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SELECTED ACOUSTIC FEATURES OF THE WELSH LATERAL FRICATIVE /Ł/

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Abstract:
The Welsh language exhibits a number of features uncommon from a cross-linguistic point of view, one of which is a relatively large number of fricative phonemes. This paper analyses selected acoustic features of the Welsh lateral fricative /ɬ/ in order to contribute to the debate on the laryngeal system in Welsh and the classification of /ɬ/ within that system. Total articulation length, voicing length and SMA parameters of the friction period are measured and analysed on the basis of recordings of 6 native speakers of Welsh. The results confirm the classification of /ɬ/ as a fortis sound proposed in earlier studies (Asmus and Grawunder 2017, Baran forthcoming) and suggest that the Welsh /ɬ/ may exhibit aspiration.

Key words: laryngeal fricative, aspiration, spectral moments, fricatives, Welsh consonants

1. Introduction

Welsh is a p-Celtic language spoken mainly in the British Isles (Watkins 2002, p.289). Because of this geographical placement, Welsh has been in contact with English for around one thousand six hundred years (Filppula, Klemola and Paulasto 2008, p.7). Having been in close contact for such a long time has influenced many aspects of both Welsh and English.[1] The effects of this contact, however, go beyond the languages themselves as they may also be claimed to have shaped the way these two languages are studied and described by linguists. This is particularly visible in the case of Welsh, which, because of enjoying lower prestige than English, was for many years described with theories and terminology that work well for English, but do not fit Welsh and inhibit its successful analyses in a long perspective. The issue of laryngeal distinctions may be used as

[1] It has to be mentioned here, that while English influence on Welsh has never really been disputed, the influence of Welsh on English was marginalised in linguistic research until the emergence of the *Celtic hypothesis* which proposes that Welsh has actually influenced numerous subsystems of English leaving traces going far beyond lexicon (see Filppula, Klemola and Paulasto 2008 for more details).

an example here. For many years, the voiced-voiceless distinction was applied to the analysis of Welsh consonants, which did not allow for an appropriate analysis of such language-central phenomena as morpheme-initial consonant mutations (referred to as mICM in this paper). The situation has changed in recent years, with research projects exploring different possibilities of accounting for consonant differences in the Welsh language (see for instance Asmus and Grawunder 2017; Baran 2020; Baran forthcoming).

The need for separate approaches to Welsh and English is also visible in the issue focal to this paper, i.e. Welsh fricative inventory. The Welsh language, depending on the variety, features up to nine fricative phonemes, i.e. /f, v, θ, ð, s, h, ʃ, χ, ɬ/. Such a high number of fricative phonemes poses two major problems for, what may be called, English-centric analyses. The first issue is the apparent lack of symmetry between the segments grouped in the two series in the laryngeal system. Analyses that are, to some extent, shaped by voiceless-voiced analysis arrive at the conclusion that the Welsh fricative inventory is dominated by voiceless segments, while the voiced ones are far less numerous (see Hannahs 2013, p.16 as an example of such an approach). However, a redesigned model of the Welsh laryngeal system, based on the fortis-lenis distinction (proposed, for instance, in Asmus and Grawunder 2017, Baran 2020 or Baran forthcoming), shows that the system is actually much more symmetrical, which, again, proves that Welsh does not benefit from analysing it as a language that is fundamentally similar to English. Secondly, the Welsh fricative inventory contains two sounds that are foreign to English, i.e. /χ, ɬ/. The English language is typically described as having only labiodental (/f, v/), dental (/θ, ð/), alveolar (/s, z/), postalveolar (/ʃ, ʒ/) and glottal (/h/) fricatives (Roach 2012, p.52). Welsh /χ, ɬ/ are classified as lateral and uvular respectively (Hannahs 2013, p.21), so they are fully alien to English and are unlikely to appear in it, even as allophones. As a result, it is difficult to analyse these sounds in Welsh if one assumes that Welsh and English are similar to each other and that their consonant inventories are structured along comparable principles. This may, potentially, be the reason for the fact that these two sounds have received very little attention in acoustic phonetics research on Welsh, which results in limited knowledge on these sounds.

The Welsh lateral fricative /ɬ/ is claimed to be the best-known example of a lateral fricative phoneme cross-linguistically (Ladefoged and Maddieson 1996, p. 203). However, as previously mentioned, apart from being studied along other Welsh fricatives in a few acoustic phonetic studies (see for example Jones, 1984; Ball and Muller 1992; Jones and Nolan 2007; Asmus and Grawunder 2017), it has not been a sole focal point of an acoustic study yet. As a result, the body of knowledge on this segment is limited by methodological choices of the aforementioned studies such as focusing on one word-position only or using a narrow range of phonetic cues to study the sounds. Therefore, it seems that this paper may open a debate leading to the filling of this gap in the description of the

Welsh lateral fricative and subsequently contribute to the ongoing research on issues that are relevant to the whole Welsh consonant inventory.

The research conducted for this paper is a part of a bigger project focused on verifying and improving the existing phonetic and phonological descriptions of Welsh consonants. The methodology used here has been developed on the basis on one of the earliest outputs of this project, i.e. the study by Asmus and Grawunder (2017) that was later followed by papers discussing various aspects of laryngeal contrasts in Welsh (see for instance Asmus, Jaworski and Baran 2019, Baran 2020, Jaworski and Baran 2021). Research conducted so far suggests that Welsh consonants are best organised as being divided into fortis and lenis series which are phonetically distinguished based on acoustic cues such as aspiration or total segment length rather than based on phonetic voicing as it appears to be inconsistent and accidental.

As the study by Asmus and Grawunder study (2017) classifies the Welsh lateral fricative /ɬ/ as a fortis sound on the basis of mICM-mirroring phonological contrast with /l/ marked phonologically by coda and preceding vowel length, it seems reasonable to expand this analysis by adding data on acoustic features of /ɬ/ in word-initial position to further confirm the aforementioned classification. Moreover, the initial screening of recordings analysed here revealed a number of realisations in which spectrograms of /ɬ/ contain patterns of acoustic energy concentration characteristic of aspiration. This observation does not find confirmation in previous research on that segment as none of the previous studies confirmed surface aspiration in the Welsh /ɬ/. Taking into consideration the fact that aspiration is contrastive in Welsh plosives, it is interesting to see if it also surfaces in /ɬ/ - a sound of a different manner of articulation. Answering this question may help to decide if aspiration of /ɬ/ in Welsh should be studied further or not.

2. Theoretical background

The aim of this section is to discuss three key elements of the theoretical background of this study. Firstly, section 2.1 introduces lateral fricatives as a class of sounds seen from a cross-linguistic perspective, discussing some of the common features in the group, together with areas in which specific phonemes show variety. Then, section 2.2 introduces what is currently known about the phoneme that is studied in this paper, i.e. the Welsh laryngeal fricative /ɬ/. Finally, section 2.3 discusses spectral properties of fricatives as spectral analysis is the approach used in this paper to study the aspirated realisations of the Welsh /ɬ/.

2.1. Lateral fricatives in the world's languages

Ladefoged and Maddieson (1996) devote a whole chapter to a discussion of lateral sounds, focusing not only on the cross-linguistically most popular lateral phonemes, but discussing the less popular ones as well. The next two paragraphs provide an overview of the most important claims these two authors make regarding lateral fricatives (Ladefoged and Maddieson 1996, pp.198-210).

Even though the class of lateral phonemes is dominated by ones that are approximant in manner and voiced in terms of laryngeal setting, there are other lateral segments that are significantly different from this *prototypical* laryngeal phoneme (Ladefoged and Maddieson 1996, p.198). The first area where some variety is observed in lateral sounds is phonation type. Phonation type is to some extent relevant for this study. Even though, as previously mentioned, laryngeal sounds are mostly voiced, they may also be voiceless, breathy voiced or laryngealised (Ladefoged and Maddieson 1996, p.198). It should be remembered, however, that these voiceless, breathy voiced or laryngealised laterals are still approximants as far as manner of articulation is concerned. Interestingly, a q-Celtic language, Irish, is given as one of examples of languages that contrast voiced approximant laterals with the voiceless ones (Ladefoged and Maddieson 1996, p.198). This may be seen as a suggestion that Celtic languages do allow for more variety in lateral phonemes than other languages, which is important for this study.

The issue of voicelessness in laterals appears to be somewhat intertwined with varying manner of articulation. This is so, because, as Ladefoged and Maddieson (1996, p.198) note “in the case of a substantial number of other languages the available descriptions do not specify if the voiceless laterals occurring in them are approximant or fricative in nature.” The two authors suggest solving this typological problem, by limiting the term approximant to the voiceless laterals that are pronounced with an opening similar to the one in voiced lateral approximants, while voiceless laterals pronounced with openings smaller than the one typically seen in approximants are analysed as fricatives. This is supported by experimental data that shows that, in comparison to voiceless lateral fricatives, voiceless lateral approximants exhibit a lower amplitude of noise, are more likely to be influenced by the voicing of a following vowel and feature acoustic energy concentrated in lower parts of the spectrum (see Maddieson and Emmorey 1984 for a more detailed discussion). Nevertheless, the question still remains relevant as modern studies try to determine the actual manner of articulation of voiceless laterals in language-specific contexts. For instance, Asu, Nolan and Schötz (2015) conducted a phonetic study to check if voiceless laterals in Estonian Swedish are approximants or fricatives. Their findings suggest that it is actually difficult to assign the Estonian Swedish voiceless lateral to either of the categories as it conclusively follows neither the pattern of the Welsh /ɬ/ seen there as a voiceless lateral fricative, nor the pattern of the Icelandic /l̥/ seen as a voiceless lateral approximant. The authors conclude that their findings should lead to questioning the standard way of thinking about the concept of a phoneme within IPA system specification.

