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The monophthongs and diphthongs of North-eastern Welsh: an acoustic study

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Abstract

Descriptive accounts of Welsh vowels indicate systematic differences between Northern and Southern varieties. Few studies have, however, attempted to verify these claims instrumentally, and little is known about regional variation in Welsh vowel systems. The present study aims to provide a first preliminary analysis of the acoustic properties of Welsh monophthongs and diphthongs, as produced by a male speaker from North-eastern Wales. The results indicate distinctive production of all the monophthong categories of Northern Welsh. Interesting patterns of spectral change were found for the diphthongs. Implications for theories of contrastivity in vowel systems are discussed.

Index Terms: vowel production, acoustic analysis, Welsh

1. Introduction

The vowel inventories of the world's languages vary considerably in size. Thus, according to the UPSID corpus of 317 languages [1], the average language contains between five and six contrastive vowel categories. 5.7% of languages have no more than three vowel phonemes, and, at the other extreme, 4.1% of languages have 17 vowel phonemes or more. The most common vowel sounds are /i,a,u/. Front rounded and central rounded vowels, on the other hand, occur comparatively rarely.

In terms of its vowel inventory, Welsh, a member of the Brythonic branch of Celtic languages, is an interesting case. The language, which is spoken as a native tongue by approximately 700,000 people, or 21% of the population of Wales [2], distinguishes as many as thirteen monophthongs and the same number of diphthongs. Interestingly, however, the number of contrastive vowel categories varies across different regional accents. Thus, while Northern and Southern Welsh contain the front vowels /iː,ɪ,eː,ɛ/, the open vowels /ɑː,a/, the back vowels /oː,ɔ,uː,ʊ/, and the mid central vowel /ə/, only Northern Welsh also contains the high central vowels /ɨː/ and /ɨ/, according to auditory descriptions of the language [3, 4]. Note that in the South, the latter are not distinguished from /iː/ and /ɪ/, respectively, such that Northern Welsh *tŷ* ('house') /tɨː/ and *ti* ('you') /tiː/, for instance, are homophones in southern varieties and pronounced [tiː].

Northern and Southern Welsh also differ in the realization of vowel phonemes. Thus, with the exception of /ə/, the Southern Welsh monophthongs occur in tense-lax pairs that are distinguished in terms of both quality and duration, as in English. In contrast, according to descriptive accounts (cf. [3, 4]), Northern Welsh only distinguishes these vowel pairs, as well as /iː/ and /ɨ/, on the basis of temporal information.

Finally, Northern and Southern Welsh also differ in terms of their contrastive diphthong categories: while both varieties contain the front closing diphthongs /aɪ,əɪ,ɔɪ,ʊɪ/ and the back closing diphthongs /ɪʊ,əʊ,ɛʊ,aʊ/, Northern Welsh also distinguishes the back closing diphthong /ɨʊ/ and the central closing diphthongs /aɨ,ɑɨ,əɨ,ɔɨ/. Note that the latter are not distinguished from the front and back closing diphthongs in Southern Welsh. Thus, Northern Welsh *hail* ('second') /haɪl/, *hael* ('liberal') /hɑɨl/, and *haul* ('sun') /haɨl/, for instance, are homophones in Southern Welsh and pronounced [haɪl] (cf. [4, 5]). Note also that Southern Welsh /ʊɪ/ is realized as /ʊɨ/ in the North, and that the relative duration of diphthong onsets and offsets may differ systematically [4, 5].

Despite the availability of auditory-based accounts, there is a dearth of instrumental acoustic studies on Welsh vowels. Moreover, the few existing studies (cf. [5, 6], also see [4]) are methodologically problematic, and only encompass some of the contrastive categories of Welsh. Furthermore, they only feature speakers from North-western parts of Wales. Unfortunately, however, beyond the basic North-South distinction, little is known about regional variation in the vowel systems of Welsh. It is, for example, not clear whether there are structural and/ or realizational differences *within* different northern and southern accents.

The purpose of the present study is to make a contribution to this latter line of enquiry by providing a first systematic acoustic account of the monophthongs and diphthongs of Welsh, as produced by a male speaker from North-eastern Wales.

