ON THE CORRELATION OF ACOUSTIC VOWEL AND CODA DURATION IN MODERN WELSH C(C)VC MONOSYLLABLES

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ABSTRACT

This project investigates the relationship of vowel duration and coda duration in modern Welsh monosyllabic words ending in a simplex consonant. Acoustic data from 16 native speakers from the two major dialectal varieties of Welsh were analysed. We found vowel duration highly predictive by coda duration, taking into account possible influences of phrase prosody, speaker and variety specific deviations. Also, prosodic prominence primarily appears to effect coda duration in Welsh.

Keywords: vowel coda interaction, Welsh, speaker specific behaviour

1. INTRODUCTION

This study investigates the distribution of vowel duration in Modern Welsh and its relationship to coda consonants in C(C)VC monosyllables. Previous studies of Welsh phonology [2, 10, 14, 18] have tended to posit the existence of distinctive vowel length in that language, but have also identified considerable contextual conditioning dependent on factors such as syllable structure and category/class of coda consonants. Regarding the latter, which is the focus of this study, there is agreement that the vowel duration contrast is neutralised in favour of the short vowels before some coda consonants and in favour of the long vowels in others. Details of this conditioning differ between authors.

Furthermore, already in the middle of the twentieth century, Falc'hun [8] showed by means of spirometry that in Breton, a Brythonic language closely related to Welsh, vowel and coda consonant duration are mutually interdependent. Falc'hun identified a bimodal distribution, with long vowels occurring before silence or 'lenis' codas in stressed syllables, and short vowels occurring in unstressed syllables and before 'fortis' codas. While a number of acoustic correlates serve to distinguish the two series of coda consonants [15], the durational parameter is particularly evident. Ball [1] demonstrates that also in Welsh, there are notable differences in perceived duration between the lenis and fortis series, but the actual relationship between vowel and consonant duration in that language has not yet been explored acoustically.

The tendency for vowels to occur short before long codas and long before short codas is well-attested in other languages (e.g. in Bavarian [11] and in Bolognese [9]). Assuming a high correspondence with the labels 'lenis' and 'fortis', there is also a cross-linguistic tendency for vowels to be longer before 'voiced' segments than 'voiceless' ones [7] and indeed the patterns observed for Breton fit into a broader typology in which there is mutual dependency between vowel and coda duration, sometimes termed V/C complementation [3]. This study tests the hypothesis that a similar pattern may be at work also in Modern Welsh.

2. DATA & METHODS

2.1. Stimuli word list and reading task

The 89 stimuli word list consisted of monosyllables of a C(C)VC-structure. It was constructed to represent all the occurring coda consonants in the Modern Welsh lexicon, except /-ŋ/, focusing on native vocabulary. A few English loan words were included for control purposes. In order to assess a likely influence of prosodic prominence, the following carrier phrase was chosen: *Dw i heb ddweud X, ond Y.* (literally 'I am without say(ing) X, but Y', actual meaning 'I did not say X, but Y'). In this way we ensured that each item occurred two times in each position (X= *position 1*; Y=*position 2*), expecting higher prominence in the second, but each time with a different pairing of words.

2.2. Participants

16 participants (7 female / 9 male) were asked to read these sentences. The speakers ranged in age from 19 to 72 and were all educated native speakers of Modern Welsh who use their language at home and at work. With regard to their origin, 11 came from North Wales and 5 (F2, F5, F6, M3, M8) from South Wales.

2.3. Recordings

Some recordings were carried out under field conditions using the soundcard of a laptop (*ASUS K5OIJ*) together with a *TRUST 16973 / STARZZ* dynamic microphone. Others were carried out in a lab or studio environment using an *Olympus LS-11* with in-built electret microphones and *sounddevice T788* with a *Audix HT5* headset microphone.

