

Fortis-lenis vs voiced-voiceless plosives in Welsh

Sabine Asmus

University of Szczecin, Poland

University of Leipzig, Germany

Sylwester Jaworski

University of Szczecin, Poland

Michał Baran

University of Szczecin, Poland

Abstract

This paper questions the voiceless-voiced distinction of Welsh consonants and claims that the fortis-lenis distinction is more appropriate for the description of the language. In light of research results of theoretical as well as experimental investigations into Welsh, e.g. the vowel-coda length dependence discovered by Asmus and Grawunder (2017), advocated further research into that matter, seeing also that the fortis-lenis distinction establishes a firm link to focal properties of Welsh, such as morpheme-initial consonant mutations (mICM). It was, therefore, decided to look at potential phonetic features that would contribute to the postulated distinction. These features are aspiration, voicing, hold phase duration and the centre of gravity (abbreviated to CoG) in the articulation of Welsh plosives. Preliminary results of the study discussed in this paper were summarised in “Fortis-lenis or Voiced-voiceless – features of Welsh consonants” (Asmus *et al.* 2019). However, expanding our research has yielded more comprehensive findings. As a result, it appears that the two series of plosives under review are different in terms of all features studied, but it is aspiration that is of major importance (thus confirming classifications of Welsh as an aspiration language).

Keywords: fortis-lenis distinction, plosives, consonant distinctions, aspiration

1. Introduction

Consonant distinctions are vital in describing a language because they facilitate any subsequent research of more complex language structures. Therefore, a language cannot be effectively analysed, taught or studied unless correct consonant distinctions are established. As far as Welsh is concerned, it is claimed here that its description as a fortis-lenis language is more appropriate than that as a voiced-voiceless tongue.

Some major accounts of the Welsh language (Ball and Fife 2002; Hannahs 2013) postulate that Welsh consonants are organised into a voiced and voiceless set. Such claims may result from the fact that the voiced-voiceless distinction is often seen as universal.¹ Ideal cases of languages based on the voiced-voiceless distinction should exhibit a phonological system, in which all obstruent phonemes can be arranged into voiced-voiceless pairs. The sound systems of Ukrainian (Shevelov 1996), Belorussian (Mayo 1996) or Polish² (Gussmann 2007; Sawicka 1995) may be quoted as examples of such consonantal inventories. For Welsh, however, this is certainly not the case as becomes clear in the course of this paper (see also Asmus *et al.* 2019 and Grawunder and Asmus 2017).

As Welsh is not the only language that does not feature such a phonological system, the universal status of the voiced-voiceless distinction has been challenged by various researchers. Some postulate that it is only one of the possible options of laryngeal contrast. Kiparski (2006), for instance, discusses so-called voicing and non-voicing languages, where the latter exhibit a different type of laryngeal contrast, not based on the presence or absence of phonetic voicing. Honeybone's (2005) laryngeal realism points to two major systems based on laryngeal contrast, one of which is the fortis-lenis distinction.³

Back in 1983, Jaeger discussed both notions referring to the terms 'fortis/lenis' as "used to characterize a basic phonological contrast in consonant systems which cannot be explained in terms of a voicing distinction" (1983: 177).⁴ In context of the Insular Celtic languages, the voiced-voiceless distinction has also been questioned. A look at Bednarska (2016) reveals a fortis-lenis divide at work in Breton, which, like Welsh, is an Insular p-Celtic language.

Ball (1984), Jones (1984), Ball and Williams (2001), Morris and Hejná (2019) and Iosad (forthcoming) have also employed the fortis-lenis terminology in analyses, but rather in order to describe some features of Welsh consonants, e.g. aspiration where phonetic voicing is not enough to describe them (see Jaeger and the case of English below), than identifying Welsh as

¹ See Maddieson (2013) for such an approach. On the basis of such approaches and the features of the degree of obstruction of the vocal tract during the production of the sound and the absence or presence of voicing, a sonority scale was defined, which is by some also seen as universal (see Carr 2008: 160, Davenport and Hannahs 2005: 75).

² In standard Polish, the voiced velar fricative [ɣ] seems to have lost its phonemic status; however, it is still used in the south and east of Poland.