2. Methods

A 21-year-old male native speaker of Welsh from Dyffryn Clwyd, Denbighshire, in North-eastern Wales participated in the study. He had spent all his formative years locally, attending a Welsh-medium school, and uses only Welsh when conversing with family and friends. His first significant exposure to English only occurred in a school context. This indicates that he is a Welsh-dominant early consecutive bilingual.

The materials used in the study were selected so as to provide ample opportunity for the speaker to produce all the contrastive categories of Welsh. These include the monophthongs /iː,ɪ,ɨː,ɨ,eː,ɛ,ɑː,a,oː,ɔ,uː,ʊ,ə/ and the diphthongs /aɪ,əɪ,ɔɪ,ʊɪ,ɪʊ,əʊ,ɛʊ,aʊ,ɨʊ,aɨ,ɑɨ,əɨ,ɔɨ/. To control for phonetic context effects, all the vowels were embedded in the frame /hVd/ to yield the target words 'hîd', 'hid', 'hûd', 'hud', 'hêd', 'hed', 'hâd', 'had', 'hôd', 'hod', 'hŵd', 'hwd', 'hyd', 'haid', 'heid', 'hoid', 'hwyd', 'hiwd', 'hywd', 'hewd', 'hawd', 'huwd', 'haud', 'haed', 'heud', and 'hoed', respectively. Note that most of these are non-words. However, Welsh spelling conventions are consistent (cf. [4]), and the target words were therefore not expected to pose problems. Nevertheless, in order to ensure activation of the intended vowel categories,

each /hVd/ word was primed by the use of high-frequency real words of Welsh that contain the relevant vowels.

Recordings were made in a quiet room of a local Welsh language society. To obtain high-quality acoustic data, a *Zoom H2 Handy Recorder* with integrated microphone was positioned a few centimetres from the subject's mouth. The recording session commenced with a brief conversation in Welsh between the subject and the second author, a native speaker of Welsh. This was done to achieve full activation of the bilingual subject's Welsh language mode (cf. [7]). Upon familiarization with the target words, the subject read the real-word primes for each vowel category out aloud at a natural pace followed by three instances of the corresponding /hVd/ word embedded in the carrier phrase *Dyweda X hefyd* ('Say X also'). In total, this yielded 26 x 3 = 78 sentences. The recording session lasted approximately 20 minutes overall.

The acoustic material was directly transferred onto a standard PC and analyzed using PRAAT software [8]. Following extraction of the target words from the carrier phrase, the duration of the test vowels was measured from the first positive peak in the digitized waveform up to, but not including, the following portion of acoustic silence that signals the constriction of the post-vocalic plosive. The frequencies of the first three formants were then measured at vowel mid-point for the monophthongs, and at the 25% and 75% portions for the diphthongs, using formant trackers. Note that due to limitations of space, only the values for F1 and F2 will be presented here. In the few instances where mistracking occurred, the automatically tracked formants were hand corrected.

3. Results

3.1. Monophthongs

Figure 1 depicts the mean frequency of the first and second formant of each of the thirteen Welsh monophthongs, as measured at the respective vowel mid-points. For F1 and F2 mean values and standard deviations, see Table 1. For duration values of the thirteen monophthongs, see Figure 2.