The other issue central for this paper discussed by Ladefoged and Maddieson (1996) is the possible variation in stricture of lateral phonemes. The authors mention that apart from lateral approximants, there are also lateral fricatives, affricates, flaps or taps (Ladefoged and Maddieson 1996, p.202). Out of these four groups, only lateral fricatives are directly relevant for this paper. As mentioned in the introduction, Ladefoged and Maddieson (1996, p.203) see the Welsh /ɬ/ as the best-known example of a voiceless lateral fricative. The observations on this sound are discussed in detail in section 2.2, devoted fully to the Welsh /ɬ/. Apart from the Welsh voiceless lateral fricative, Ladefoged and Maddieson (1996, pp. 203-210) also report examples of such a sound in Bura, Diegueño, Pashto, Taishan Chinese, Zulu or Archi. The two authors do not make any comments on the common acoustic characteristics of voiceless lateral fricatives in these languages. Voiceless lateral fricatives are still interesting to phoneticians which is reflected in a number of modern phonetic studies devoted to these sounds. Two such studies, one on the Kuman voiceless velar lateral fricative by Steed and Hardie (2004) and the other on the Estonian Swedish lateral /ɬ/ by Schötz, Nolan and Asu (2015) are summarised below.

Steed and Hardie (2004) studied the Kuman voiceless lateral fricative with a specific focus on the F-pattern and unusual features of articulation. Interestingly, they use /ʟ̥/ to refer to the sound under review. The authors claim that the voiceless fricative allophone of the velar lateral in Kuman is an allophone occurring in the syllable coda. The analysis focused on a recording of one speaker and was intended to be an initial step in studying Kuman phonetics. The authors measured time-domain features and frequency-domain features of the sound under review. The study revealed that in the case of that particular speaker, the velar lateral fricative exhibits F-pattern features that are strongly influenced by its prevocalic environment. Additionally, the study suggested that, in many realisations, there is extrinsic pre-stopping manifested as ‘a period of low amplitude periodicity followed by a transient reflecting a closure opening up to the lateral fricative segment’ (Steed and Hardie 2004, p.351).

Schötz, Nolan and Asu (2015) studied the voiceless lateral /ɬ/, a rare phoneme in Swedish, exhibited mainly in Estonian Swedish. The aim of the study was to analyse the Estonian Swedish /ɬ/ phonetically and compare it both to the Icelandic /ɬ/ and other laryngeal consonants of Estonian Swedish. Estonian Swedish has four lateral phonemes, i.e. a voiced dental/alveolar lateral /l/, a voiced supradental lateral /ɭ/ appearing in the context /r/ + /l/, a voiced retroflex lateral flap /ɽ/ and a voiceless alveolar lateral fricative /ɬ/ (Schötz, Nolan and Asu 2015, p.23). The aforementioned goals were achieved by recording six elderly speakers of Estonian Swedish and then analysing their speech with a specific focus on the phonetic properties of /ɬ/. The results of the study lead the authors to a number of conclusions, i.e. (i) the Estonian Swedish /ɬ/ is a single consonant rather than a cluster, (ii) it exhibits some tendencies to anticipate the voicing of the following sound, (iii) the intensity of the Estonian Swedish /ɬ/ is comparable to that of a corresponding sound in Icelandic, (iv) the Estonian Swedish /ɬ/ is phonemic and may be realised both as short and long.

2.2. Lateral fricative /ɬ/ in Welsh

As mentioned in the introduction, the Welsh lateral fricative /ɬ/ has not yet been the sole subject of a phonetic study. It has, however, been analysed by larger studies, both of phonetic and phonological nature. This section summarises selected studies to show what is already known about this sound and highlight the areas that need further analysis.

Jones (1984) in a paper devoted to presenting an overview of the Welsh consonant inventory provides descriptions of Welsh consonants, focusing on articulation and distributional features. He claims that /ɬ/ is created by the articulatory gesture that involves making contact between (i) the tip and blade of the tongue and the upper alveolar ridge, and (ii) the rims of one side of the tongue with the upper side teeth. This results in creating friction that is voiceless (Jones 1984, p.47). Jones (1984) does not discuss potential variation in the laryngeal setting of the sound under review, so there is no discussion of potential aspiration appearing in some realisations. As far as distribution is concerned, /ɬ/, according to Jones (1984, p. 48), may appear in initial, medial and final position in citation forms in Welsh.

Hannahs (2013), in his book intended to be a comprehensive account of Welsh phonology, provides, like Jones (1984), descriptions of Welsh consonants. /ɬ/, listed with fricatives, is described as a voiceless lateral fricative and is claimed to appear in word-initial, word-medial and word-final position (Hannahs 2013, pp.16-17). As with Jones (1984), no claims regarding possible variation withing the /ɬ/ phoneme are made, so there is no discussion of potential aspiration either.

The paper by Jones and Nolan (2007) is probably the closest one methodologically to this study. The two authors aimed to provide the reader with an acoustic study of place of articulation contrasts of the North Welsh voiceless fricatives, reporting data on /f, θ, s, ʃ, ɬ, χ/. The study was based on recordings of five native speakers of North Welsh. The target sounds were placed in word-initial position of mostly monosyllabic words with a low vowel. The authors reported results for amplitude, duration and COG (centre of gravity) of the six Welsh voiceless fricatives. Not all the results and conclusions of the study are relevant for this paper, but there are a number of relevant claims regarding /ɬ/. First of all, Jones and Nolan (2007, p.875) claim that COG of /ɬ/ is lower than those of /s/, /f/ and /θ/, but higher than those of /ʃ/, /χ/. Secondly, in terms of relative amplitude, /ɬ/ forms a pair with /χ/, exhibiting results that are lower than those of /s/ and /ʃ/, but higher than those of /f/ and /θ/ (Jones and Nolan 2007, pp.874-875). Finally, as far as relative duration is concerned, /ɬ/ seems to be longer only than /f/, while the remaining four voiceless fricatives exhibit longer relative duration (Jones and

Nolan 2007, p.874). Again, like Jones (1984) and Hannahs (2013), there are no remarks regarding potentially aspirated realisations of the Welsh /ɬ/.

Asmus and Grawunder (2017) studied Welsh vowel length in monosyllables and revealed that there is a pattern wherein fortis consonants are preceded by short vowels while lenis consonants are preceded by long vowels. /ɬ/, described there as a fortis lateral fricative, behaves similarly to other fortis sounds in that it is preceded by short vowels (Asmus and Grawunder 2017, p.34). Some irregularities are thought to result from the fact that the fortis-lenis contrast between /ɬ/ and /l/ is no longer a well-defined one in coda position. This finding is not in line with what had been previously claimed about the length of Welsh vowels. Awbery (1984, pp.66-71), for instance, claims that there are long vowels preceding /ɬ/, but allows for dialectal variation, i.e. long vowels preceding /ɬ/ in South Welsh and short vowels preceding /ɬ/ in North Welsh. Similar claims may be found in studies by Schrijver (see for instance Schrijver 1995). Asmus and Grawunder's (2017) study does not mention any potential variation of the Welsh /ɬ/, but its theoretical assumptions allow for it. If /ɬ/ is considered fortis, then it may be expected to exhibit some articulatory similarities to other fortis sounds such as fortis plosives or other fortis fricatives. Therefore, as it has been shown that aspiration is of considerable importance in marking the fortis-lenis contrast in Welsh plosives and its influence was not ruled out for fricatives (see, for instance, Baran 2020), aspiration of the Welsh /ɬ/ is possible from a theoretical point of view, and, as such, should be studied phonetically.

2.3. Spectral properties of fricatives

The potential aspiration of the Welsh fricative /ɬ/ is analysed in this paper with the use of SMA (spectral moments analysis). In order to provide the reader with the necessary theoretical background of this methodology, this section presents brief definitions of the four key spectral moments, i.e. centre of gravity (COG), spectral standard deviation, skewness and kurtosis.

As described by Lee (2020, p.148), SMA is regarded as a quantification method that systematically analyses the acoustics of speech in the spectral domain. The first of the four key spectral moments in SMA is COG also referred to as spectral mean. It may be defined as "the simple average of distributed energy in the spectrum" (Lee 2020, p.148) and may be used to determine where the biggest concentration of energy within the spectrum occurs. The second spectral moment, spectral standard deviation or variance shows 'the amount of variance in terms of mean' (Lee 2020, p.148). The third spectral moment, skewness may be used to analyse "the degree to which the amount of energy accumulated at either end of the distribution" and its positive values represent higher energy concentration at lower frequency while negative values point to higher energy concentration at higher frequency (Lee 2020, p.148). Finally, the fourth spectral moment analysed in SMA is kurtosis. It may be defined as a measure of peakness of distribution wherein higher values point to a highly peaked distribution and lower values indicate the flat distribution of values (Lee 2020, p.148).

3. The study

3.1. Methodology

For the purposes of the study, 6 native speakers of North Welsh, who use their language at home and at work, were interviewed between 2013 and 2018. The study included three male and three female speakers whose age ranged from 19 to 71 years old. The analysis was undertaken both in the onset and coda of monosyllabic native lexemes currently in use. The lexemes and reading list were taken from previous corpora (Asmus and Grawunder 2017). The reading list was created by putting the target lexemes in the carrier phrase *Dw i heb ddweud X ond Y!* 'I didn't say X but Y!' and were ordered in such a way that every lexeme appears in the recording twice in strong and twice in weak prosodic position. As a result, the reading list allowed the elicitation of 20 realisations of /ɬ/ in every context under review (word-initial weak prosodic position, word-initial strong prosodic position, word-final weak prosodic position and word-final strong prosodic position) per speaker.