³ It has also been established that languages may have a three-way distinction among fortis, lenis and aspirated plosives. In such systems, several articulatory, acoustic and aerodynamic factors contribute simultaneously to the contrast formation. According to Chang (2007), the lenis, fortis and aspirated plosives of Korean differ from each other with respect to linguo-palatal contact, glottal configuration, subglottal and intraoral pressure, laryngeal and supralaryngeal articulatory tension, voice onset time (VOT), fundamental frequency (f0) of vowel onset, intensity of vowel onset, and voice quality of vowel onset. Chang (2007: 21) also stresses the fact that "none of these cues alone differentiates all three series from each other due to a high degree of overlap between two or sometimes all three categories with respect to their range of realizations of these phonetic dimensions". Welsh distinguishes between a fortis, a lenis and an aspirated [r] (Jaworski and Asmus 2018), as well as between a fortis, lenis and aspirated variant of [l]. These may seem like an instance of a division similar to the Korean contrast, but they are in fact a remnant of an incomplete development of the four-fold Old Irish sonorant system in Welsh (see Asmus and Grawunder 2017), which came to an end in the 10th century CE, probably due to a limited influence of palatalisation resulting from language contact.

⁴ Other uses of the term 'fortis/lenis' may refer to secondary phonetic features as is seen in the following.

a language that displays a fortis-lenis phonological system.⁵ However, van Sluis described in 2019 that aspiration, together with general articulation length, is decisive for the distinction between the radical fortis plosives, lenited fortis plosives and radical lenis plosives in Old and Middle Welsh (2019: 75).

When Baran and Asmus (2019) revisited morpheme-initial consonant mutations (mICM) in Welsh and Irish, they showed that lenition processes, i.e. deaspiration /p, t, k/ > /b, d, g/, spirant mutation /p, t, k/ > /f, θ, χ/ (i.e. lenition of fortis plosives plus aspiration), approximantisation /t, r^h/ > /l, r/ and debucculisation /s/ > /h/⁶ established a whole system of phonetic contrasts that are used in order to mark morphological and syntactic features in the language. In addition, Asmus and Grawunder (2017) found out that there is little or no final devoicing – also referred to as contrast neutralisation of voiced and devoiced codas – in Welsh monosyllables ending in simplex codas. To the contrary, the maintenance of the fortis-lenis codas is semantically relevant and, whereas devoicing is largely absent, consonant length is decisive.

As can be seen, there is a clear phonological contrast in Welsh consonants, which cannot be explained by a voicing distinction. This is also confirmed by minimal pairs, which clearly follow the fortis-lenis divide. Whereas English features the voiced-voiceless⁷ distinction between /s/ and /z/, like in *seal* and *zeal*, Welsh exhibits minimal pairs along the fortis-lenis divide⁸ as can be seen in the following:

- (1) *sil* ‘seed’ vs *hil* ‘breed’

In addition, this minimal pair⁹ cannot be explained within the voiced-voiceless framework because both sounds are voiceless.

⁵ It may be interesting though that Ball and Müller deny the applicability of this sonority scale to the Insular Celtic languages in 2016 and 2019.

⁶ The contrast between /s/ and /h/ stopped being productive in Welsh in the 6th century CE and nowadays it is no longer productive in the mutation system (Jackson 1953: 12–513, 517–521, 525–527, 625), so it is often omitted by researchers (see for instance Ball 1984) but see also below.

⁷ Some scholars refer to English in certain frameworks as a fortis-lenis language, the implication being that fortis sounds involve a greater amount of articulatory effort (Cruttenden 1996: 31). However, Jaeger rightly declines this idea (1983: 177–179) claiming that in English the voiceless stops are considered fortis only because of the presence of aspiration and the fortis-lenis distinction, understood in that way does not have any further phonological or phonetic implications. In the English language, the phonological status of aspiration is thus somewhat ambiguous due to it occurring in predictable contexts.

⁸ This phonetic change /s/ - /h/ has already been referred to as a specific form of lenition, i.e. debucculisation, above. It is part of the lenition processes in Europe apparent in the 1st century CE. Whereas – as said above – lenition became grammaticalised in the Insular Celtic languages, it can still be found as a dialectal marker in several varieties of Spanish, e.g. Andalusian, Mexican or Caribbean Spanish (see Hualde 2005; Penny 2000).

