5.2 The phonetic manifestation of stress in Welsh: Briony Williams

5.2.1. Background

5.2.1.1. The Welsh language

The Welsh language is spoken in Wales, which until 1536 was an independent kingdom of the island of Britain. It dates from the late sixth century AD, and is thus the oldest continuously-spoken language in Britain. It derives from Brittonic, which was probably spoken in Britain from around 600 BC, and is an Indo-European language of the Celtic family.

The form of Celtic spoken in Britain and ancient Gaul is known as P-Celtic, as the original Indo-European [k^w] sound became [p] in Gallo-Brittonic. This is the group containing Welsh, Cornish and Breton. P-Celtic contrasts with the form of Celtic spoken in Ireland (and later in Scotland and the Isle of Man), which is known as Q-Celtic (or Goidelic Celtic) since it retained the IE [k^w] sound, in the form of [k]. Gaulish became extinct around 500 AD, under pressure from Latin and neighbouring Germanic languages. The other Continental Celtic languages died out earlier, in the first century BC (these being Lepontic, in Northern Italy; Celtiberian or Hispano-Celtic, in the Iberian peninsula; and Galatian, in Asia Minor). Brittonic speakers colonised Brittany between around 450 and 650 AD. Their language evolved into Welsh and Breton, which are still spoken. The other Brittonic Celtic language, Cornish, died out in the eighteenth century AD. Q-Celtic gave rise to Irish, Scottish Gaelic and Manx Gaelic. The latter died out, while the remaining two languages survive to some extent.

Of the modern Celtic languages, it can be said that Welsh is in the strongest position. It is spoken to some extent by at least half a million people, according to the 1991 census: this represents about eighteen percent of the population of Wales. For the first time in generations, a higher proportion of children than adults are claimed to have some knowledge of it: a demographic fact that has important implications for the future state of the language.

5.2.1.2. Stress location in Welsh

In the parent Brittonic language, polysyllabic words were stressed on the penult, while the final syllable (the ultima) formed the inflectional ending. All content words ended in an inflection, which was normally of one syllable but could in some cases be two syllables long. The loss of the final syllable of inflectional endings around the end of the sixth century AD marked the change from Brittonic to Welsh. The stressed syllables were now in word-final position. Around the late eleventh century, word stress shifted to the penult in polysyllabic words, marking the change from Old Welsh to Middle Welsh. It has remained on the penult ever since (details on the Old Welsh Accent Shift may be found in Jackson 1953). In Breton, a sister language of Welsh, word stress also lies on the penult in most polysyllabic words. In the Goidelic Celtic languages, however, word stress is largely on the initial syllable of the word.

Evidence for the Old Welsh accent shift is based on various historical sound changes. One of these is the monophthongisation of newly-unstressed ultimas. For example, earlier *Matauc* (a name) becomes *Matoc* (Jackson 1953: 296). Another sound change involves the clusters /mp/, /nt/ and /ŋk/, which became /mh/, /nh/ and /ŋh/ before the accent shift. When immediately before the (new) stress, the /h/ was retained, but in all other positions (including before the ultima) it was lost at some point subsequent to the accent shift. For example, British *Brigantinos* (with stress on the penult) became Old Welsh *brennhin*, plural *breenhined* (with stress on the new penult) and Modern Welsh *brenin*, plural *brenhinoedd* 'king, kings' (Jackson 1953: 506). Thus, after the accent shift, the occurence of this phoneme was restricted to the newly-stressed syllable.

Some modern Welsh words are exceptionally stressed on the ultima. This may or may not be marked orthographically by an accented vowel, and often derives from the coalescence of two historically separate vowels. Examples are as follows (where a South Welsh accent is assumed).