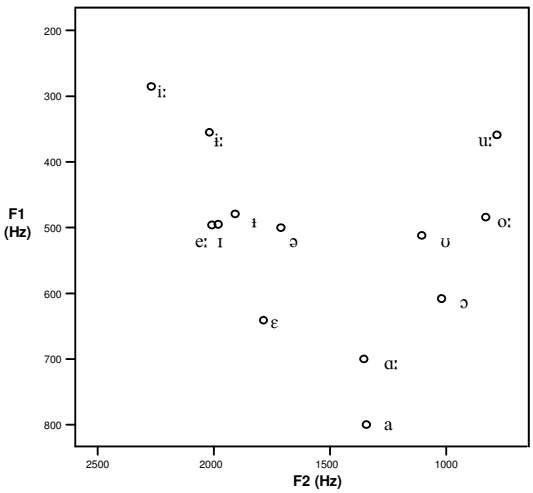

Figure 1: *F1-F2 plot (in Hz) of thirteen Welsh monophthongs*

Figure 1 indicates that the subject from North-east Wales spectrally distinguished the eleven monophthongs that are common to Northern and Southern varieties of Welsh, perhaps with the exception of /eː/ and /ɪ/ which overlap in his productions in terms of F1 and F2, but not duration (cf. Figure 2). This finding is interesting since descriptive accounts [3, 4] claim that pairs of Northern Welsh vowels are only differentiated on the basis of temporal, but not spectral information.

The acoustic results also show some interesting patterns for specific categories. For example, /ə/ was produced with F2 values that are almost as high as those of front vowels, and the two open vowels /ɑː/ and /a/, while similar in F2, were clearly distinguished on the basis of their first formant frequencies.

Finally, the results also indicate that the subject's inventory contains the central vowels /ɨː/ and /ɨ/, which are a characteristic of Northern Welsh varieties. This is evident when inspecting the F2 values of /ɨː/ and /ɨ/ which are considerably lower than those of their front vowel counterparts /iː/ and /ɪ/, respectively (cf. Figure 1, Table 1). Note also that /ɨː/ is more open than /iː/, as a comparison of their first formant frequencies shows.

Vowel	*F1 (Hz)*	*F2 (Hz)*
iː	**285** (16)	**2270** (61)
ɪ	**495** (30)	**1982** (58)
ɨː	**355** (13)	**2020** (44)
ɨ	**479** (4)	**1909** (18)
eː	**496** (8)	**2009** (18)
ɛ	**641** (41)	**1787** (9)
ɑː	**700** (25)	**1354** (55)
a	**800** (32)	**1344** (53)
oː	**484** (6)	**830** (38)
ɔ	**608** (24)	**1020** (80)
uː	**359** (17)	**782** (47)
ʊ	**512** (32)	**1105** (38)
ə	**500** (9)	**1712** (15)

Table 1: *Mean F1 and F2 frequency of thirteen Welsh monophthongs; SDs in parentheses.*

In addition to the spectral properties of the Welsh monophthongs, their duration was determined. The mean duration values in Figure 2 show that the subject clearly distinguished between phonologically long and short vowels. Thus the vowel pairs [iː-ɪ], [ɨː-ɨ], [eː-ɛ], [ɑː-a], [oː-ɔ] and [uː-ʊ] were not only differentiated on the basis of spectrum, but also duration.

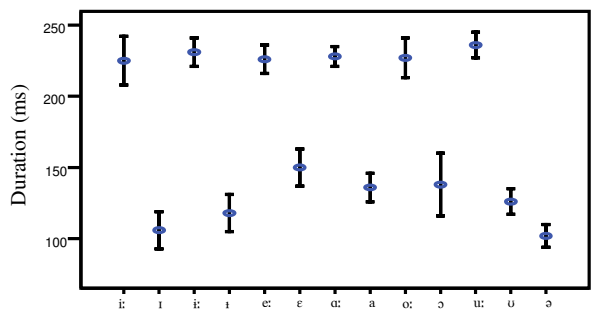

Figure 2: *Duration (in ms) of thirteen Welsh monophthongs; circles indicate mean values, error bars indicate +/- 1 SD.*

3.2. Diphthongs

Figure 3 depicts the direction of spectral change in F1 and F2 from the onset points (25% portion) to the offset points (75% portion) of each of the thirteen Welsh diphthongs. See also Table 2 for F1 and F2 means and standard deviations.