⁹ The word *sil* and *hil* can still be understood as ‘seed’ (for the confirmation thereof, we would like to thank Dr. Guto Rhys), although *hil* would normally be used in the sense of ‘lineage’ and ‘race’ these days (*Geiriadur Prifysgol Ar Lein*). Another good minimal pair is *sedd* - *hedd*. Both share the same etymology, but specialised on the current meanings ‘seat’ and ‘peace’ respectively. A shared etymology can also be established for *soch/swch* and *hwch* ‘pig’. Although the latter is now a specific pig, i.e. ‘a swine’, the first is only loosely linked to the animal these days and normally understood as ‘ploughshare’ or ‘snout’. However, the children’s book *Jaci Soch* (Jones 2004) talks about the adventures of a little pig, not least because “*soch, soch*” may be used onomatopoeically in

In order to present the phonological fortis-lenis divide as a fully distinct one, phonetically distinctive features that distinguish between the two series must be identified. It can be assumed that features or their combination may be different for different manners of articulation. Therefore, the influence of voicing, aspiration, articulatory timing/hold phase duration and the centre of gravity (CoG) of the aspiration noise that follows the release of Welsh plosives is investigated here.

The remaining part of the article is structured as follows. Section 2 introduces the phonetic properties of plosives and describes how they contribute to making speech sounds distinct. Section 3 is devoted to an investigation into specific features of Welsh plosives, which might prove our claim, and specifies the objectives, describes the research methodology and presents the results. The article ends with conclusions, which also include suggestions for further research in this area.

2. Phonetic properties of plosives and their importance in laryngeal contrasts

The first of the features analysed in our current studies is phonetic voicing. Trask (1996: 381) defines it as vocal folds vibration happening while articulating a given sound. He claims that this may be the one parameter that distinguishes between voiced and voiceless sounds. Ladefoged (1975) in his feature system differentiates between five different values of the voice feature: glottal stop, laryngealised, voice, murmur and voiceless. Measuring voicing in Welsh plosives may answer the question whether this feature alone is enough to distinguish between the minimal pairs of sounds resulting from laryngeal contrast. If it were, it would provide phonetic evidence for a phonological voiced-voiceless distinction, but previous phonetic analyses of Welsh consonants such as Ball (1984) and Asmus and Grawunder (2017) suggest that the influence of phonetic voicing, especially word-finally, is incidental at the most.

The second feature, i.e. aspiration may generally be defined as ‘a period of voiceless breathing’, that follows an obstruent (Stevens 1998: 451; Trask 1996: 36). As far as experimental phonetics is concerned, aspiration manifests itself as friction following the release of a plosive. It is closely connected with the voice-onset time (abbreviated to VOT), i.e. the time between the release of the plosive to the beginning of modal voicing signifying a vowel. Ladefoged and Maddieson (1996: 45) argue that languages make use of three modal possibilities, namely, voiced, voiceless unaspirated and voiceless aspirated. When VOT equals zero or is very short, it normally means that a sound is an unaspirated voiceless plosive. Long, positive VOT may indicate an aspirated voiceless plosive and a negative VOT suggests that voicing starts before the release of the closure, a feature characteristic of voiced unaspirated plosives.¹⁰ Aspiration,

Welsh for the sound of a pig (I would like to thank Prifardd Meirion MacIntyre Huws for this information). More examples could be listed for Welsh (see also Asmus and Grawunder at https://www.academia.edu/33509077/Language_structuring_consonant_mutation_s_in_Welsh_and_Irish). However, the /s/ - /h/ contrast is fully phonologically productive in other Insular Celtic language, i.e. Irish. All in all, it makes good sense to include this contrast in our investigation.

¹⁰ In some language, e.g. Polish, phrase or sentence initial voiced plosives are always pre-voiced, i.e. vocal folds vibration begins during the hold phase, a few tens of milliseconds before the closure is released (Sobkowiak 2004).

together with general articulation length, is seen to have been decisive for the distinction between the radical fortis plosives, lenited fortis plosives and radical lenis plosives observable in Old and Middle Welsh before the lenited fortis plosives blended with the radical lenis ones forming the consonant system known from Modern Welsh (van Sluis 2019: 75).

The plosive sounds of the Welsh language, despite being assigned to either the lenis or fortis category, do not fall neatly into the pattern as they are aspirated, irrespective of the group they belong to. As a consequence, the fortis-lenis dichotomy in Welsh appears to be a combination of two factors, namely, aspiration and voicing. As for the former, the amount of aspiration following the Welsh plosives, as in other languages, e.g. English, is closely related to their place of articulation, with the velars being followed by the longest and the bilabials by the shortest period of aspiration. The latter feature is superimposed on aspiration to a varying degree, with the lenis plosives having typically more voicing than the fortis ones.