(4)	Cymraeg	'Welsh (language)'	/kəmˈraɪg/
	paratoi	'to prepare'	/paraˈtoɪ/
	mwynhau	'to enjoy'	/muɪnˈhaɪ/

A very small number of exceptions are stressed on the antepenultimate syllable: these are largely loan-words from English. Examples are:

(5)	methodist	'Methodist'	/ˈmɛθɔdɪst/
	monopoli	'monopoly'	/mɔˈnɔpɔlɪ/
	catholig	'Catholic'	/ˈkaθɔlɪg/

5.2.1.3. Outline of investigations

In the work reported here, the acoustic correlates of word stress in Modern Welsh are investigated. To begin with, some preliminary measurements of a small amount of speech are reported (in §5.2.1.4.). The results of these measurements give rise to further measurements of durations in a larger sample of speech (in §5.2.2.). Both vowels and consonants are measured, and then rhythmic feet are investigated. After this, a speech perception experiment is carried out (in §5.2.3.), in order to test whether the findings obtained from the earlier measurements are also relevant from the perceptual point of view. Finally, in §5.2.4., there is a discussion of the implications of these investigations for the phonetic nature of stress in Welsh. §5.2.5. contains a summary and conclusions.

5.2.1.4. Preliminary measurements

As a preliminary investigation of the acoustic correlates of stress in Welsh, a native Welsh speaker was recorded reading a list of isolated Welsh words and of sentences. The sentences ended in the word of interest, which was therefore in nuclear position in all cases, as apart from cases of contrastive emphasis the nucleus is normally the last content word in the tone-unit (Ceinwen H. Thomas 1967 outlines the framework of Welsh intonation). The total number of target words was twenty in this first set, and all were regularly-stressed polysyllabic words (i.e. stress on the penult). Spectrograms were made of these utterances (details are in Williams 1986). Two non-Welsh-speaking English speakers then listened independently to the utterances and made judgements as to which syllable sounded stressed to them. Unsurprisingly, the syllables they chose tended to be those in which the vowel had a longer duration than the other vowels of the word, and where the vowel had a greater overall amplitude and a greater degree of F_0 change than the other vowels. This corresponds to the realisation of linguistic stress in English words. The syllables chosen were usually not the phonologically stressed ones, but the final syllables (which in many cases were more acoustically salient).

A native Welsh speaker then also gave stress judgements (a comparatively redundant procedure, as stress location in Welsh is fixed). The vowels chosen as stressed by the Welsh speaker (the penult vowels in this case) tended to have shorter duration than unstressed vowels, lower overall amplitude, and a change in F_0 of less than 10 Hz during the vowel. Thus, in the case of Welsh stressed penult vowels, the acoustic realisation of stress is very different from that of English. It is usually the phonologically unstressed ultima that is characterised by greater duration and intensity, as demonstrated in the English-speakers' perceptions above. Stressed monosyllabic words in Welsh also exhibit great acoustic salience (it is to be borne in mind that this set of measurements did not consider stressed monosyllabic words).

The same set of measurements was also carried out for recordings of continuous Welsh speech, carried out with a portable cassette recorder at the 1981 Eisteddfod (national cultural festival). There was a total of 46 target words, comprising polysyllabic and a few monosyllabic words. Pre-pausal and irregularly-stressed words were excluded. Although the pattern was not as clear-cut as with the isolated words, the same trends were clearly present when the acoustic properties of phonologically-stressed vowels were measured. In particular, shorter vowel duration seemed to be a reliable cue to phonological stress, since in over 80 percent of the polysyllabic words the stressed syllable had shorter duration than the other syllable or syllables of the same word. This result could have been due to distributional factors, as detailed in the following section.

5.2.2. Measurements of speech production

5.2.2.1. Motivation

The curious result that shorter duration appears to be a cue to stress may (at least partly) be due to distributional features of vowels in Welsh. Diphthongs are comparatively rare in stressed penults, while reasonably common in unstressed ultimas (and stressed monosyllabic words). In addition, the shortest vowel of all, schwa, appears only in non-final syllables (and in some grammatical monosyllabic words which are not under consideration). Thus the fairly frequent occurrence of stressed schwa in penults may have done much to decrease the duration of penults in relation to the ultima, which frequently contains diphthongs but never schwa. Since duration (or lack of it) appears to be the most reliable cue to stress in Welsh, further durational measurements were carried out.