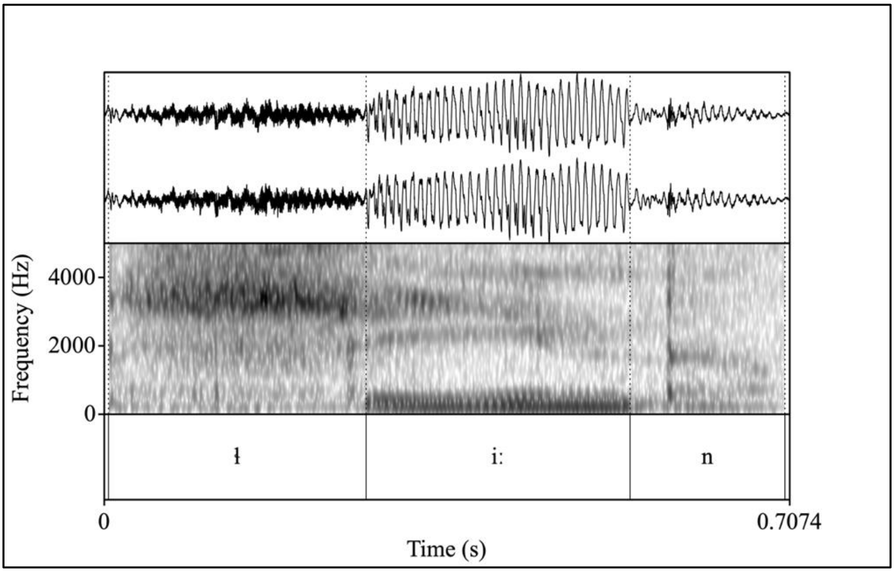
During the recording session, the speakers were seated 30 centimetres from a microphone connected to a laptop running Praat, used to record the speech of the participants. The recordings were not altered by resampling, preemphasising or filtering. The influence of these procedures on the results is going to be investigated in the forthcoming studies on the issue under review here as this preliminary study of the Welsh /ɬ/ is intended as the first step in studying laryngeal specification and potential acoustic variation of this phoneme.

The recordings made in the way described above were later analysed with Praat (Boersma and Weeink, 2019). Total articulation length was measured from the point where the friction started to the point where the articulation of following vowel began (word-initial position) or to the point where friction ceased (word-final position). These three articulatory events were identified on the basis of a visual inspection of the spectrogram.

Phonetic voicing length was measured from the point where Praat detected pulses associated with glottal folds vibration to the point where these pulses disappeared or to the point where the articulation of the following vowel started. Similarly to the procedure of measuring total articulation length, the procedure of measuring phonetic voicing length also identified the key articulatory events on the basis of a visual inspection of the spectrogram.

The procedure of the SMA was more complex than those of the previous two measurements. Firstly, the target words with /ɬ/ in word-initial and word-final position were isolated from the recordings. Then, based on visual inspection[2], the parts of *clean* friction and *clean* friction accompanied by aspiration were identified. *Clean* friction is here understood as friction resulting from the acoustic gesture of /ɬ/ described in detail in section 2.1 and is referred to as F period in the rest of this paper. *Clean* friction accompanied by aspiration is here understood as a period in articulating the sound wherein friction resulting from the acoustic gesture of /ɬ/ is accompanied by energy concentrated in lower parts of the spectrum, characteristic of aspiration. In the remaining part of this article, *clean* friction accompanied by aspiration is referred to as A period. To illustrate the distinction between F and A periods, Figure 1. below presents the annotated waveform and spectrogram of the word *llun* 'picture' pronounced by Speaker 3.

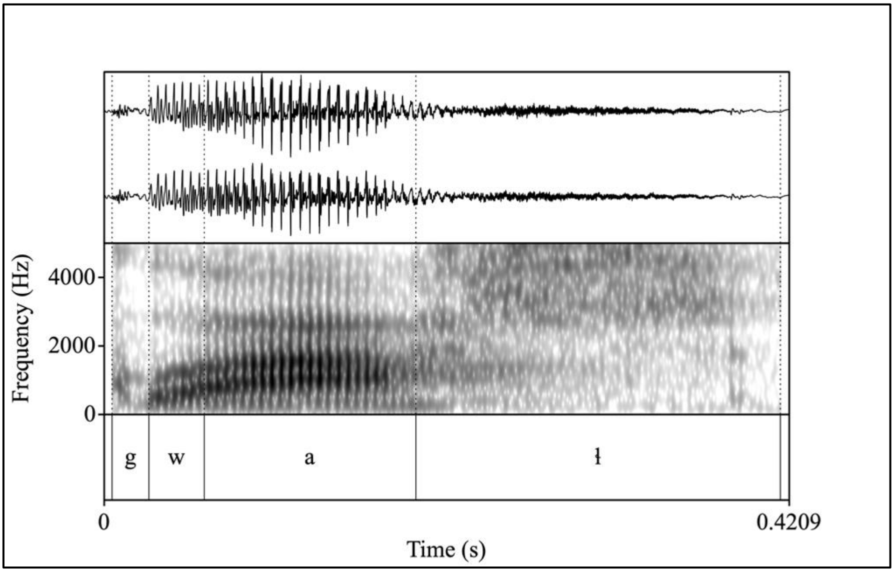
Figure 1. The annotated waveform and spectrogram of the word llun 'picture' pronounced by Speaker 3 in strong prosodic position



In the realisation presented in Figure 1., the target sound /ɬ/ is pronounced in word-initial position. The acoustic energy below 2,500 Hz visible in the very last stage of /ɬ/ is here considered to be the A period, while the rest of the sound is considered to be the F period. To demonstrate the visual interpretation of the spectrogram in word-final position, Figure 2. below presents the annotated waveform and spectrogram of the word *gwall* 'mistake' pronounced by Speaker 1.

[2] In the case of SMA, segmenting realisations of /ɬ/ on the basis of a visual inspection is not an ideal methodological choice as it may significantly influence the results of the SMA. This is why these initial results have to be further verified in studies featuring other ways of segmenting the realisations under review such as using time frames of a regular length.

Figure 2. The annotated waveform and spectrogram of the word gwall 'mistake' pronounced by Speaker 1 in strong prosodic position



The realisation presented in Figure 2. above features the target sound /ɬ/ pronounced in word-final position. Similarly to the example in Figure 1., there is acoustic energy below 2,500 Hz concentrated near the end of this sound and it is considered to be the A period. The remaining part of the sound is the F period. Following the identification of the two periods of articulation in each realisation of /ɬ/, spectral slices were generated for both periods. Spectral slices were generated by an automated command in Praat using the default settings. SMA of the spectral slices was then conducted with a Praat script written by the author of this study that calculated COG, spectral standard deviation, skewness and kurtosis for the spectral slices using the default settings given in Praat.

Figures 3. and 4. Below show spectral slices of F and A periods respectively for the word-initial /ɬ/ in the word *llun.*

Figure 3. Spectral slice of the F period of the word-initial /ɫ/ in llun

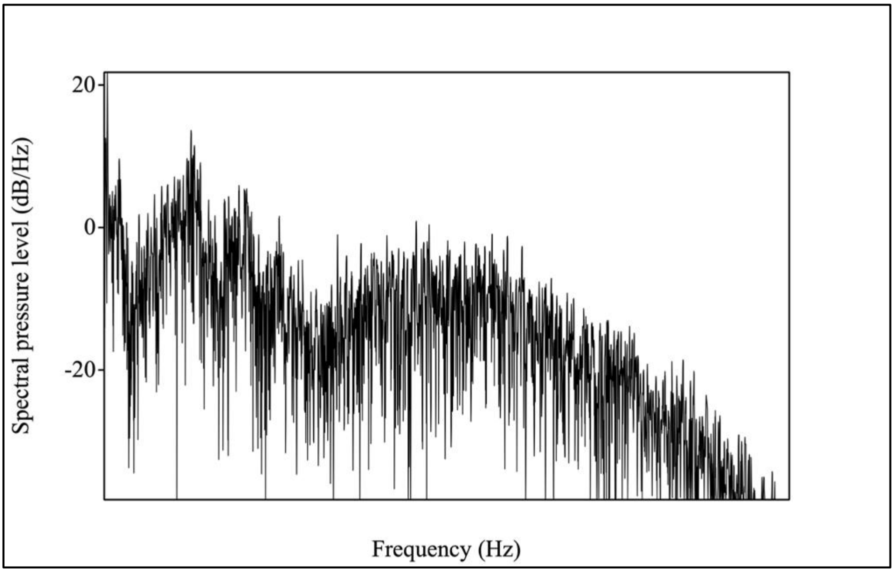
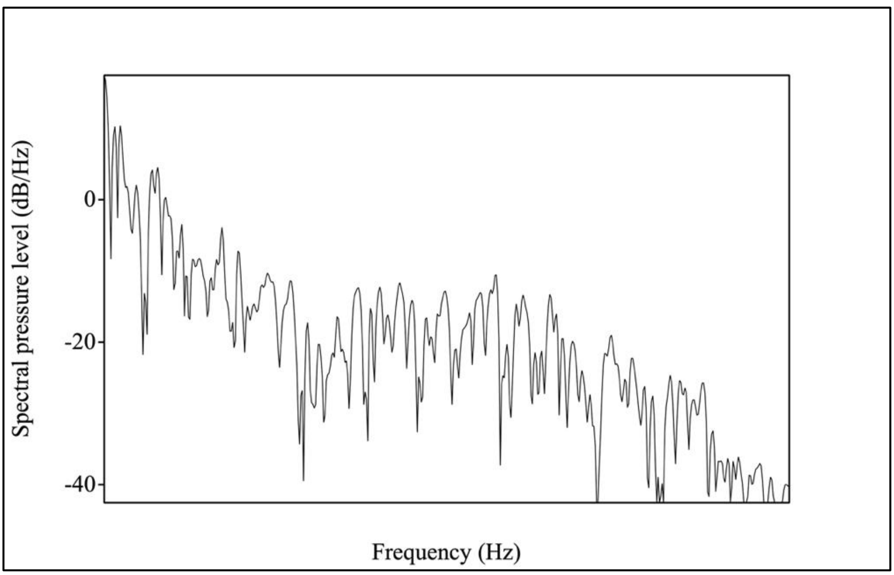


Figure 4. Spectral slice of the F period of the word-initial /ɫ/ in llun



The difference between the spectral slices visible above was later confirmed by SMA as COG of the spectral slice from Figure 3. is 2,791 Hz, while COG of the spectral slice from Figure 4. is 623 Hz. The same is demonstrated for word-final /ɫ/ in *gwell* in Figure 5. showing the spectral slice of the F period and Figure 6. showing the spectral slice of the A period.

