normalized (fraction of greatest distance for each speaker) distance to centroid in men.*

5. DISCUSSION

In the first part of the study, we found that the algorithm for automatic segmentation performs rather poorly when it comes to estimating vowel and consonant duration. However, it allows a reasonable estimate of SR from the output of vowel detection, which accords with a previous study aimed at testing automatic SR estimation on several languages [18]. It must however be remembered that many syllable nuclei in English are consonantal.

The durational features extracted here from a forty-syllable excerpt in 14 dialects support our hypothesis: if the perceived distinctive rhythm of the Celtic countries results from differences in stressing habits (degree of stress) and phonological vowel length, which in turn bring about relatively small durational reduction and relatively low dispersion in the distribution of vowel duration, then our metrics seem to capture at least part of this phenomenon. In [6], we used mean_npviv obtained after automatic segmentation and found that the lowest values were those of the two dialects of Scotland in our database: *shl* and *gla*. This time, the two Irish dialects, *uls* and *roi*, had the lowest values with the former clearly standing apart from the other 12 (once *roi* has been excluded).

Concerning the metrics, ΔV had the highest between-dialect variance/within-dialect variance ratio. As expected, varcoV had a lower such ratio because it factors out SR, the latter having been shown to vary across dialects. We unfortunately have no theoretical argument to put forward in order to explain this SR difference, especially given that the material under investigation is a read text, and not spontaneous speech. As a tentative answer, we can only suggest that unbalance in literacy, or age, as attested by auditory inspection, may have influenced SR. Besides, individual variation in speaking style – some speakers adopted a somewhat theatrical elocution, which the sailor passage is prone to induce – may be more salient in some dialects. It is therefore our impression that varcoV is probably a better metric for our purposes. As for %V, in our case, it is a little too sensitive to the procedure adopted for the segmentation, i.e. *uls* has the lowest value not only because of dialect specific characteristics, but also because it was easier in this dialect (among a few others) to tell a postvocalic /r/ from the preceding vowel.

The skewness of the distribution for the normalized distances to the individual's F1/F2 centroid – as crude a metric as it may be – yielded a difference between genders (so did the standard deviation of normalized distances to the centroid, but to a lesser extent). The greater departure from the normal distribution in Figure 2 (distribution more positively skewed than in Figure 3) suggests that female speakers use comparatively more centralized forms. Normalization was done on a within-speaker basis, which leads us to believe that this difference may be said to be clearly attested, all other things being equal. We cannot, however, assess precisely how much information was removed during normalization. As stated above, centralization – except in some cases, e.g. <fellow> pronounced /felə/ – can be equated with standard pronunciation. [14] showed that women were more sensitive to overt prestige and were more prone to use standard forms than men. Our results support these findings for the ABI database.

As for dialects, there is reason to believe that our metric for vowel reduction does not really gauge what the literature leads us to expect.

6. CONCLUSION

Rhythm in the dialects of the British Isles is only partially characterized by our durational metrics based on consonantal and vocalic intervals. However, the tendency observed accords with traditional dialectology: it is tempting to say that the dialects of the Celtic countries exhibit less stress-timing than the others. Yet, it seems that, with the method employed, more significant results are very likely not attainable. Our metric for centralization shows differences in gender. In future research, we will consider improving the gauging of vowel reduction.

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[a] http://www.aurix.com/dynamic/default.aspx

[b] Abbreviations: *brm*: Birmingham; *crn*: Cornwall, *ean*: East Anglia; *eyk*: East Yorkshire; *gla*: Glasgow; *ilo*: Inner London; *lan*: Lancashire; *lvp*: Liverpool, *ncl*: Newcastle; *nwa*: North Wales; *roi*: Republic of Ireland; *shl*: Scottish Highlands, *sse*: Standard Southern British English; *uls*: Ulster.