5.2.2.2. Vowels

Welsh contains both phonologically long and phonologically short vowels (at least in South Welsh accents). Full details are to be found in G.E. Jones (1984), and a summary is given here. The short vowels comprise the following:

(6)	/ɪ, ɛ, a, ɔ, ʊ, ə /	(in all Welsh accents)
	/ɨ/	(in North Welsh accents only

All of the above vowels, including schwa, may appear in stressed syllables. The phonologically long vowels comprise the following vowels. In the case of diphthongs, the first element is the vocalic one. All the long vowels may appear in stressed syllables.

(7)	/i, e, ɑ, o, u /	(in all accents)
	/ɨ:/	(in South Welsh accents only)
	/aɪ, əɪ, ɔɪ, ɪu, ɛu, au, əu/	(in all accents)
	/ʊɪ/	(in South Welsh accents only)
	/ɨu, aɨ, ɑɨ, ɔi, ʊɨ, əi/	(in North Welsh accents only)

The data was the continuous speech referred to above, measuring all the vowels (221 in total). Fuller details are in Williams (1986). Unsurprisingly, prepausal vowels (at 129 msec) were significantly longer than non-prepausal vowels (at 78 msec, $p < 0.01$). Also, phonologically long vowels (diphthongs and long monophthongs) were significantly longer (at 123 msec) than phonologically short vowels (at 69 msec, $p < 0.01$). Since long vowels occur only in stressed syllables in Welsh, the next set of measurements concerned only phonologically short vowels, which may occur in both stressed and unstressed syllables. Additionally, only non-prepausal short vowels were considered, to avoid the distorting effects of final lengthening. No significant difference was found between the duration of short stressed vowels and that of short unstressed vowels. This lack of significant duration difference contrasts with the highly significant durational difference found between stressed long and stressed short vowels. This result suggests that the correlation found earlier between stress and shorter vowel duration was due to the distribution of schwa rather than to any stress-conditioned shortening of any given vowel.

5.2.2.3. Consonants

The 176 consonants of the continuous speech were classed into four groups: after unstressed vowel, after stressed vowel, before unstressed vowel, and before stressed vowel. Only one significant duration difference was found between these categories: a consonant following a stressed vowel (at 94 msec), was longer than one following an unstressed vowel (at 81 msec, $p < 0.05$). This correlates with the longer duration of the post-stress consonant perceived auditorily by a phonetician after short vowels and in stressed monosyllabic words in three Welsh dialects (Robert O. Jones 1967).

5.2.2.4. Rhythmic feet

The place of rhythm in Welsh stress was then investigated, using the same continuous speech data as above. This was analysed in two different ways, using the Abercrombian concept of the rhythmic "foot" (Abercrombie 1967: 131). Firstly, the strings of syllables were segmented into "Welsh speaker's feet" (WSF), which began at a stressed penult or stressed monosyllabic word and ended just before the next stressed penult or stressed monosyllabic word (or end of utterance). The duration of each foot was measured, and was then divided by the number of syllables in the foot to obtain the mean syllable duration of that foot. Secondly, the strings of syllables were segmented into "English speaker's feet" (ESF), which began at an ultima or stressed monosyllabic word (i.e. the syllables with acoustic salience that would appear stressed to an English speaker). For each case, all prepausal feet were discarded. Two product-moment correlations were then calculated for each type of foot: the correlation between foot duration and the number of syllables in the foot, and the correlation between mean syllable duration and the number of syllables per foot. The results are shown in Table 14.