Figure 5. Spectral slice of the F period of the word-final /ɬ/ in gwell

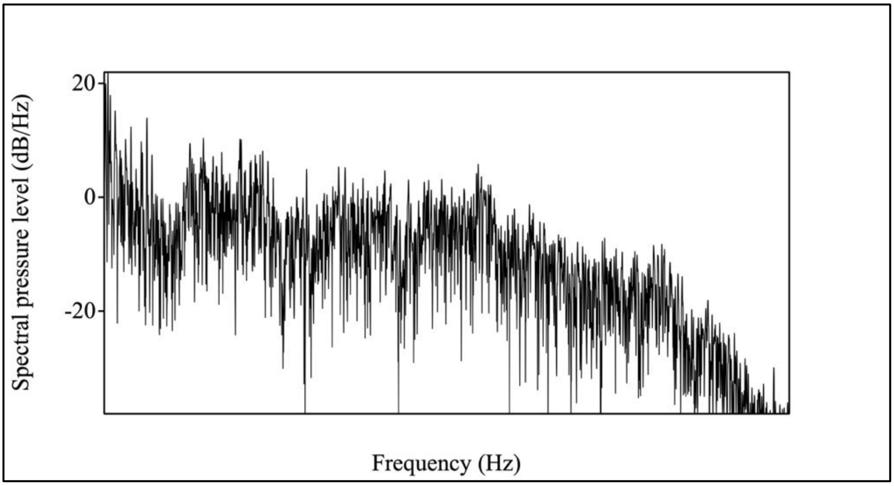
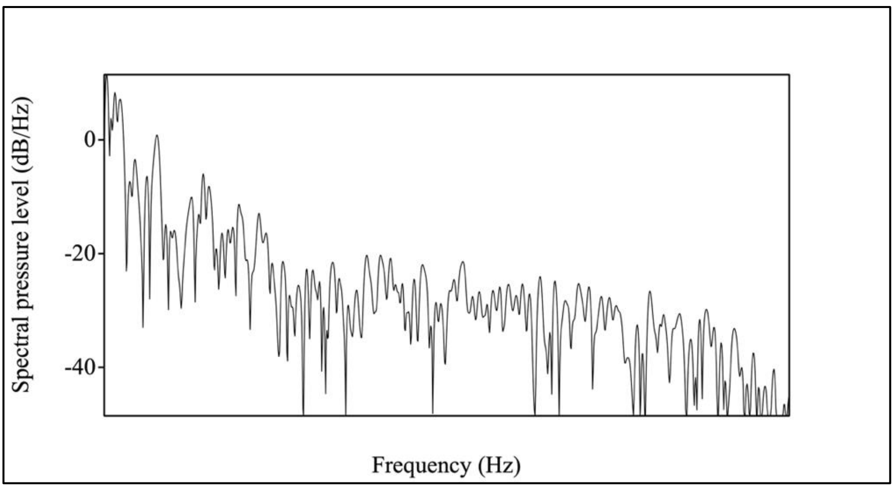


Figure 6. Spectral slice of the A period of the word-final /ɬ/ in gwell



Similarly to the situation in word-initial position, the difference between the two spectral slices is reflected in SMA as the F period has COG of 3,145 Hz, while the A period has COG of 574 Hz.

Having conducted the SMA in the way described above, it was possible to distinguish between the realisations in which SMA confirmed the presence of aspiration postulated on the basis of visual inspection and those in which the presence of aspiration predicted on the basis of visual inspection was disproved by SMA. As in the sound under review here, the potential aspiration overlaps with friction of /ɬ/, it impossible to impose cut-off points on the basis of the typical

COG values of glottalic friction. As a result, the realisations in which COG of the A period was lower than that of the F period were interpreted as aspirated here.

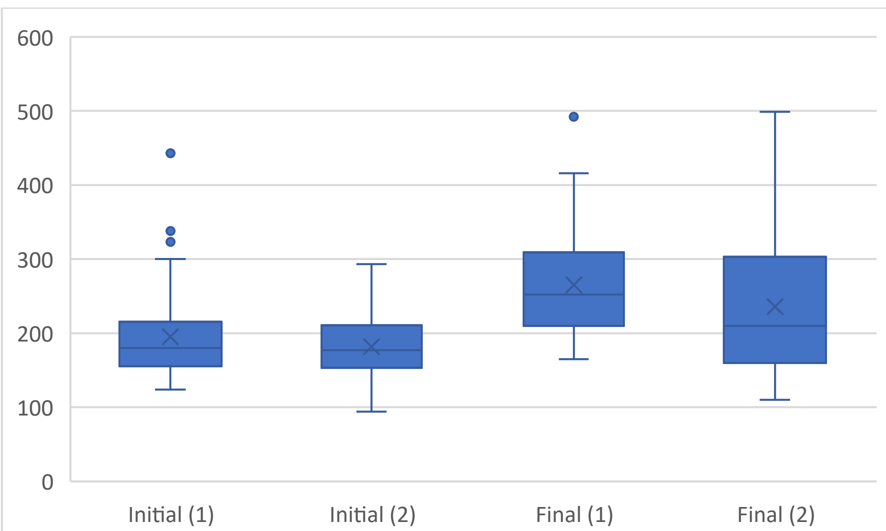
3.2. Results

The aim of this section is to present the results of (i) total articulation and phonetic voicing length measurements and (ii) SMA. The results of (i) are discussed in Section 3.2.1. which allows for a comparison with similar durational measurements of other Welsh consonants from the study by Baran (forthcoming). The results of (ii) are discussed in Section 3.2.2.

3.2.1. Total articulation length and voicing length

The analysis of total articulation length is conducted separately in word-initial and word-final position. Additionally, in each of these positions, two prosodic positions are taken into consideration, i.e. strong and weak. Figure 7. below presents box and whisker plots of total articulation length of /ɬ/ in four configurations, i.e. word-initial strong prosodic position, word-initial weak prosodic position, word-final strong prosodic position and word-final weak prosodic position.

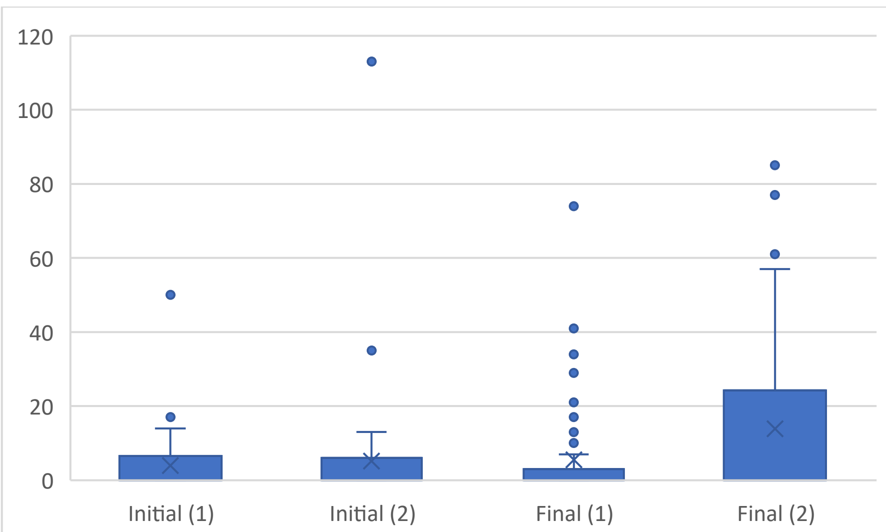
Figure 7. Total articulation length of /ɬ/ in word-initial strong prosodic position (Initial (1)), word-initial weak prosodic position (Initial (2)), word-final strong prosodic position (Final (1)) and word-final weak prosodic position (Final (2))



Overall, total articulation length of the Welsh lateral fricative /ɬ/ falls between 100 and 500 milliseconds. It is visible that the sound under review is longer in word-final position than in the word-initial one. Moreover, weak prosodic position realisations are slightly shorter than the ones in the strong one. As a result, /ɬ/ is the shortest in word-initial weak prosodic position realisations with the average total articulation length of 182 milliseconds. The word-initial strong prosodic position realisations are slightly longer with the average total articulation length of 195 milliseconds. Word-final weak prosodic position realisations exhibit the average total articulation length of 236 milliseconds. Finally, word-final strong prosodic position realisations are the longest with the average value of 265 milliseconds.

Phonetic voicing length is the other measurement discussed in this section. Figure 8. below presents box and whisker plots of phonetic voicing length in /ɬ/ in four configurations, i.e. word-initial strong prosodic position, word-initial weak prosodic position, word-final strong prosodic position and word-final weak prosodic position.

Figure 8. Phonetic voicing length in /ɬ/ in word-initial strong prosodic position (Initial (1)), word-initial weak prosodic position (Initial (2)), word-final strong prosodic position (Final (1)) and word-final weak prosodic position (Final (2))

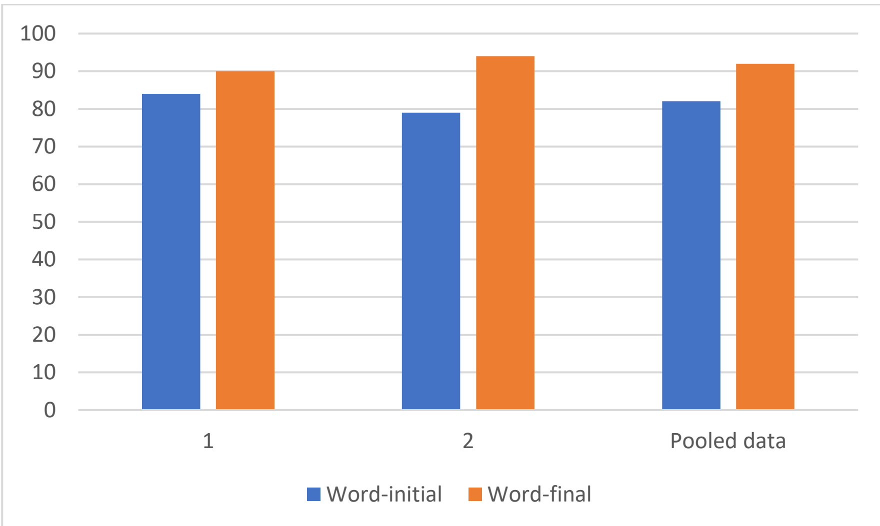


In the realisations of the Welsh /ɬ/ analysed in this paper phonetic voicing length takes from 0 milliseconds to more than 60 (but not more than 113) milliseconds of the total articulation length. Phonetic voicing length in word-initial strong prosodic position, word-initial weak prosodic position and word-final strong prosodic position is very short with average values of 4, 5 and 6 milliseconds respectively, while word-final weak prosodic position realisations exhibit phonetic voicing length of 14 milliseconds on average. It is, therefore, visible that phonetic voicing length forms a different position pattern than total articulation length.