2.4. Acoustic Measurements & Data

The acoustic sequences of carrier phrases and vowels were grossly segmented in an automatic fashion by means of PRAAT[6]-based intensity and pitch detection. The remaining manual segmentation and adjustment was carried out by a person unfamiliar with the topic and the language, and checked for accuracy and consistency by the first author. Based on the usual conventions, stop onsets were labelled at the release of the stop, while other onsets were identified by first zero crossings, and vowel onsets and offsets with regard to F2-energy. For better control of speaker-specific performance, including speaking rate, relative measures were additionally determined. The relative measures of vowel duration considered either the entire word length or word length excluding onset as reference, i.e. we use simply vowel or coda duration as a ratio of the actual duration and entire word duration (RATIO1) and as a ratio the of the vowel or coda duration and the word less its onset (RATIO2).

2.5. Statistical Analysis

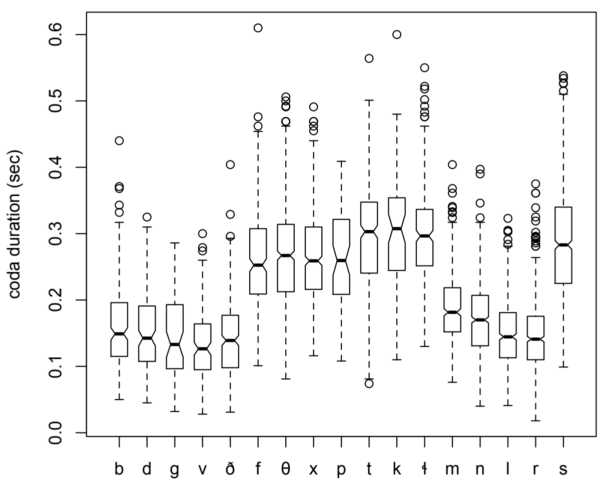
In order to test the predictions, we applied linear mixed effects models in *R* [16] using maximum likelihood estimation by means of the package *lme4* [5]. Along with fixed effects, we applied a maximal random effects structure [4] with random intercepts as well as random slopes for coda category (CODA-CAT), speaker (SPEAK), position (POSIT) and vowel (VOWEL). Maximum likelihood ratio tests served as bases for reported p-values.

3. RESULTS

3.1. Overall tendencies in duration

Vowel duration in our corpus (N=5816) ranged between 51*ms* and 541*ms*, with a median of 231*ms* (71.8), while coda duration values ranged from 20*ms* to 610*ms* with a median of 204*ms* (90.1). Hence vowels constitute a (mean) proportion of 0.42 (0.13) with respect to total word duration and 0.52 (1.5) with respect to vowel + coda duration only. Codas show a proportion of 0.4 (0.14) and 0.50 (0.15) respectively, ranging from 5% to 79% of the word length (RATIO1) and ranging from 6% to 90% of the part following the onset (RATIO2).

Figure 1: overall plot of absolute coda duration grouped by coda consonants comprising 16 speakers



3.2. Prediction of vowel duration by coda duration

In order to test how well vowel duration is predicted by coda duration, a linear mixed effects (LME) model was constructed with SPEAKER, VOWEL and POSITION as random intercepts and slopes for coda duration. The reported *correlation of fixed effects* -0.594 shows the negative correlation of the two measures ($\chi^2(1) = 14.174, p = 0.000166$). Pearson product moment correlations for absolute vowel and coda duration measures ranged among speakers between -0.219 (spk M6) and -0.536 (spk M3). However, relating the values with respect to total word duration (RATIO1) to each other, correlations range between -0.623 (spk M4) and -0.766, all of which are significant. On the other hand, if we test onset duration as predictor for vowel duration in a similar LME we gain a non-significant maximum likelihood ratio. Since also correlations of range very low (-0.116 and -0.140) too, onset duration can be assumed to explain only little of the variance in vowel duration.

3.3. Coda grouping for coda categories

Applying recursive partitioning by conditional inference using *party*-package [12] in *R*, we found that the highest ranked splits in the data based on relative coda duration give /-k, -x, -f, -ɬ, -m, -p, -s, -t, -θ/ on the one hand and /-b, -d, -ð, -v, -g, -l, -n, -r/ on the other, whereas the absolute coda duration values would still group /-m/ with the 'lenis' obstruents. These splits are seemingly independent of the preceding vowel qualities and of position and represent for the obstruents what had been proposed as *fortis vs. lenis* contrast in Modern Welsh. A subsequent sub-split between 'lenis' obstruents and /-n, -m, -l, -r/ is considerably less clear and seems to be very speaker specific.