Correlation of:	**Welsh speaker's foot**		**English speaker's foot**	
	coeff**.**	significance	coeff**.**	significance
Foot duration/no. of sylls in foot	0.58	0.0001	0.59	0.0001
No. of observations	n = 53		n = 54	
Syll. duration/no. of sylls in foot	-0.51	0.0001	-0.39	0.0033
No. of observations	n = 53		n = 54	

Table 14: Correlation coefficients for two (non-prepausal) foot types

The correlation between foot duration and number of syllables per foot is, not surprisingly, high, positive and highly significant in both cases. The correlation between mean syllable duration and number of syllables per foot is fairly high, negative and highly significant only in the case of the WSF. In the case of the ESF, this correlation is lower and slightly less significant (though sufficiently so as to indicate a real phenomenon). Thus the WSF shows a slightly greater degree of isochrony (the tendency for stressed syllables to recur at equal intervals irrespective of the number of intervening unstressed syllables). This means that, if the penult rather than the ultima is counted as stressed, a greater tendency towards isochrony is seen. It could be said that the prominence of the penult is therefore due less to its intrinsic acoustic properties than to its function as the starting-point of the rhythmic unit, which appears to be crucial for the realisation of stress in Welsh.

5.2.3. Speech perception experiment

5.2.3.1. Motivation

Having located some cues to stress in examples of speech production, one of those cues, the greater duration of the post-stress consonant, was then tested from the point of view of speech perception. It was decided to use resynthesised speech with a controlled continuum of post-stress consonant duration, in a randomised set of stimuli. Listeners would be asked to give stress judgements, which would then be analysed in relation to the duration of the post-stress consonant. Any effect of F_0 pattern on stress judgements would also be analysed, particularly in relation to its possible interaction with the effect of post-stress consonant duration on stress judgements.

A (quasi-)minimal pair of words was chosen, differing only in stress placement: *ymladd*, 'to fight', with stress regularly on the penult, and *ymlâdd*, 'to tire oneself out', with stress exceptionally on the ultima. Because of the fixed nature of Welsh stress location, minimal pairs of this kind are exceedingly rare, and this one arises only because initial *ym-* can function as a stressless reflexive proclitic. The pronunciations are respectively /ˈəmlað/ and /əmˈlɑð/ (in the second word, unlike the first, the vowel of the second syllable is phonologically long).

5.2.3.2. Stimuli

The two target words were recorded, embedded in nuclear position in carrier sentences, by a female native Welsh speaker. A software sound editing package was then used to excise the target words and modify the length of the [m] segment. For each source word, a series of versions was produced where the [m] duration increased from 13 msec to 255 msec in steps of 11 msec or 15 msec (representing an integral number of cycles). Including the original recorded versions, the total number of stimuli was then 40, comprising 20 from each source word. These stimuli were then resynthesised with certain F_0 patterns overlaid (see below) and randomised. Full details are given in Williams (1985).

The spectrum of the vowel of the second syllable was analysed for each source word. It was found that there was effectively no difference in vowel quality between the phonologically long and the phonologically short vowel. There was a durational difference, however: the vowel of *ymlâdd* was 201 ms, while that of *ymladd* was 145 ms, a durational difference that is readily perceptible.

5.2.3.3. Experiment

Three types of F_0 pattern were superimposed on the stimuli, using LPC resynthesis. In the first set (set a), all F_0 variation was cancelled out by superimposing a monotone at 280 Hz on resynthesis (this was similar to the speaker's characteristic frequency). In the second and third sets (b and c) F_0 patterns were manually superimposed using a digitiser pad and associated pen instrument, as detailed below. Since the utterances used as input already had some F_0 variation that differed according to the source word, the resulting F_0 patterns likewise differed according to the source word, as seen in figure 18 below. This would later make it possible to test whether durational cues to stress could completely override F_0 cues in Welsh.

The second set (set b) of F_0 patterns was characterised by a long ultima which either started at the same level as the penult and fell gently (if from original *ymladd*), or began at a lower level than the penult and remained at this level (if from original *ymlâdd*). Thus the ultima could be described as a fall/step-down. The third set (set c) was characterised by a long ultima which either started at a much higher level than the penult and then fell steeply (if from original *ymladd*), or else started at a slightly higher level than the penult and fell gently (if from original *ymlâdd*). Thus the ultima could be described as a step-up and fall.