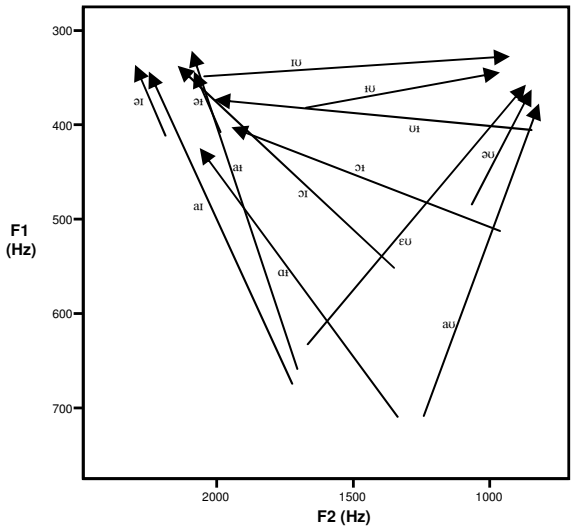

Figure 3: *F1-F2 plot of thirteen Welsh diphthongs*

The results indicate that the subject distinguished all thirteen diphthong categories of Northern Welsh. Moreover, the broad direction of spectral change and the targets of the diphthong offset points are roughly in line with descriptive accounts [3, 4, 5]. Thus, the back closing diphthongs /ɪʊ,ɨʊ,ɛʊ,əʊ,aʊ/ were produced with comparable offset points, as were the central closing diphthongs /ɑɨ,aɨ,əɨ,ɔɨ,ʊɨ/ and the front closing diphthongs /əɪ/ and /aɪ/. Interestingly, however, the offset point of /ɔɪ/ is characterized by a comparatively low F2 value which is in the area of the central closing diphthongs.

Vowel	*F1 (Hz)*		*F2 (Hz)*	
	25%	*75%*	*25%*	*75%*
aɪ	671 (29)	340 (18)	1713 (41)	2258 (14)
aɨ	662 (2)	340 (21)	1695 (25)	2073 (16)
ɑɨ	713 (6)	421 (6)	1327 (41)	2072 (99)
ɔɪ	548 (23)	334 (6)	1361 (42)	2133 (48)
ɔɨ	508 (11)	399 (29)	963 (55)	1936 (144)
ʊɨ	402 (29)	370 (20)	857 (57)	1999 (36)
əɪ	408 (10)	333 (15)	2198 (38)	2309 (22)
əɨ	411 (25)	325 (21)	1996 (51)	2081 (51)
ɪʊ	352 (13)	324 (16)	2035 (113)	916 (56)
ɨʊ	377 (7)	341 (19)	1673 (25)	973 (23)
ɛʊ	629 (22)	361 (13)	1677 (57)	858 (3)
əʊ	488 (7)	366 (13)	1056 (29)	837 (34)
aʊ	705 (5)	374 (13)	1252 (72)	810 (48)

Table 2: *Mean F1 and F2 frequency of 13 Welsh diphthongs measured at the 25% and 75% portions; SDs in parentheses.*

Interesting patterns were also found for the diphthong onset points. Thus, the vowels in *hoid* and *hoed*, i.e. /ɔɪ/ and /ɔɨ/ were produced with completely different F2 onset values, although the same IPA symbol is used to denote them. The same holds true for the use of /ə/ in /əɪ/, /əɨ/ and /əʊ/, and /a/ in /aɪ/ and /aʊ/. It is also interesting to note that the onset point of /ɪʊ/ was produced with a comparatively low F2 value. Not surprisingly, the F2 onset point of /ɨʊ/ was lower still.

In addition to diphthong onset and offset points, dynamic differences in spectral change were investigated. After all, previous accounts indicate that the relative contribution of the two elements of a diphthong to vowel identity may vary [4, 5]. In what follows, a brief qualitative account of spectral change in some of the Welsh diphthongs will be given. For a full account, please see [9].

To begin with, dynamic changes in F1 and F2 were assessed in the diphthongs /aɪ/, /aɨ/ and /ɑɨ/. Recall that these categories are not distinguished in Southern varieties of Welsh and produced [aɪ]. Inspection of Figure 4 shows that the first element of /ɑɨ/ is considerably longer, with a 'flatter' F2 curve, than that in the other two diphthongs. Interestingly, its offset point is close to that in /aɨ/. The main difference between /aɪ/ and /aɨ/, in turn, is the comparatively higher F2 offset point in /aɪ/.