3.2.2. SMA

Distribution of the aspirated realisations in general and in individual speakers' pronunciation are the first two aspects that can be studied with the data collected in this part of the experiment. Figure 9. below shows the percentage of realisations interpreted as aspirated in word-initial and word-final position.

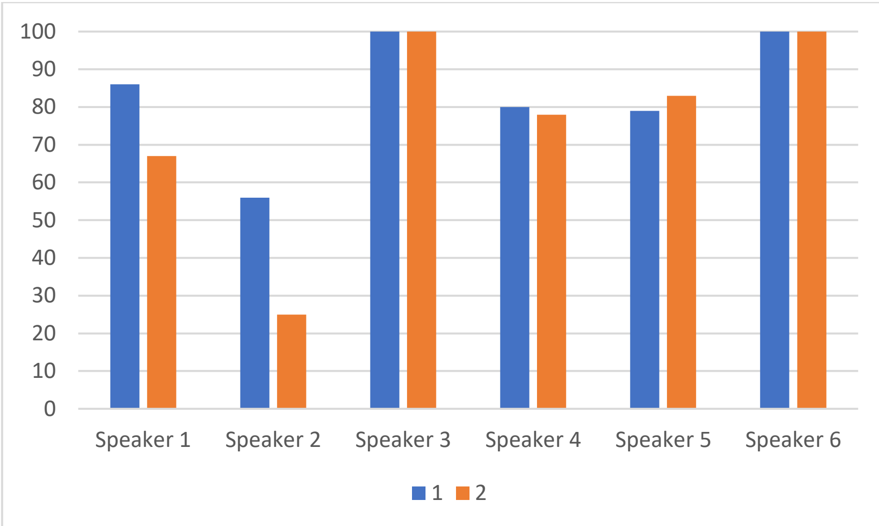
Figure 9. Percentage of realisations interpreted as aspirated in word-initial and word-final position in strong (1), weak (2) prosodic position and in pooled data



As shown above, the majority of realisations are interpreted as aspirated, regardless of the position within the word and the prosodic position. A closer look at the data reveals, that aspirated realisations are more common in word-final position. Word-initial realisations are aspirated in 84 per cent of cases in strong prosodic position, 79 per cent of cases in weak prosodic position and 82 per cent of cases in polled data. In contrast, word-final realisations are aspirated in 90 per cent of cases in strong prosodic position, 94 per cent of cases in weak prosodic position and 92 per cent of cases in polled data.

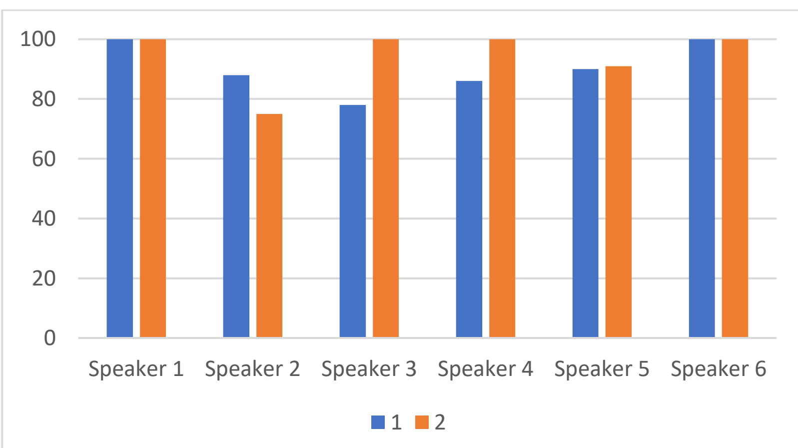
Speakers differ in terms of the distribution of aspirated realisations in their speech. To demonstrate that, Figure 10. below shows percentage of realisations interpreted as aspirated in word-initial realisations of Speakers 1-6.

Figure 10. Percentage of realisations interpreted as aspirated in word-initial position in strong (1) and weak (2) prosodic position pronounced by Speakers 1-6



On the basis of the analysis displayed above, one may distinguish between three types of Speakers as far as distribution of aspirated realisations is concerned. There are speakers (3 and 6) whose realisations are all interpreted as aspirated. Then, there are speakers whose realisations are aspirated in 67 to 86 per cent of cases (1, 4 and 5). Finally, Speaker 2 is the one with the lowest percentage of realisations interpreted as aspirated in both prosodic positions; in this case the difference between the two prosodic positions is the most visible.

Figure 11. Percentage of realisations interpreted as aspirated in word-final position in strong (1) and weak (2) prosodic position pronounced by Speakers 1-6



In word-final position, two types of speakers may be distinguished. The first type of speaker (1 and 6) produces aspirated realisations in 100 per cent of cases, regardless of the prosodic position. The second type of speaker (2, 3, 4 and 5) produces aspirated realisations in 75 to 100 per cent of cases and the distribution varies depending on the prosodic position. Interestingly, only Speaker 6 exhibits the same tendencies in word-initial and word-final position, while others fall into different categories depending on the position.

Another aspect to be discussed on the basis of the collected data in this part of the study is actually the focal one for this paper and it is the SMA of the realisations that are identified as aspirated. As mentioned earlier , four spectral moments are analysed here, i.e. COG, spectral standard deviation, skewness and kurtosis. Figure 12. shows box-whisker plots of COG values in word-initial realisations of /ɫ/ identified as aspirated.

Figure 12. Box-whisker plots of COG values of F (COG F) and A (COG A) periods in word-initial realisations of /ɫ/ in strong prosodic position (1) and weak prosodic position (2) and in pooled data (P)

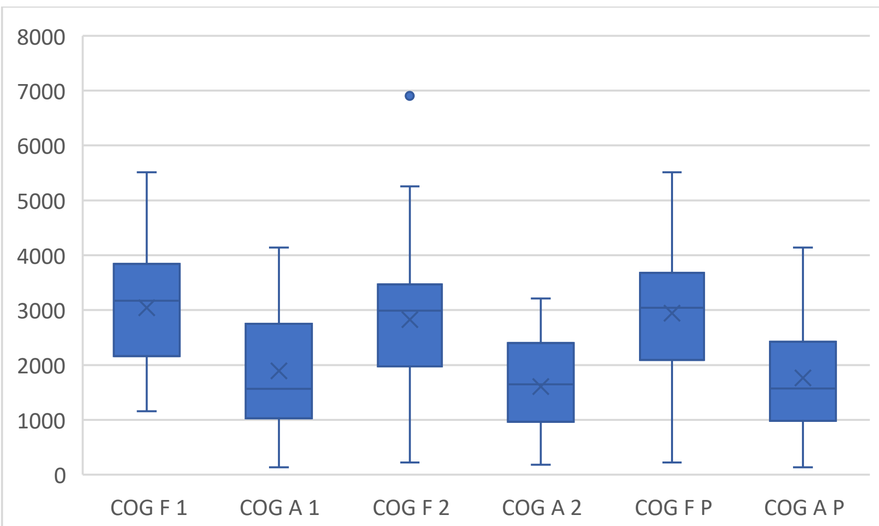
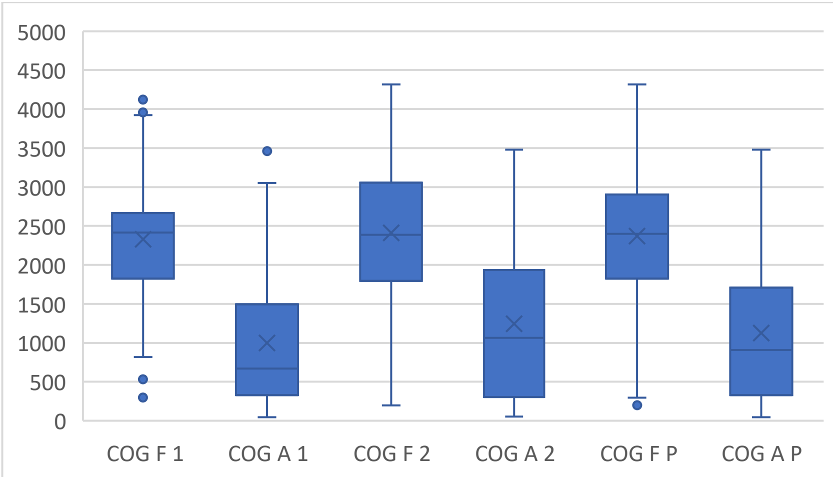


Figure 12. clearly shows that, regardless of the prosodic position, the parts of /ɫ/ articulation identified as A period have lower COG values than the ones identified as F period. A periods exhibit an average COG of 1894 Hz in strong prosodic position, 1610 Hz in weak prosodic position and 1765 Hz in pooled data, while F periods have average COG values of 3044 Hz, 2826 Hz and 2945 Hz respectively. It may also be noticed that weak prosodic position causes the COG values to be lower in both periods under review.

Figure 13. below shows box-whisker plots of COG values in word-final realisations of /ɫ/ identified as aspirated.