To illustrate the point, a lenis plosive, pronounced in the word *dŵr* ‘water’, is depicted in Figure 1. The second half of the 25-millisecond aspiration period is voiced as indicated by the pulses of vocal fold activity. In the case of /b/ and /d/, it is not uncommon for voicing to be present not only throughout the aspiration, but also during the preceding hold phase.

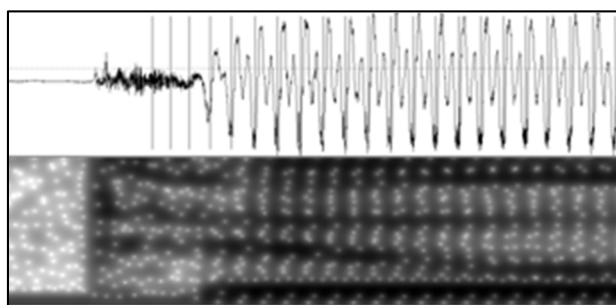


Figure 1: *Partially voiced period of aspiration in the word dŵr ‘water’*

By contrast, fortis plosives are characterised by considerably longer aspiration periods, which tend to be voiced to a much lesser extent than those of lenis plosives. As illustrated in Figure 2, the period of aspiration of the /t/ plosive is 186 ms long, the last 17 ms of which is voiced. Although the voiced section of aspiration is slightly longer than that of *dŵr* (cf. Figure 1), it constitutes less than 10% of the total duration of the aspiration period. Since the Welsh lenis and fortis plosives differ with respect to the amount of aspiration they are followed by, as well as in regard to the duration of the voiced section of the aspiration noise, it is hypothesised in this work that both aspiration and voicing constitute crucial features underlying the fortis and lenis series.

The third factor under review is the hold phase, also called approach. It is sometimes claimed that in citation forms or after a pause, /p, t, k/ feature a longer hold phase than /b, d, g/, but the differences are not evident in connected speech (Ogden 2009: 98). Hold phase duration is here seen as one of the articulatory timing features and as such seems to be worth measuring because of the apparent vowel-coda duration dependence discovered by Asmus and Grawunder (2017). Recording statistically relevant differences in hold phase duration between the fortis and lenis series could suggest that length and articulatory timing are decisive in the fortis-lenis distinction.

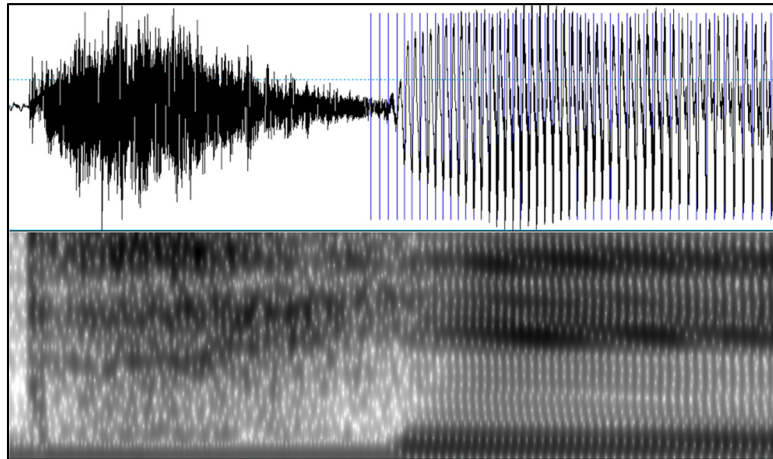


Figure 2: *Partially voiced period of aspiration in the word tir 'land'*

The last phonetic factor under review is centre of gravity of aspiration noise (henceforth CoG). This parameter can be thought of as the average frequency of aperiodic noise in a spectrum, which is correlated with the place of articulation of a fricative consonant (Ladefoged and Maddieson 1996; Stevens 1998). In general terms, the energy of front fricatives tends to be concentrated at higher frequencies than that of back ones. The burst release of a plosive consists of a certain amount of noise, which can be analysed in the same way as fricative sounds. If the CoG values of the aspiration noise following the Welsh plosives turn out to be significant, they might be considered as a potential phonetic factor that distinguishes between the lenis and fortis plosives.