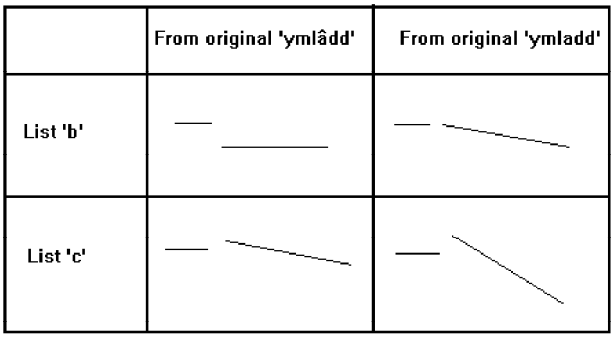

Figure 18: Schematic representation of F_0 contours of stimuli in List b and List c, by source word.

The three sets of stimuli (corresponding to different F_0 patterns) were intended to test the interaction of intonation and word stress perception. In set a (monotone) there was no F_0cue to stress at all, and so this environment provided the most favourable opportunity for the effects of other cues to word stress to be seen. The F_0 pattern of set b (slight fall/step-down) can be interpreted only one way in terms of Welsh intonational categories: as an unstressed syllable followed by a lower-pitched falling nuclear syllable. This pattern would therefore tend to condition the perception of stress

on the second syllable. The pattern of set c (step-up and fall) could be interpreted in two ways according to Welsh intonational categories: either with stress on the first syllable, or with stress on the second. Thus, the list c F_0 pattern does not bias stress judgements in either direction. The performance of non-intonational cues to stress in set c relative to set b would therefore give an indication of the robustness of these cues.

The randomised stimuli were recorded to an experimental tape which was presented to a group of ten native Welsh speakers. The subjects were provided with forced-choice answer sheets on which they had to indicate which of the two possible words they heard in each of the 40 cases. A statistical analysis was carried out on the listeners' stress judgements, grouped by the three F_0 categories (a, monotone; b, fall/step-down; and c, step-up and fall). Since a preliminary check on inter-subject agreement revealed no great discrepancies, all the listeners' results were included in the statistical analysis.

5.2.3.4. Results

There was a significant correlation between the length of the nasal ([m]) and listeners' stress judgements, for all F_0 conditions, such that a stimulus was more likely to be judged as *ymlâdd* (i.e. with stress on the final syllable) the shorter the duration of the nasal. This bears out for speech perception the findings of the earlier work on speech production. The product-moment correlation coefficient between nasal duration and number of final-stress judgements for all three sets of stimuli is given in Table 15, where the first figure in each case is the one for stimuli from source word *ymlâdd* (stress on the final syllable) and the second figure is the one for stimuli from original *ymladd*.

F_0 pattern	**Correlation coeff.**		**Significance (p <)**	
	from *ymlâdd*	**from *ymladd***	**from *ymlâdd***	**from *ymladd***
a (monotone)	-0.84	-0.43	0.0001	0.0577
b (fall/step-down)	-0.40	-0.61	0.0914	0.0042
c (step-up and fall)	-0.53	-0.45	0.0166	0.0442

Table 15: Correlation between [m] length and number of final-stress judgements, by F_0 pattern and source word.

Although the degree of correlation in Table 15 is on the whole not particularly high, the correlations are statistically significant (except for set b from source word *ymlâdd*), and are consistent across most of the three F_0 conditions. This suggests that there was an effect of nasal duration on stress judgements. This post-stress consonant cue to stress is only partially affected by F_0 variation and never completely superseded.

The F_0 patterns alone appeared to influence listeners' stress judgements, as shown by the overall number of final-stress judgements by stimulus set, seen in Table 16.