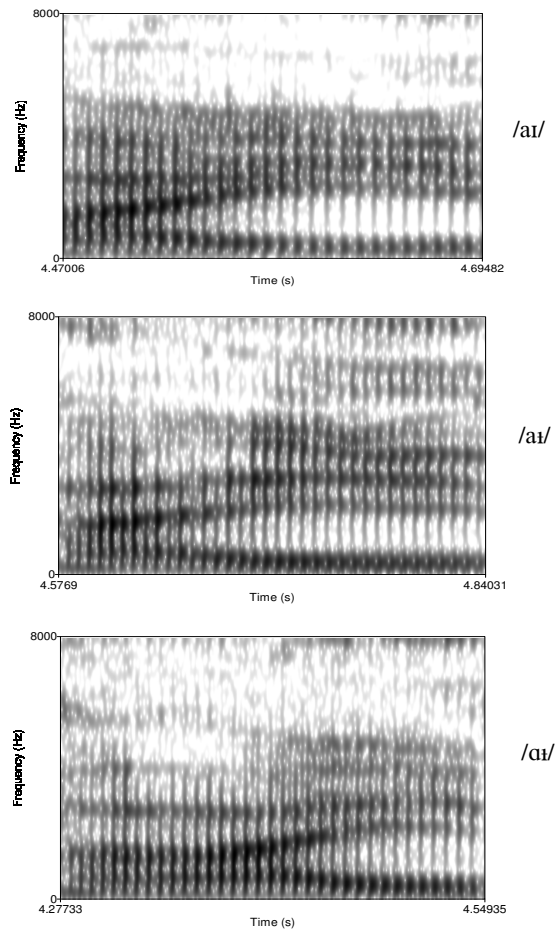

Figure 4: *Spectrogram of /aɪ/ in "haid" (top), /aɨ/ in "haud" (middle), and /aɨ/ in "haed" (bottom).*

Similar results were also found for the patterns of spectral change in /ɔɪ/ and /ɔɨ/, which, like /aɪ/, /aɨ/ and /ɑɨ/, are not distinguished in Southern varieties of Welsh. Thus, the first element in /ɔɪ/ is considerably shorter than that in /ɔɨ/ and produced with higher F2 values (cf. Figure 5). Note also the difference in F2 of the respective offset points.

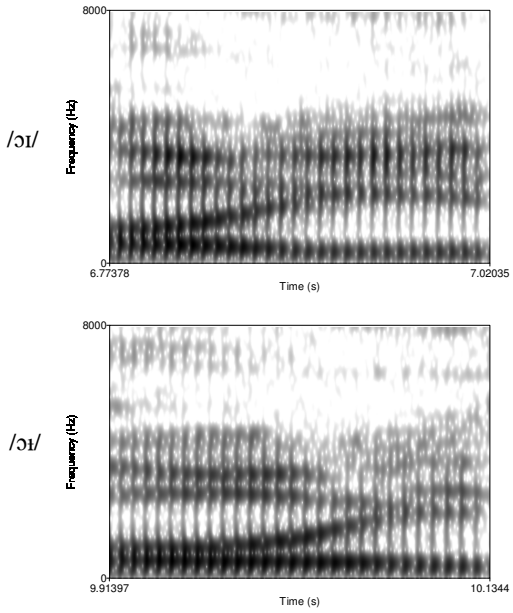

Figure 5: *Spectrogram of /ɔɪ/ in "hoid" (top) and /ɔɨ/ in "hoed" (bottom).*

Finally, the overall duration of the thirteen Welsh diphthongs was investigated. Inspection of Figure 6 shows a number of differences across the various categories. Thus, /ɑɨ/ and /aʊ/, for example, are considerably longer in the subject's productions than /əɪ/, /ɛʊ/ and /əʊ/. It is, however, unlikely that these differences are critical cues to vowel identity. After all, the productions of Welsh diphthongs exhibit a large degree of temporal overlap and were all produced with duration values between 200 ms and 300 ms, much like the long monophthongs (cf. Figure 2 above).