Figure 13. Box-whisker plots of COG values of F (COG F) and A (COG A) periods in word-final realisations of /ɬ/ in strong prosodic position (1) and weak prosodic position (2) and in pooled data (P)



In word-final position, the difference in average COG values between F and A periods is also visible regardless of the prosodic position with the former values being higher than the latter. F periods have an average COG of 2329 Hz in strong prosodic position, 2411 Hz in weak prosodic position and 2372 Hz in pooled data, while A periods have average COG values of 996 Hz, 1246 Hz and 1124 Hz respectively. In word-final position, it is the weak prosodic position that seems to promote realisations with higher COG values. Finally, it may also be claimed that the differences between the average COG values of the two periods are more pronounced in word-final position than in word-initial.

Spectral standard deviation is the second of the four spectral moments analysed in this part of the study. Figure 14. below presents box-whisker plots of spectral standard deviation in word-initial realisations of /ɬ/ identified as aspirated.

Figure 14. Box-whisker plots of spectral standard deviation (StDev) values of F (StDev F) and A (StDev A) periods in word-initial realisations of /ɫ/ in strong prosodic position (1) and weak prosodic position (2) and in pooled data (P)

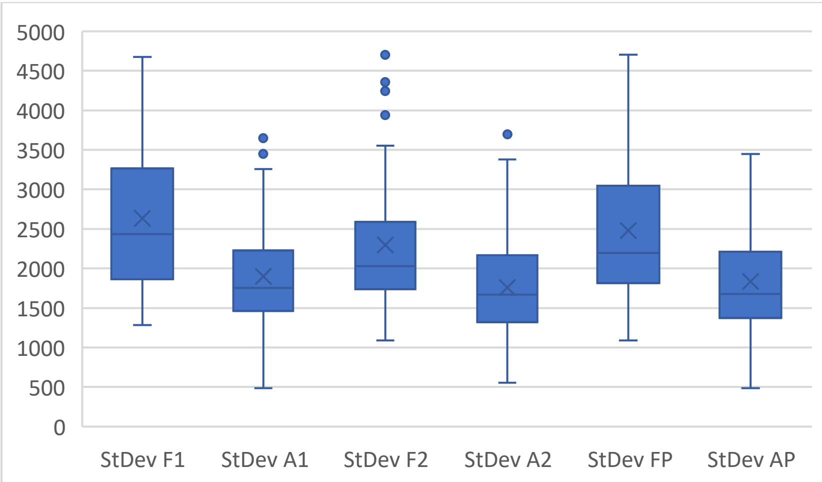
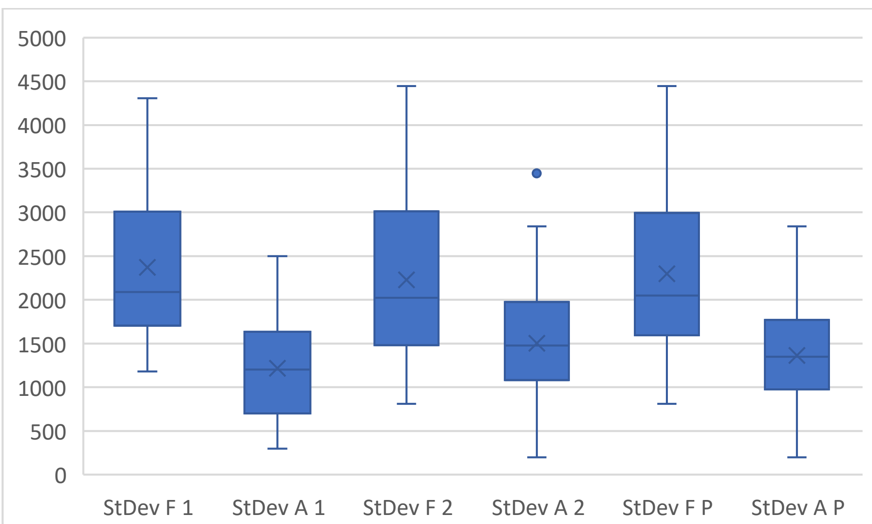


Figure 14. shows that, regardless of the prosodic position, A periods exhibit lower values of spectral standard deviation than the F periods. It may also be noticed that the values are most diverse in F periods of /ɫ/ pronounced in strong prosodic position.

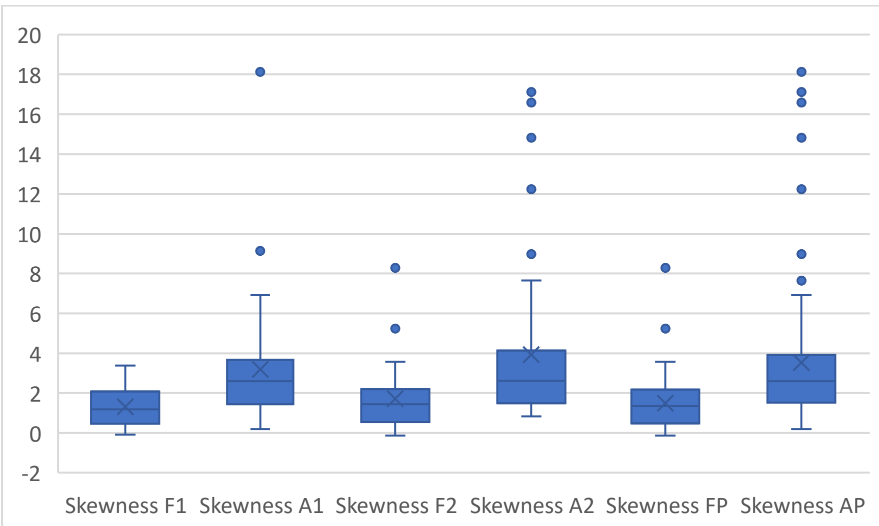
Figure 15. Box-whisker plots of spectral standard deviation (StDev) values of F (StDev F) and A (StDev A) periods in word-final realisations of /ɫ/ in strong prosodic position (1) and weak prosodic position (2) and in pooled data (P)



As displayed in Figure 15. above, the differences discussed in the previous paragraph are also visible in word-final position. A periods exhibit lower values of spectral standard deviation than the F periods. Moreover, in word-final position there appears to be a pattern wherein the F periods exhibit values of spectral standard deviation that are more diverse than those in A periods.

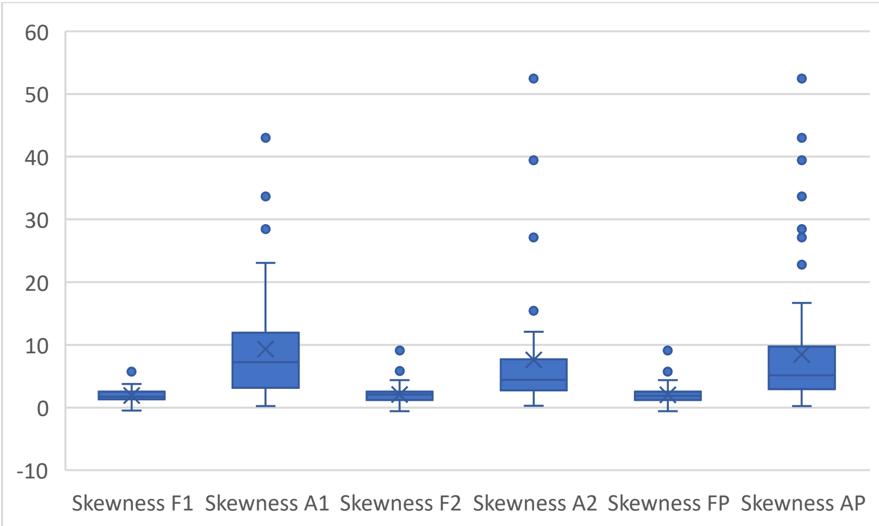
Skewness is the third spectral moment investigated in this part of the study and box-whisker plots of its values for word-initial realisations of /ɬ/ identified as aspirated are given in Figure 16. below.

Figure 16. Box-whisker plots of skewness values of F (Skewness F) and A (Skewness A) periods in word-initial realisations of /ɬ/ in strong prosodic position (1) and weak prosodic position (2) and in pooled data (P)



In word-initial position, values of skewness in F and A periods clearly differ regardless of the prosodic position in that the former are lower than the latter. Additionally, there are numerous realisations with skewness values classified as outliers. Such outlier values are more frequently found in A periods.

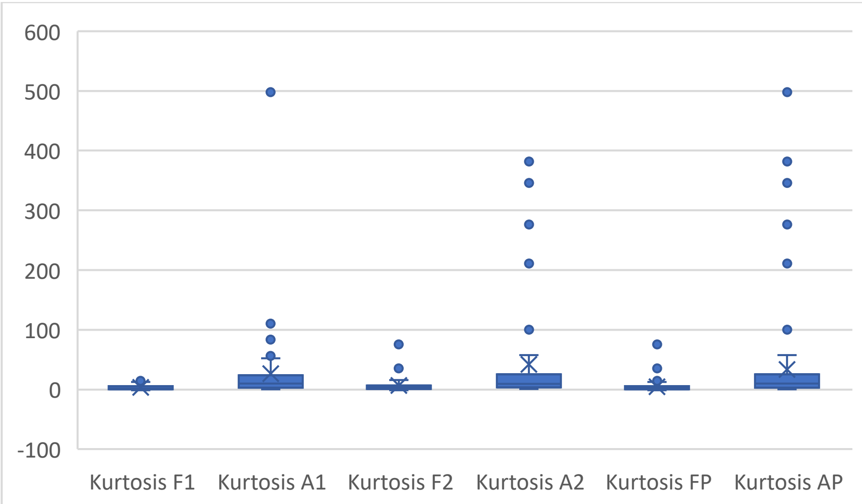
Figure 17. Box-whisker plots of skewness values of F (Skewness F) and A (Skewness A) periods in word-final realisations of /ɫ/ in strong prosodic position (1) and weak prosodic position (2) and in pooled data (P)



As shown in Figure 17. above, in word-final position, skewness values of F periods are lower than the ones of A periods, regardless of the prosodic position. This means that the patterns in word-initial and word-final positions are similar. There is, however, one notable difference, namely the fact that the differences between the sets of values are more pronounced in word-final position than in word-initial one. The box-whisker plots contain outlier values, which are more common in A periods.