F_0 pattern	**No. of final-stress judgements**
a (monotone)	188
b (fall/step-down)	229
c (step-up and fall)	203

Table 16: Effect of F_0 pattern on number of final-stress judgements

Since there were 400 possible total judgements (40 stimuli x 10 listeners), the chance level would have been 200 for each set. A chi-square test was performed on each number, and only the one for set b was found to be significantly different from chance ($p < 0.05$). This suggests that there was an effect of F_0 pattern on stress judgements in the case of set b. This list was characterised by

the fact that the F_0 of the final syllable was never higher than that of the penult, contrasting with the situation in set c, where the F_0 of the ultima began at a higher level and then fell to a lower level than the penult (other F_0 differences were not perceptually salient). This suggests that the F_0 pattern effect on judgements for set b was derived from the behaviour of the final syllable.

Another influence on listeners' stress judgements appeared to be the identity of the source word (i.e. which of the two originally recorded words formed the source of the given stimulus word). This influence may be seen in the correlation between source word identity (1 for *ymladd* and 2 for *ymlâdd*) and number of final-stress judgements. This correlation is shown in Table 17.

F_0 pattern:	**Correlation coeff.**	**Significance**
a (monotone)	0.71	0.0001
b (fall/step-down)	0.65	0.0001
c (step-up and fall)	0.85	0.0001

Table 17: Correlation between source word and number of final-stress judgements, by F_0 pattern.

The degree of correlation in each case is higher than for the nasal duration effect, and the significance is higher. There seems to be a clear effect of source word on listeners' stress judgements (however, this did not obliterate the nasal duration effect). The origin of this source word effect on listeners' stress judgements was investigated, and found to be due to the greater duration of the vowel of the second syllable when this was stressed (201 msec as against 145 msec). There was no spectral difference between the vowels, so the source word effect was purely durational in nature.

This effect of the source word on listeners' stress judgements is also the cause of the difference between the correlation coefficients for set a in Table 15 above. Since the F_0 pattern was a monotone, there could not have been any influence of F_0 variation on stress judgements, and hence the cause of the large difference between the correlation coefficients must be the identity of the source word (that is, the duration of the vowel of the second syllable).

5.2.3.5. Conclusions

Three effects on stress judgement have been isolated: the post-stress consonant duration effect, the F_0 pattern effect, and the source word effect. These effects interact, though without completely negating one another. The F_0 pattern effect interacts with the nasal duration effect, in that the latter is largest in set a and smallest in set c (see Table 15). The F_0 pattern effect also interacts with the source word effect, in that the latter is largest in set c and smallest in set b (see Table 17). The source word effect interacts with the nasal duration effect, in that the latter is greater when the source word is *ymlâdd*, with final stress (see Table 15). The F_0 pattern effect may be summarised in Table 18 below.

Set a (monotone):	**Set b (fall/step-down):**	**Set c (step-up and fall):**
F_0 pattern shifts judgements towards initial stress	F_0 pattern shifts judgements towards final stress	F_0 pattern does not affect judgements
Strong [m] duration effect	Moderate [m] duration effect	Weak [m] duration effect
Moderate source word effect	Weak source word effect	Strong source word effect

Table 18: Summary of F_0 pattern effects

It is possible to explain this activity of the F_0 pattern effect in terms of the intonational system of Welsh. A monotone is never found in Welsh speech, and so the F_0 pattern of set a would have been the most confusing for listeners. It would thus have been the most likely to make listeners have recourse to other information, such as the nasal duration effect, or the fact that the initial-stressed

form of this word is the default in Welsh. This could explain why the monotone pattern tended to shift judgements towards the form with stress on the penult.

As regards set b, only one interpretation is permissible in terms of the possible intonational categories of Welsh. If the final syllable were counted as stressed, the word would count as a low falling nucleus preceded by an unstressed syllable, pitch immaterial. If the penult were counted as stressed, the resulting configuration would not be a possible intonational pattern in Welsh (Ceinwen H. Thomas 1967 discusses Welsh intonational patterns). Thus the F_0 pattern of set b heavily biases judgements towards final stress, as seen in the results of the chi-square analysis of Table 16.