3. The study

3.1. *The objectives*

As mentioned above, the objective of this study is to determine whether the four phonetic factors: aspiration, voicing, articulatory timing/hold phase duration and CoG contribute to the phonological fortis-lenis distinction in the case of the Welsh plosives. If so, the results will indicate that the voiced-voiceless distinction is inappropriate for the Welsh plosives and that the fortis-lenis divide appears to be phonologically distinctive and language-structuring.

3.2. *The participants and methodology*

In order to achieve the objectives of the study, we conducted an acoustic analysis of the Welsh plosives, i.e. /p, b, t, d, k, g/ produced in a reading task by 31 native speakers, male and female aged 19–71, from North and South Wales, who use their language at home and at work. The analysis was undertaken both in the onset and coda of monosyllabic native lexemes currently in use. The lexemes were taken from previous corpora of native vocabulary (Asmus and Grawunder 2017), but further amended by adding additional lexical items. An occasional English loan word was used as a control item. The tokens were then placed in the carrier phrase

Dw i heb ddweud X ond Y! [I didn't say X but Y]¹¹ and were ordered in a way that every lexeme appears in the recording twice in a strong and twice in a weak prosodic position, with X being weak and Y being strong.¹² Selected native lexemes were also recorded in randomly chosen short sentences used as distractors. By so doing, we managed to record the same number of tokens of each plosive occurring in the same phonological context, which makes statistical analyses more reliable. The target items were subsequently examined with the help of the Praat software (version 5.3.85).

As regards the exact physical properties of the target sounds, the following features were measured: (i) the hold phase of word-final plosives,¹³ (ii) the duration of the aspiration phase, (iii) the duration of the voicing phase that overlaps aspiration, (iv) the duration of the voiced part of the hold phase and (v) centre of gravity for the friction following the release of a plosive. With respect to aspiration, we define it as a period of friction extending from the release of a plosive to the onset of modal voicing. In the case of Welsh lenis plosives, the presence of friction following release is an indicator of aspiration. It is also assumed that friction following an initial lenis plosive may be partially voiced. Therefore, both parameters were measured in order to establish whether their relative durations distinguish fortis plosives from their lenis counterparts.

The collected data were subjected to a statistical analysis by means of a mixed-design ANOVA, which takes into consideration the influence of random effects, i.e. factors in an experimental design that are selected from a large population of potential samples rather than deliberately arranged by the researcher. In the case of this study, the random effects include the speakers and the phonological contexts in which the target sounds occur.

3.3. Results

As assumed above, the results of the analyses strongly suggest that the fortis-lenis dichotomy in Welsh is a function of the aspiration-voicing combination. In word-initial position, the lenis plosives /b, d, g/ seem to follow the pattern found in other languages (Ladefoged and Maddieson 1996). In word-final position, however, where aspiration of lenis plosives is cross-linguistically uncommon, the same duration pattern was formed, with /g/ followed by the longest and /b/ by the shortest period of aspiration (see Table 1 and Table 2). Periods of aspiration in the Welsh initial lenis plosives tend to be partially voiced, as shown in Figure 1 above. In the case of /b/ and /d/, it is not uncommon for voicing to be present not only throughout the aspiration, but also during the preceding hold phase.¹⁴

¹¹ Literally, 'I am without say(ing) X, but Y'.

¹² Based on the analysis of their recordings, Grawunder, Asmus and Anderson (2015) found out that the second position in the carrier sentence attracts stronger prosodic prominence.

¹³ The duration of the hold phase of word-initial plosives was not determined as the informants would frequently make a short pause before producing a target word, which made accurate measurements impossible.

¹⁴ The lack of hold phase duration data for initial plosives is due to the fact that, in numerous cases, the participants hesitated before pronouncing a target word, which made it impossible to measure the length of the hold phase with an acceptable degree of accuracy.

Table 1: Average durations (in ms) of hold phases (HP), periods of aspiration (A) and periods of voicing of lenis plosives /b, d, g/ in prosodically weak position

	Weak initial		Weak final		
	A	V	HP	V	A
b	17.3 (± 3.1)	9.5 (± 2.5)	74.6 (± 13.7)	22.7 (± 7.8)	47.3 (± 18.6)
d	21.8 (± 4.64)	13.7 (± 3.1)	83.4 (± 14.2)	29.4 (± 6.3)	56.6 (± 17.1)
g	33.4 (± 5.1)	17.1 (± 4.4)	97.3 (± 15.6)	40.1 (± 7.2)	66.2 (± 17.9)
p	90.3 (± 16.6)	14.2 (± 2.2)	157.3 (± 20.2)	24.6 (± 5.9)	82.4 (± 19.4)
t	113.4 (± 20.7)	16.9 (± 3.3)	177.8 (± 26.4)	19.2 (± 6.8)	96.9 (± 22.5)
k	138.6 (± 25.8)	13.8 (± 3.1)	195.7 (± 34.4)	17.3 (± 2.7)	120.1 (± 28.8)