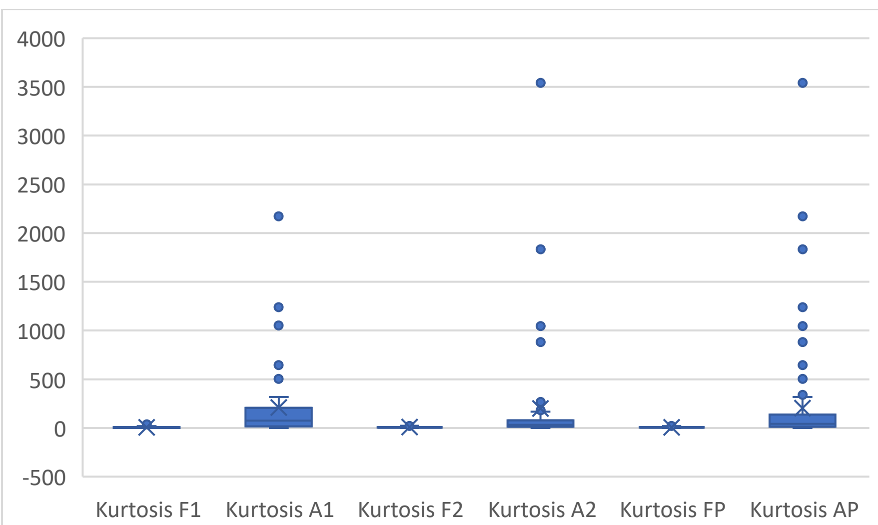
Kurtosis is the last of the spectral moments analysed in this part of the study. Figure 18. below, shows box-whisker plots of kurtosis values in word-initial realisations of /ɫ/ interpreted as aspirated.

Figure 18. Box-whisker plots of kurtosis values of F (Kurtosis F) and A (Kurtosis A) periods in word-initial realisations of /ɬ/ in strong prosodic position (1) and weak prosodic position (2) and in pooled data (P)



Kurtosis values of word-initial realisations of /ɬ/ exhibit a pattern wherein the F periods have lower kurtosis values than A periods. The pattern is visible in strong and weak prosodic position, and, as a results, in the pooled data. All datasets displayed above contain outlier values, but they are more likely to occur in A periods.

Figure 19. Box-whisker plots of kurtosis values of F (Kurtosis F) and A (Kurtosis A) periods in word-final realisations of /ɬ/ in strong prosodic position (1) and weak prosodic position (2) and in pooled data (P)



In word-final realisations of /ɬ/, kurtosis values form the same pattern as in the word-initial position. Regardless of the prosodic position, F periods have lower kurtosis values with fewer outlier values while A periods have higher kurtosis values with more outlier values. The differences between the two are more pronounced in word-final position than in word-initial.

The last aspect that was analysed in this part of the study was the length of the F and A periods. Table 1. below presents average length values in word-initial and word-final realisations of /ɬ/ interpreted as aspirated.

Table 1. Average values of F and A periods length and percentage of articulation accompanied by aspiration.

	Word-initial			**Word-final**		
	1	**2**	**Pooled data**	**1**	**2**	**Pooled data**
Length F (ms)	163 (±66)	150 (±49)	157 (±59)	201 (±66)	213 (±52)	207 (±59)
Length A (ms)	20 (±16)	29 (±11)	30 (±14)	37 (±16)	47 (±16)	42 (±16)
Percentage of articulation accompanied by aspiration	16 (±10)	18 (±10)	17 (±10)	16 (±6)	18 (±7)	17 (±7)

Two observations may be made on the basis of the data presented in the table above. First of all, word-final realisations of /ɬ/ are longer than word-initial ones (23% longer in strong prosodic position, 42% longer in weak prosodic position and 32% longer in pooled data). Secondly, regardless of the aforementioned overall length differences, the A periods take comparable periods of the overall length in word-initial and word-final position.

4. Conclusions

The main aim of this study was to verify the laryngeal specification of the Welsh lateral fricative /ɬ/ by looking at the selected acoustic features of this sound in word-initial and word final position. Additionally, this study aimed to check if the Welsh /ɬ/ is occasionally pronounced with periods of aspiration accompanying the final part of the articulation of the sound.

The results of the durational measurements discussed in Section 3.2. 1 suggest that the Welsh lateral fricative /ɬ/ is a relatively long sound. Moreover, there seems to be measurable influence of the position within the word and the prosodic position on the length of that sound. These results can be used in the attempt to confirm the laryngeal specification of /ɬ/, but in order to do so, they have to be contrasted with similar measurements for other Welsh fricatives

(Baran forthcoming). Table 2. below presents total articulation length of selected[3] Welsh consonants in four configurations, i.e. word-initial strong prosodic position, word-initial weak prosodic position, word-final strong prosodic position and word-final weak prosodic position.

Table 2. Total articulation length of selected Welsh fricatives in word-initial strong prosodic position (Initial (1)), word-initial weak prosodic position (Initial (2)), word-final strong prosodic position (Final (1)) and word-final weak prosodic position (Final (2))

	/s/	/h/	/f/	/v/	/θ/	/ð/	/χ/	/ɬ/
Initial (1)	199	148	194	131	-	-	-	195
Initial (2)	195	143	181	130	-	-	-	182
Final (1)	333	-	270	187	300	181	280	265
Final (2)	216	-	207	119	205	117	215	236

Out of the sounds presented in Table 2. above, /s/, /f/, /θ/, /χ/ and /ɬ/ are labelled as fortis while /h/, /v/ and /ð/ are labelled as lenis by Asmus and Grawunder (2017) and Baran (2020; forthcoming).[4] It is visible that the total articulation length of /ɬ/ reported in this study confirms the labelling of this sound as fortis as its length is comparable to that of other fortis segments. As a result, the pattern emerges wherein the fortis fricatives of Welsh are longer than the lenis ones.

Table 3. below presents average values of phonetic voicing length in selected Welsh fricatives in four configurations, i.e. word-initial strong prosodic position, word-initial weak prosodic position, word-final strong prosodic position and word-final weak prosodic position.

Table 3. Phonetic voicing length in selected Welsh fricatives in word-initial strong prosodic position (Initial (1)), word-initial weak prosodic position (Initial (2)), word-final strong prosodic position (Final (1)) and word-final weak prosodic position (Final (2))

	/s/	/h/	/f/	/v/	/θ/	/ð/	/χ/	/ɬ/
Initial (1)	8	24	11	60	-	-	-	4
Initial (2)	7	26	13	73	-	-	-	5
Final (1)	26	-	26	60	37	47	28	6
Final (2)	27	-	22	52	27	48	18	14

[3] Data on some Welsh fricatives is unavailable because of (i) methodological choices of the study by Baran (forthcoming) and (ii) Welsh phonotactics.

[4] However, this should not lead to an assumption that the Welsh fricatives form phonologically contrastive pairs with each other. Actually, only /s/ and /h/ form a phonologically contrastive pair, while other fricatives discussed here form phonologically contrastive pairs with sounds of other manners of articulation. This mirrors the mICM pattern (see Asmus and Grawunder, 2017, for a detailed discussion).

The data presented in Table 3. shows that the average phonetic voicing length as reported in this paper is comparable to that of other fortis fricatives of the Welsh language. It should, however, be mentioned that this acoustic feature is of limited importance in Welsh as (i) it is a fortis-lenis language in which phonetic marking is not realised via phonetic voicing and (ii) it features phonologically contrastive pairs of sounds in which a fricative is paired with a sound of a different manner of articulation – those pairs cannot be accounted for by the voiceless-voiced distinction and as a result are not expected to be marked phonetically with phonetic voicing.

In order to study the potential aspiration of /ɬ/, two main assumptions were made, i.e. each realisation under review was divided into F and A period based on visual inspection of the spectrogram and then the realisations in which A periods had lower COG than F periods were considered to be aspirated. As a result, 82 per cent of word-initial realisations and 92 per cent of word-final realisations were classified as aspirated and subjected to SMA focused on COG, spectral standard deviation, skewness and kurtosis values. The fact that some realisations featured lower COG values of A periods than those of F periods may be taken as an argument for the claim that segmenting the realisations based on a visual inspection of a spectrogram does not lead to results that seem to confirm aspiration in every single case. Additionally, this study does not attempt to compare the realisations interpreted as unaspirated with the ones interpreted as aspirated, but it focuses on the SMA of the latter. Therefore, the results of this part of the study should be considered useful, but, as aforementioned, they have to be verified by studies involving different segmenting methods.

Table 4. below summarises the average values of the four spectral moments included in the SMA in word-initial realisations of the Welsh /ɬ/.

Table 4. Average values of centre of gravity (COG), spectral standard deviation (StDev), skewness and kurtosis for F and A periods in strong (Position 1) and weak (Position 2) prosodic position and in pooled data in word-initial realisations of /ɬ/ interpreted as aspirated

	Position 1		**Position 2**		**Pooled data**	
	Friction	**Aspiration**	**Friction**	**Aspiration**	**Friction**	**Aspiration**
COG (Hz)	3044	1894	2826	1610	2945	1765
StDev (Hz)	2633	1898	2297	1757	2480	1834
Skewness	1.31	3.19	1.71	3.94	1.49	3.53
Kurtosis	2.09	26.6	6.69	42.34	4.83	33.75

The average values of COG in word-initial realisations of the Welsh /ɬ/ identified as aspirated are higher for the F than A periods regardless of the prosodic position. This is hardly surprising, considering the fact that COG measurements were used as the main factor influencing the identification of a given realisation as either aspirated on unaspirated and that only the realisations interpreted as aspirated were analysed further. Nevertheless, this difference is still important in that (i) the difference noticeable upon visual inspection of spectrograms finds confirmation in numerical data and (ii) A periods do have a considerable amount of acoustic energy concentrated in lower frequencies, which results in lowering the average COG values. The latter is here considered to have originated from aspiration overlapping with the final part of the /ɬ/ articulation.