In the case of set c, both interpretations are possible in terms of the Welsh intonation system. If the penult is counted as stressed, the resulting pattern is either a very common pre-nuclear pattern, or a fairly common nuclear pattern. If the ultima is counted as stressed, the resulting pattern would comprise a high falling nucleus preceded by an unstressed syllable. Thus the F_0 pattern does not bias stress judgements in either direction, and the durational source word effect comes into its own here. The fact that the source word effect (i.e. the duration of the open vowel) was stronger than the [m] duration effect suggests that vocalic duration is a more salient cue to stress in Welsh than is consonantal duration, and hence that the [m] duration was the weakest cue of all those found. This inference is supported by a comparison of the size of the correlation coefficients in Table 17 with those in Table 15: it is clear that the source word effect (based on a difference in vowel duration) is stronger than the [m] duration effect. The phonological facts of Welsh reflect this situation, in that phonological vowel length is distinctive (though only in stressed syllables), but there is no longer any phonologically distinctive consonant length (although it existed in earlier stages of the language). Thus the post-stress consonant length cue to stress is weaker than the vowel duration cue to stress.

5.2.4. Discussion

5.2.4.1. Interpretation of phonetic cues to stress

In the preceding section it was shown how F_0 and stress perception in Welsh are not directly correlated, but rather filtered through the system of intonational categories provided by the grammar. Unlike English, therefore, it cannot be said that a rise or fall in F_0 automatically cues the perception of stress.

In addition, there are segmental cues to stress that depend for their interpretation on the listener's knowledge of phonetic facts about the language, rather than being in a one-to-one relationship with perceived stress. For example, a longer vowel duration does not automatically cue the perception of stress. Even the longer /ɑ/ of original *ymlâdd* can be overridden by the longest [m] stimuli, cueing penultimate stress perception even on a short schwa vowel (especially under the monotone F_0 of set a). This is possible because the long /ɑ/ could be interpreted by the listener in terms of utterance-final lengthening, which is not significant for stress perception, and also because the penultimate-stressed form is the default provided by the grammar.

It is noteworthy that, in the case where the F_0 pattern gives an unambiguous interpretation of the stimulus in terms of final stress (set b), the two segmental cues are weaker and the intonational cue takes precedence. This suggests that the principal cue to stress placement in Welsh, as in English, is the intonational pattern. However, the post-stress consonant cue is never entirely neutralised, and this forms a different type of stress cue to those seen in languages such as English.

5.2.4.2. The present-day effects of the Old Welsh accent shift

The situation, therefore, is one in which a stressed penult may contain a vowel that is shorter and less intense than the following ultima, but in which stress is signalled by the F_0 configuration and segmental cues such as post-stress consonant lengthening. This contrasts with stress in English, in which a stressed vowel is usually longer and more intense than unstressed syllables in the same word, in which an F_0 peak usually acts as a direct cue to stress, and in which consonantal duration is not particularly significant. The origin of this difference in stress behaviour may be sought in the Old Welsh Accent Shift, mentioned above, during which the word accent shifted from the ultima to the penult in the late eleventh century.

D.M. Jones (1949) has stated that, before the accent shift, Welsh word stress had both a "stress element" and a "pitch element". At the time of the accent shift the stress element shifted to the penult while the pitch element remained on the ultima. This view is supported by the fact that, at least for non-nuclear words, the unstressed ultima often has a higher F_0 than the preceding stressed penult (Ceinwen H. Thomas 1967).