Table 2: Average durations (in ms) of hold phases (HP), periods of aspiration (A) and periods of voicing of lenis plosives /b, d, g/ in prosodically strong position

	Strong initial		Strong final		
	A	V	HP	V	A
b	19.9 (± 3.1)	11.3 (± 2.8)	96.2 (± 28.9)	21.2 (± 5.3)	66.8 (± 25.4)
d	22.8 (± 4.2)	12.1 (± 2.5)	109.5 (± 38.7)	20.4 (± 4.6)	89.6 (± 19.7)
g	33.4 (± 3.7)	13.8 (± 3.6)	123.3 (± 42.2)	22.1 (± 3.9)	95.9 (± 22.3)
p	117.6 (± 24.5)	13.4 (± 2.6)	208.2 (± 39.8)	17.4 (± 3.1)	119.6 (± 27.7)
t	129.3 (± 34.6)	12.2 (± 2.1)	203.6 (± 46.3)	13.4 (± 2.4)	124.7 (± 39.4)
k	148.2 (± 41.4)	13.5 (± 1.9)	226.9 (± 49.5)	16.1 (± 2.6)	142.6 (± 40.8)

There is speaker-specific variation regarding the amount of aspiration. Predictably, the speaker effect turned out to be significant ($p < .0001$). It is worth pointing out that the Welsh lenis plosives have considerably more aspiration than voiced plosives in non-aspiration languages, e.g. (Sobkowiak 2004), Polish, but also in English (Ladefoged and Maddieson 1996). The difference seems to relate to the amount of friction noise, which includes intensity and/or duration, following the release; an aspect that will be further investigated in a different study.

With respect to the final lenis plosives, they are regularly aspirated to a greater extent than initial ones. Importantly, the aspiration noise is never voiced, yet a certain amount of voicing may occur in the hold phase (cf. Asmus and Grawunder 2017). The amount of aspiration following final /b, d, g/ forms the same pattern as in initial position.

By comparison, the fortis plosives /p, t, k/ are characterised by significantly longer periods of aspiration and relatively shorter periods of voicing in the hold phase. In the case of the hold phase, the differences are highly significant, regardless of the place articulation of plosive

($p < .00001$). The data in Table 1 and Table 2 indicate that this finding refers to both prosodic positions investigated in this study.

The analysis of the CoG values of the aspiration noise following the Welsh plosives produced inconclusive results. Cross-linguistically speaking, the CoG values, falling within the 2,400–3,700 Hz range, tend to be much lower than those obtained for sibilant fricatives produced in various places of articulation (Stevens 1998; Żygis *et al.* 2015). What is more, in the study conducted by Wallin and Koffi (2017), which focuses on whispered speech, the CoG values for the non-sibilant fricatives [f], [v], [θ], [ð] are much lower than those of the sibilants [s], [z], [ʃ], [ʒ]. Thus, the findings strongly suggest that the aspiration friction that follows the Welsh plosives is generated at the glottis.