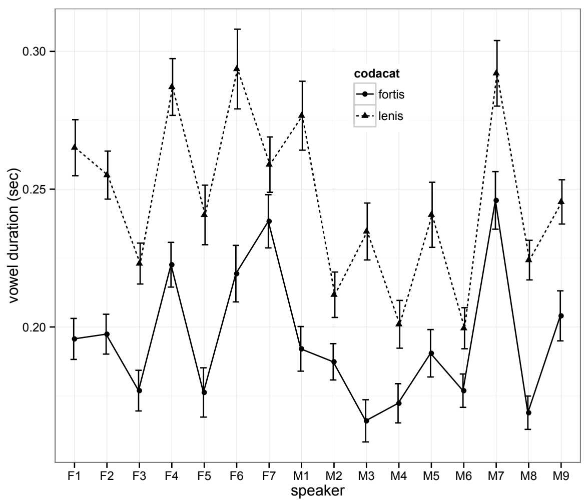
3.4. Prediction of vowel duration by coda categories

We then tested how the achieved and proposed (*fortis/lenis*) coda categories serve as predictors for vowel duration. This involved constructing a LME model with SPEAKER, VOWEL and POSIT as random intercepts and slopes for CODACAT. This model only reached significance ($\chi^2(1)$=14.104, p=0.0001729) in predicting the relative vowel length (vowel/word duration ratio). We recognise that a phonetically plausible sub-category of nasals and liquids /-n, -m, -l, -r/ can be tested as well, since the overall coda duration of these seems to range in between the two obstruent categories (Figure 1). But here the LME model reaches significance also only for absolute values ($\chi^2(2)$=8.9466, p=0.01141).

3.5. Speaker & variety-specific results

Testing the prediction of vowel duration by CODACAT reaches only significance if SPEAKER is added as fixed effect ($\chi^2(16) = 94.128$, $p = 4.314e-13$). Speakerwise testing of the vowel duration difference between the coda categories ('fortis/lenis') reveals for speaker F7 a non-significant result, which may be confounded by influence of POSIT. As well as examining the range of correlation (s. 3.2) and testing predictions by individual speaker (s. 3.2), we used biographical data, i.e. geographical origin of each speaker, as a means to test the null hypothesis with respect to the factor of VARIETY (*North/South; N/S*). We first checked the coda duration split using

Figure 2: Plot of means of absolute vowel durations for individual speakers grouped by coda categorie; vertical bars show confidence intervals



all three coda duration measures (s. 3.3) for each individual speaker. Using absolute measures, only two speakers (S; N) show a coda split whereby /-m/ is grouped with the 'fortis' obstruents. However, under RATIO1 /-m/ is 'long' for all 5 Southern speakers and for half of the Northern speakers. For the other half of the Northern speakers the /-m/-values group with the 'lenis' obstruents. The situation changes again when RATIO2 is under consideration. In this case, /-m/ groups with the 'fortis' consonants for all speakers, while for seven speakers /-n/ is also 'long' and for one speaker /-b/ as well. Only with RATIO2, and only for a few speakers, VOWEL is a relevant secondary split factor. In these cases, longer codas split with high vowels (<i,y,u,w>). Additionally we constructed LMEs with VARIETY as interacting predictor, but found no effect.