More recently, a Welsh scholar (Alan Thomas 1979) has suggested that it may be necessary to recognise two different types of "accent realisation" in Welsh: rhythmic stress on the penult, and pitch-prominence on the final syllable. This interpretation would fit the findings reported here, where the penult plays an important part in the rhythmic unit while the ultima often has a higher F_0 and is more acoustically salient. There could be some justification for regarding the ultima as "stressed" in a certain sense, as it is the only syllable immune from the morphological process of vowel reduction known as "vowel mutation", whereby certain underlyingly high vowels are reduced to schwa (e.g. *mynydd* 'mountain' /ˈmənɪð/; *mynyddoedd* 'mountains' /məˈnəðɔɪð/, South Welsh pronunciation assumed). This is a relic from the older pattern of stress which is seen in these irregularly inflected forms.

In Welsh, therefore, it is the phonetic realisation of stress which is problematic, rather than its phonological patterning: there are no phenomena such as the backshifting seen in English, since stress location is fixed. However, the older pattern of stress has clearly left traces even in the modern language, and this is seen in the surprising acoustic salience of the supposedly unstressed ultima.

5.2.5. Summary and conclusions

The phonetic nature of Welsh word stress has been investigated, first by measurements of isolated and continuous Welsh words and sentences, and then by a perceptual experiment using synthesised stimuli. The results may be summarised as follows.

Measurements of syllables in isolated words, and in words excised from continuous speech, indicate that stressed penults in Welsh often show less acoustic salience than the supposedly unstressed ultima (stressed monosyllables, which are also acoustically salient, were not independently measured). The next set of measurements (of phonologically short vowels) indicate that stress status does not directly affect vowel length. This means that stress-related duration differences are probably due to distributional features of vowels in Welsh, in particular the fact that schwa may occur only in non-final syllables. The third set of measurements (of consonants) indicate that a consonant after a stressed vowel may be longer than a consonant after an unstressed vowel.

Measurements of syllables in sentences indicate that there is a rhythmic aspect to penultimate stress in Welsh. A greater tendency towards isochrony is seen if the rhythmic foot is taken to begin with a stressed penult, than if it is taken to begin with an unstressed ultima (stressed monosyllables also starting new feet in both cases).

The results of the perceptual experiment build on the results of these measurements. The duration of the consonant after a stressed vowel, previously found in productions of speech, is found also to affect the perception of stress to some extent (the [m] duration effect). Vowel duration likewise affects stress perception, filtered through the listener's knowledge that phonologically long vowels can only appear in stressed syllables in Welsh (the source word effect). Also, the F_0 of the word affects stress perception, as filtered through the listener's knowledge of the available intonation patterns of Welsh (the F_0 pattern effect). Since it is quite possible for a stressed penult to be at a lower F_0 than the unstressed ultima in the same word (in fact, this is a common prenuclear pattern, according to Cenwen H. Thomas 1967) then it is no surprise that the preliminary measurements of syllables are unable to show that higher F_0 is a reliable cue to stress. However, if F_0 is considered in terms of patterns rather than isolated heights, it appears that it is a fairly strong cue to word stress. This is because the only truly unambiguous F_0 pattern (that of set b) shifts judgements to a statistically significant degree (as seen in the chi-square analysis of Table 16). The perceptually weakest cue to word stress appeared to be that of post-stress consonant duration.

Penultimate stress in Welsh is thus associated with shorter overall duration (due to the fact that schwa may appear here but not in the ultima), and also with a longer following consonant, as well as playing an important role in rhythmic patterning. Irregularly-stressed ultimas and stressed

monosyllabic words, on the other hand, have a longer mean duration (since schwa cannot appear in them) and thus pattern more like stressed syllables in English. This confused picture is due to the fact that word stress once fell on the syllable that is now the unstressed ultima (as well as on stressed monosyllabic words). Despite the Old Welsh accent shift, there is still a residue of the old stress pattern. This is due to the restriction on schwa distribution mentioned previously, and to the fact that the unstressed ultima often has higher F_0 than the preceding stressed penult. In Welsh, therefore, it is not the phonological location of word stress that is problematic, but rather its phonetic manifestation.

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