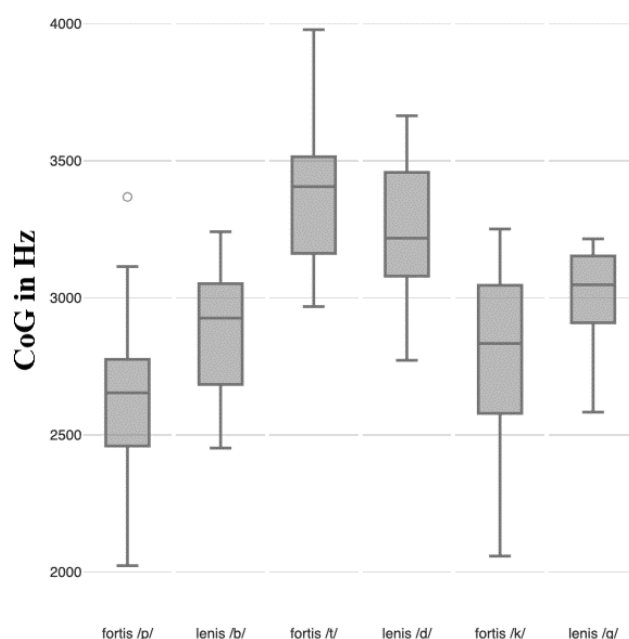


Figure 3: Mean CoG values of aspiration noise following the Welsh plosives

When the place of articulation is taken as a variable, the data presented in Figure 3 form a pattern inconsistent with what has been established regarding the relationship between the place of articulation of a plosive and its CoG. For both the lenis and fortis series, the mean CoG's of the aspiration following the velars are lower than in the case of alveolars, while the aspiration following the bilabials has the lowest CoG values. The differences between the velars and alveolars, as well bilabials and alveolars, turned out to be statistically significant ($p < .05$), whereas those between the velars and bilabials did not reach the level of statistical significance ($p > .05$).

Somewhat surprising are the data relating to the fortis-lenis pairs produced in the same place of articulation. The general impression is that the friction that follows the lenis plosives has a higher CoG than that of its fortis counterpart. In our study, this rule holds for the bilabials and velars, with statistically significant differences between the lenis and fortis segments. As for the alveolars, the CoG of the aspiration following /d/ is lower than that of /t/, yet the difference did not appear to be significant in terms of statistics ($p = 0.1259$).

4. Conclusion

The authors of this paper claim that the fortis-lenis distinction is more appropriate to describe the phonological system of Welsh than the voiced-voiceless one, at least when looking at Welsh plosives. The claim is based on previous research, e.g. into basic phonetic processes at work in the Welsh mICM system, the correlation between the length of simplex coda consonants and preceding vowels in Welsh monosyllables and minimal pairs in the language, which cannot be explained by a voice-voiceless distinction.

This research was continued and supplemented by an investigation into specific features of Welsh consonants, which promised to prove our claim, because, ideally, the proposed consonant distinction should be identified by a set of phonetic correlates in order to be seen as separate from the voiced-voiceless distinction. Supported by a literature review, four phonetic correlates, namely, aspiration, voicing, hold phase duration and centre of gravity, were selected for this analysis.

The collected data point to the conclusion that both voicing and aspiration contribute to differentiating between fortis and lenis plosives. The period of aspiration following the lenis plosives is significantly shorter than that of their fortis counterparts in both word-initial and word-final position, while the differences in voicing do not form a consistent pattern. Also, the ratio between the length of the voiced period of aspiration and its total duration is significantly higher in the case of /b, d, g/. A similar relationship can also be established in word-final position, where the voiced part of the hold phase of the lenis plosives appears to be relatively longer than that of fortis /p, t, k/. Fortis plosives were found to have significantly longer hold phases than their lenis counterparts (see Tables 1 and 2). These findings agree to a considerable extent with data reported by Ball (1984), Jones (1984), Ball and Williams (2001), Morris and Hejná (2019) and Iosad (forthcoming). However, we think the data form a basis for seeing the fortis-lenis distinction from a wider perspective, not restricted to accounting for aspiration in plosives.

In brief, the acoustic investigation of the first two phonetic features, i.e. aspiration and voicing, offers promising phonetic evidence for a potentially phonological fortis-lenis divide as indicated by grammatical and semantic patterns. The effects of aspiration and voicing contribute to our claim that Welsh should be classified as a fortis-lenis language rather than a voiced-voiceless one, in particular when considering the general articulation length of Welsh simplex codas and the devoicing of lenis codas (Asmus and Grawunder 2017). What is more, general articulatory length (hold phase and aspiration) forms a pattern similar to that described by van Sluis (2019) for Old and Middle Welsh.

With regard to the CoG data collected for the purposes of the study, they seem to be inconclusive, yet they indicate that the aspiration noise following a plosive is generated at the glottis. Somewhat surprisingly, however, the fortis plosives, with the exception of /t/, are followed by friction whose CoG is lower than that of their lenis counterparts.¹⁵ For this reason,

¹⁵ In the study by Wallis and Koffi (2017), [v] has a higher CoG than [f], while the CoG of [θ] is higher than that of [ð]. In the case of sibilants, the value of CoG is always higher in the case of voiceless fricatives.

the data must be treated with caution and can only be regarded as one of the potential phonetic criteria that differentiate between lenis and fortis plosives.

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