



# Multiplicity of the acoustic correlates of the fortis-lenis contrast: plosives in Aberystwyth English

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## Abstract

Using evidence from Aberystwyth English, this study shows two points relevant for the phonetic implementation of the fortis-lenis contrast in plosives and two points concerning the diachronic scenarios proposed as ways in which pre-aspiration (one of the correlates of this contrast) innovates. Firstly, a wide range of acoustic features distinguishes the fortis and the lenis series. Release duration is a correlate of the contrast in three foot-positions (initial: *tot* vs *dot*; medial: *cotter* vs *codder*; final: *cot* vs *cod*), as is vowel duration and the presence of voicing. Furthermore, pre-aspiration and breathiness differentiate the two series foot-medially and foot-finally. For one speaker, glottalisation rather than pre-aspiration distinguishes the series foot-finally. Secondly, whilst the plosives are frequently post-aspirated foot-initially, the release of /t/ and /d/ is realised variably with affrication and/or post-aspiration in all three positions: rather than presence or absence of affrication or post-aspiration then, it is release duration that distinguishes the series. Thirdly, the data is not supportive of the suggestion that pre-aspiration innovates in the fortis series as a consequence of the loss of voicing in the lenis series or the other way round [1] and [2] or, fourthly, as a step on a degemination trajectory [3], [4].

**Index Terms:** fortis-lenis contrast, plosives, pre-aspiration, breathiness, voicing, post-aspiration, affrication, vowel duration, VOT, allophony, typology

## 1. Introduction

English and Welsh fortis-lenis contrast in plosives (/p/, /t/, /k/ vs /b/, /d/, /g/) has been most commonly seen as being based on the presence of post-aspiration ([5] and [6]) and the duration of the preceding vowel ([7] and [8, p. 13]), the latter of which gave rise to discussions of prefortis clipping. The treatment of post-aspiration via VOT sometimes includes discussions of voicing in the lenis series as well (e.g. [9]). Although it has been suggested that Welsh English is more strongly post-aspirating than other varieties of English [4], acoustic analyses have not been carried out to confirm these impressionistic descriptions. Similarly, it is not known whether preceding vowel duration plays any role, although based on our knowledge of English and Welsh phonetics [7] and [8], such an effect is to be expected.

The duration and the presence of post-aspiration, and the duration of the preceding vowel are nonetheless not the only phonetic aspects which may be essential in the implementation of the contrast in Welsh English. More recently, it has been shown that Welsh English, like other accents of English found

in the British Isles, is also a strongly pre-aspirating variety of the language [10], [11], and [12, pp. 36 and 48]. From a typological perspective, there seem to be two relationships that pre-aspiration and post-aspiration enter into in the world's languages: the two phenomena are either allophonic, as in Faroese, Icelandic, Mongolian, Sámi, Scottish Gaelic [13, p. 70], [14], and [15], and could implement the contrast in a distributionally complementary way, or they co-occur in the same environment, as is the case in Italian [16], Welsh [11], and at least some British English accents [17], and they could implement the contrast in the same distributional environments. We could suggest that the latter scenario could lead to trade-offs, which in turn could lead to the allophonic pattern in diachrony. Since pre-aspiration seems to be found only in languages which also exhibit post-aspiration, we would expect both to be involved in the implementation of the contrast in languages which show pre-aspiration.

Additionally, recent reports have observed a considerable amount of affrication in Welsh English and English English /t/ [12, p. 270] and [17]. It is not certain then whether it is post-aspiration or affrication that serves as a correlate of the contrast regarding this phoneme (or indeed other phonemes).

Finally, it has been suggested that pre-aspiration innovates in the fortis series as a consequence of the loss of voicing in the lenis series or the other way round ([1] and [2]) or as a step on a degemination trajectory [3], the latter of which can be tested on Welsh English as this variety shows lengthened consonants [4].

In the context of this evidence, the present study addresses the following questions:

- Is post-aspiration an acoustic correlate of the contrast in foot-initial (post-pausal and post-vocalic), foot-medial, and foot-final (pre-pausal and pre-sonorant) environments?
- Is vowel duration an acoustic correlate of the contrast foot-medially and foot-finally?
- What role do pre-aspiration and breathiness have in distinguishing the two series?
- Do pre-aspiration and post-aspiration implement the contrast in an allophonic way?
- Is /t/ affrication more important in distinguishing /t/ and /d/ than /t/ post-aspiration?
- Is presence of pre-aspiration in the fortis series concomitant with the absence of voicing in the lenis series?
- Does the increasing in the duration of pre-aspiration lead to the decreasing in the duration of closure?