3.6. Word-specific results

In order to generalise the observations for (vowel) durations in individual words and to talk about trends ('long' and 'short') we can, therefore, posit a kind of grid with regard to the maxima occurring in the vowel duration distribution and mean values for the two positions (s. Fig. 3). Some words are expected to behave as shibboleths. For example, *heb* ('without') and *grêt* ('great') are often considered to be diagnostic for dialectal background. In our data we can observe that, as expected, *heb* is pronounced by the Southern speakers with a relative vowel duration in the mid range under RATIO1, while most speakers from North Wales had a lower ratio. However, other words of similar structure, such as *neb* ('no-one'), show to a degree the opposite behaviour. However, *grêt* is pronounced by all speakers in the mid to low range, thus generally following the predicted tendency, i.e. short vowel before fortis coda. For certain codas, such as /-s/, there is a tendency for the vowel duration of individual words to be reasonably consistent, but some words have generally 'longer' vowels, while others have 'shorter' ones. Thus, the vowel of *gwas* ('servant') has a high relative duration, whereas that of *blas* ('taste') is in the mid to low range. Similarly, some words with /-n/ show a bimodal distribution of vowel duration values, in which, e.g. *brân* ('crow'), shows higher duration ratios, while, e.g. *rhan* ('part') shows a lower duration ratios.

3.7. Prosodic influence

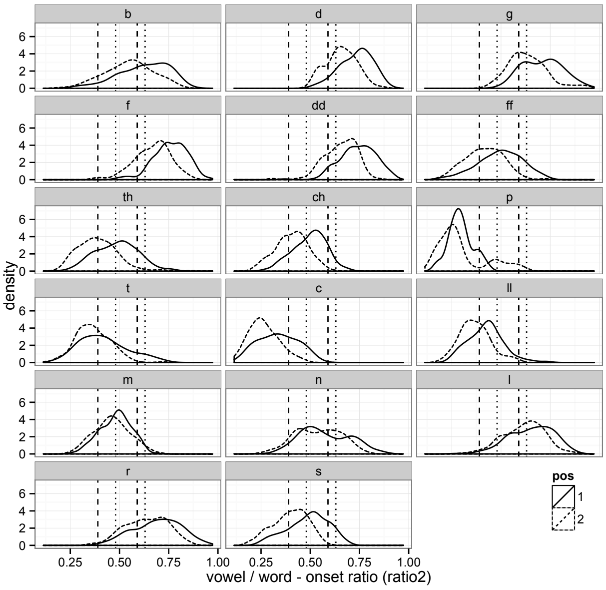
Throughout the analyses, it became evident that the second position in the carrier sentence indeed attracts stronger prosodic prominence. Measuring f0 within the vowel portions of the two target words, we see a general mean f0 shift in the second position. There is an interaction of gender in this: female participants, regardless of their dialect background, show this ($+12.2Hz$, $\chi^2(3) = 10.762$, $p = 0.01308$). We also observe aberrant patterns for some speakers, shifting the main focus of the sentence to position 1 or attempting to emphasise both. In all, there is a consistent trend for position 2 to show longer coda duration. However, the median differences of vowel duration with respect to lenis-fortis codas are located at $56.3ms$ (30.37) for position 1 and at $56.8ms$ (28.53) for position 2, which is not indicative of a significant difference between these conditions.

4. DISCUSSION

Attempting to extrapolate from elicited speech to real speech, we were able to account for the effects of prosodic positions in the phrase, variability of a speaker and word specific nature. Our data suggest that coda duration in Modern Welsh C(C)VC monosyllables is a very good indicator for preceding vowel duration. However, a few exceptions may be found, which suggests a possible contrast or at least a word specific grammaticalisation before certain codas. These point to the possible limits of predictability, i.e. higher error probability for learners.

We can compare our analyses with phenomena such as incomplete neutralisation of coda obstruents in German [17] or Polish [13], where small differences in the preceding vowels are found, with longer vowels before lenis obstruents and *vice versa*. However, the effects measured in our data set are of a different order of magnitude.

Figure 3: Densities of vowel duration grouped by CODA (panels) und POSITION (line type); vertical lines mark the threshold area for individual positions



By means of the maxima of the vowel duration distribution we gain potential margins of categorical boundaries for Modern Welsh speakers that remain to be tested, as do subsequent perceptual implications in terms of possible sound changes in coda consonants.

Our findings also support those of Williams [19] of longer coda duration in stronger prosodic positions, such as the focus positions in our study.

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