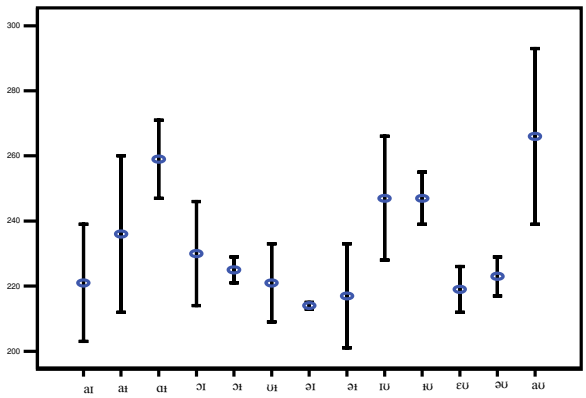

Figure 6: *Duration (in ms) of thirteen Welsh diphthongs; circles indicate mean values, error bars indicate +/- 1 SD.*

4. Discussion and Conclusion

The purpose of the present study was to provide a first systematic acoustic account of the monophthongs and diphthongs of Welsh, as produced by a male native speaker of Welsh from Dyffryn Clwyd in North-eastern Wales.

The results indicate that the subject distinguished all contrastive monophthong categories of Welsh in his productions, including the Northern Welsh vowels /iː/ and /ɨ/. Moreover, pairs of monophthongs were not only differentiated on the basis of duration, but also quality. This finding is surprising since tense-lax distinctions of this kind are traditionally viewed as a characteristic of Southern Welsh vowel systems only [3, 4].

The subject also distinguished all contrastive diphthong categories of Northern Welsh. His productions exhibited interesting patterns of spectral change, in particular in relation to the relative duration of the diphthong onsets and offsets. While the broad direction of spectral change in his productions was roughly in line with previous accounts [3, 4], the specific locations of the diphthong onset and offset points in the F1-F2 vowel space did not always conform to the predicted patterns.

The results presented in this paper, although confined to a single individual, provide a first indication of the acoustic properties of Welsh vowels. As such, they constitute a meaningful starting point for future work, and contribute to ongoing work on variation in accents of Welsh (e.g. [9]). The results also raise theoretical questions. For example, they indicate that it may not be sufficient to describe diphthongs in languages with a large inventory purely in terms of the targets of their onset and offset points. Rather, the specific timing of changes in spectral quality across diphthong trajectories may also be an essential cue to vowel identity. Further work on the role of vowel inherent spectral change (cf. [10]) in relation to languages with a large vowel inventory, eg. Welsh, is required.

5. Acknowledgements

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6. References

[1] Maddieson, I.M. (1984). *Patterns of Sound.* Cambridge: Cambridge University Press.

[2] Office for National Statistics, United Kingdom, Census 2001, 'Welsh language', http://www.statistics.gov.uk/CCI/nugget.asp?ID=447&Pos=&ColRank=1&Rank=374

[3] Ball, M.J., Jones, G. E. (1984) (eds.) *Welsh Phonology. Selected Readings.* Cardiff: Cardiff University Press.

[4] Ball, M.J., Williams, B. (2001). *Welsh Phonetics.* Lewiston, Queenston & Lampeter: The Edwin Mellen Press.

[5] Ball, M.J. (1983). "A spectrographic investigation of three Welsh diphthongs," *Journal of the International Phonetic Association* 13: 82-89.

[6] Oftedal, M. (1969). "A new approach to North Welsh vowels," *Lochlann* 4: 243-269.

[7] Grosjean, F. (2001). "The bilingual's language modes," In Nicol, J. (ed.). *One Mind, Two Languages: Bilingual Language Processing* (pp. 1-22). Oxford: Blackwell.

[8] Boersma, P., Weenink, D. (2008). *PRAAT: Doing Phonetics by Computer. Version 5.0.* Institute of Phonetic Sciences, University of Amsterdam, http://www.fon.hum.uva.nl/praat/.

[9] Mayr, R., Davies, H. (in preparation) "An acoustic study of Northern and Southern Welsh vowels"

[10] Morrison, G.S., Nearey, T.M. (2007) "Testing theories of vowel inherent spectral change," *Journal of the Acoustical Society of America* 122: EL15-EL22.