The average values of spectral standard deviation in word-initial realisations of the Welsh /ɬ/ identified as aspirated are consistently higher in F than A periods regardless of the prosodic position. This is correlated with the COG values discussed in the previous paragraph, i.e. the difference in COG of F and A periods is reflected in their spectral standard deviation and so are the differences resulting from prosodic position as both COG and spectral standard deviation values are higher in strong prosodic position than in weak. As a result, it may be claimed that F periods are more diverse in terms of COG values exhibited than A periods.

The average values of skewness in word-initial realisations of the Welsh /ɬ/ identified as aspirated are consistently higher in A than F periods regardless of the prosodic position. In line with the assumptions made in section 2.3., it may be claimed that it means that A periods exhibit higher concentration of energy at lower frequencies than F periods. Again, similarly to the COG values, it seems to confirm the existence of aspiration accompanying the final part of /ɬ/ articulation.

The average values of kurtosis in word-initial realisations of the Welsh /ɬ/ identified as aspirated are consistently much higher in A than F periods regardless of the prosodic position. As suggested by other studies on SMA, this means that A periods exhibit thin and peaked distribution while F periods have more of a broadand flat distribution. In connection with the previously mentioned conclusions, it may be claimed that it is the energy concentrated in lower frequencies that is responsible for the peak in A periods. This may be seen as another argument supporting the presence of aspiration postulated here.

Table 5. Average values of centre of gravity (COG), spectral standard deviation (StDev), skewness and kurtosis for friction and aspiration periods in strong (Position 1) and weak (Position 2) prosodic position and in pooled data in word-final realisations of /ɬ/ interpreted as aspirated

	Position 1		**Position 2**		**Pooled data**	
	Friction	**Aspiration**	**Friction**	**Aspiration**	**Friction**	**Aspiration**
COG (Hz)	2329	996	2411	1246	2372	1124
StDev (Hz)	2372	1218	2227	1504	2298	1364
Skewness	1.94	9.33	2.08	7.58	2.01	8.44
Kurtosis	7.16	211.37	9.06	199.5	8.13	205.3

The average values of COG in word-final realisations of the Welsh /ɬ/ identified as aspirated are higher for the F than A periods regardless of the prosodic position. Similarly to the situation in word-initial position is should not be seen as surprising, but the same two conclusions may still be drawn, i.e. (i) the difference visible on spectrograms is reflected in COG measurements and (ii)

A periods do have considerable amount of acoustic energy concentrated in lower frequencies which results in lowering the average COG values. As a result, it may be claimed that in the word-final realisations of /ɬ/, like in the word-initial ones, the differences in COG result from aspiration overlapping with the final part of the /ɬ/ articulation.

The average values of spectral standard deviation in word-final realisations of the Welsh /ɬ/ identified as aspirated are consistently higher in F than A periods regardless of the prosodic position. Like in word-initial position, this is correlated with the COG values discussed in the previous paragraph, i.e. the difference in COG of F and A periods is reflected in their spectral standard deviation. In word-final position, however, the results of the prosodic position are not the same as far as COG and spectral standard deviation are concerned. This is so, because in weak prosodic position the average value of F periods COG is higher than in strong one, while for spectral standard deviation it is the strong prosodic position that has higher F period average value than the weak one. Nevertheless, it may still be claimed that F periods are more diverse in terms of COG values exhibited than A periods.

The average values of skewness in word-final realisations of the Welsh /ɬ/ identified as aspirated are consistently higher in A than F periods regardless of the prosodic position. It may therefore be claimed that this means that A periods exhibit a higher concentration of energy at lower frequencies than F periods. It seems to confirm the existence of aspiration accompanying the final part of /ɬ/ articulation in the same way as in word-initial position.

The average values of kurtosis in word-final realisations of the Welsh /ɬ/ identified as aspirated are consistently much higher in A than F periods regardless of the prosodic position – the difference is even more pronounced than in word-initial position. This means that A periods exhibit very thin and peaked distribution while F periods have more of a broad and flat distribution. As a result, like in word-initial position, it may be claimed that it is the energy concentrated in lower frequencies that is responsible for the peak in A periods. This energy concentration is here understood as aspiration.

Length measurements do not lead to many conclusions pertinent to the discussion at hand. The part of the articulation accompanied by aspiration is very similar in all configurations under review here. This may indicate that aspiration seems to be quite regular in the realisations identified as aspirated in this paper.

All in all, it seems that the classification of the Welsh lateral fricative /ɬ/ as a fortis sound is confirmed by the results of this paper. /ɬ/ exhibits total articulation length and phonetic voicing length (i) similar to that of other fortis sounds and (ii) considerably different from that of other lenis sounds. If the Welsh /ɬ/ is a fortis sound, then it is possible that it features acoustic characteristics of other fortis sounds in Welsh, such as aspiration. The SMA conducted here seems to support the postulated existence of aspiration accompanying the final part of the Welsh /ɬ/ articulation. The differences between the average values of the four spectral moments are consistently visible in all positions under review here. Moreover, the interpretation of these differences is consistent with the effect aspiration would have on a fricative spectrum. Such findings are also in line with what is currently known about the phonetic marking of the fortis-lenis contrast in Welsh consonants. Aspiration has been shown to mark the fortis plosives and distinguish them from lenis ones and its surfacing in fricatives or even sonorants should not be ruled out.

On the other hand, the SMA results have to be verified in future studies. The method of segmenting the realisations used here does not automatically result in values suggesting aspirated realisations in 100 per cent of cases, but, being based on a visual inspection of the spectrograms, it is to a large extent subjective. Therefore, further studies on aspiration of the Welsh /ɬ/ should make use of other ways of segmenting the realisations to further confirm the claims made here. Additionally, such studies should also use a wordlist that allows for controlling the vowel effect and ideally involve more speakers to increase the size of the database.

Acknowledgment

This study was inspired by a publication by Asmus and Grawunder (2017) and the research methodology applied there was the basis for designing the present experiment.

References

Asmus, Sabine and Sven Grawunder, 2017. Vowel length in Welsh monosyllables, its interrelation with Irish and related problems. Lewiston: Edwin Mellen Press.

Asmus, Sabine, Sylwester, Jaworski and Michał Baran, 2019. Fortis-Lenis or Voiced-Voiceless – Features of Welsh Consonants. Proceedings of the International Conference of the Phonetic Sciences XIX, pp. 3773-3776.

Asu, Lina E., Nolan, Francis and Susanne Schötz, 2015. Comparative Study of Estonian Swedish Voiceless Laterals: Are Voiceless Approximants Fricatives? Proceedings of the International Conference of the Phonetic Sciences XVIII.

Awbery, Gwenllian M., 1984. Phonotactic Constraints in Welsh. In: Ball, M.J. and G.E. Jones, eds. Welsh Phonology: Selected Readings. Cardiff: University of Wales Press.

Ball, Martin J. and Nicole Müller, 1992. Mutation in Welsh. London and New York: Routledge.

Baran, Michał, Defining the fortis/lenis and voiceless/voiced distinction of consonants in Welsh and English. Forthcoming

Baran, Michał, 2020. Fortis-Lenis Distinction of Fricatives and Plosives in Welsh – Phonetically Distinctive Factors. Linguistics Beyond and Within, vol. 6, pp. 47-59. https://doi.org/10.31743/lingbaw.11830

Boersma, Paul, and David Weenink, 2019. "Praat: Doing Phonetics by Computer" (version 5.3.43) (DOA December 18, 2022).

Filppula, Markku, Klemola Juhani and Heli Paulasto, 2008. English and Celtic in Contact. London and New York: Routledge. https://doi.org/10.4324/9780203895009

Hannahs, S.J., 2013. The Phonology of Welsh. Oxford: Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199601233.001.0001

Jaworski, Sylwester and Michał Baran, 2021. Acoustic features of burst release: a study of Welsh plosives. Roczniki Humanistyczne, vol. 69, no. 11, pp. 89-105. https://doi.org/10.18290/rh216911-5s

Jones, Glyn E., 1984. The Distinctive Vowels and Consonants of Welsh. In: Ball, Martin J. and Glyn E. Jones, eds. Welsh Phonology: Selected Readings. Cardiff: University of Wales Press.

Jones, Glyn E. and Francis Nolan, 2007. An Acoustic Study of North Welsh Voiceless Fricatives. Proceedings of the International Conference of the Phonetic Sciences XVI, pp. 873-876.

Ladefoged, Peter and Ian Maddieson, 1996. The Sounds of the World's Languages. Cambridge: Blackwell Publishers.

Lee, Sungmin, 2020. Spectral analysis of english fricatives /s/ and /ʃ/ produced by people with profound hearing loss. Clinical Archives of Communication Disorders, vol. 5, no. 3, pp. 147-153. https://doi.org/10.21849/cacd.2020.00269

Maddieson, Ian and Karen Emmorey, 1984. Is There a Valid Distinction between Voiceless Lateral Approximants and Fricatives? Phonetica, vol. 41, pp. 181-190. https://doi.org/10.1159/000261725

Roach, Peter, 2012. English Phonetics and Phonology. Cambridge: Cambridge University Press.

Schrijver, Peter, 1995. Studies in British Celtic Historical Phonology. Amsterdam: Rodopi. https://doi.org/10.1163/9789004653733

Steed, William and Peter Hardie, 2004. Acoustic Properties of the Kuman Voiceless Velar Lateral Fricative. Proceedings of the 10th Australian International Conference on Speech Science & Technology, pp. 346-351.

Watkins, T. Arwyn, 2002. Welsh. In: M.J. Ball and J. Fife, eds. The Celtic Languages. London and New York: Routledge, pp. 289-348.

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