## 2. Methodology

### 2.1. Data

Ten female speakers, all of whom are native speakers of Welsh who were born and raised in Aberystwyth, were recorded with H4 Zoom Handy Recorder in conjunction with a head-mounted AKG C520 microphone in quiet environments. The recordings were sampled at 44.1 kHz.

The prosodic environments of interest were the foot-initial (*bap* vs *pap*), the foot-medial (*cabbie* vs *capper*), and the foot-final (*cab* vs *cap*) positions. Minimal and near minimal pairs were balanced for the amount of fortis and lenis plosives by prosodic condition. The same word was never analysed in more than one prosodic condition.

The tokens of interest were part of a bigger wordlist which focused on a number of linguistic phenomena. Each token was produced three times by each speaker, once in isolation (e.g. *tot*) and twice in a carrier sentence (*Say tot once.*). This enabled, among other things, analyses of the acoustic correlates of the fortis-lenis contrast foot-initially with a voiced segment as opposed to a pause preceding the target plosive (*Say tot once.* vs *Say dot once.* vs *tot* vs *dot*). This was also of relevance in the foot-final context, where the final plosive was either followed by a voiced segment or a pause (*Say cot once.* vs *Say cod once.* vs *cot* vs *cod*).

In total, 1,976 tokens were analysed in this study. For more details on the segmental composition of the tokens and their lexical frequency, see [12, pp. 204–5].

The segmentation and the phonetic analyses were done using Praat [18]. Statistical analyses were carried out with R Studio [19], using R packages lme4 1.1-7. [20], lmerTest [21], and blme [22].

### 2.2. Measurements

In line with [12], pre-aspiration was defined as a period of voiceless (primarily glottal) friction whilst breathiness was identified as a period of voiced (primarily glottal) friction. The same was applied to post-aspiration and post-aspiration-induced breathiness, as demonstrated in Figure 1.

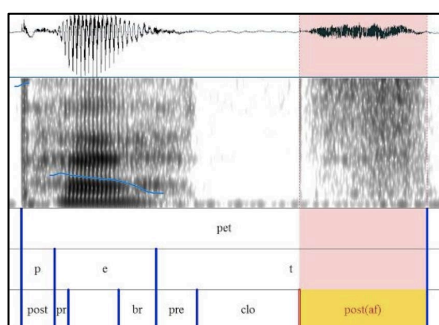


Figure 1: Post-aspiration (*post*), breathiness (*br*), pre-aspiration (*pre*), voiceless closure duration (*clo*), and affricated release (*post(af)*).

The presence of voicing was determined on the basis of the sound wave as well as the spectrogram, as illustrated in Figure 2. See [12] for more details.

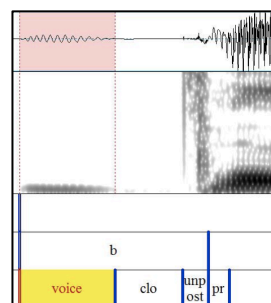


Figure 2: Identification of voicing onset and offset.

For the purposes of this study, vowel onset was equated to the onset of voicing and vowel offset to that of the offset of voicing (Figure 1). Closure duration refers to a period of voiceless closure duration (Figures 1-2), i.e. where voicing is present, its duration is excluded from “closure” as referred to here.

Affrication was identified on the basis of the presence of oral friction (portion highlighted in Figure 1), indicated by the concentration of energy in higher frequencies. Whilst this was not problematic in case of /t/, deciding on the presence of affrication with /d/ was more challenging as the release duration is considerably shorter. A real challenge was discriminating cases of affrication and those of post-aspiration. The two could be distinguished in many cases (Figure 3, with highlighted post-aspiration); however, there were many cases where both phenomena seemed to be realised at least partially simultaneously.

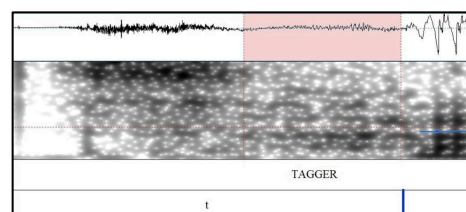


Figure 3: Affrication followed by post-aspiration.

The categorical variables analysed for correlations with the fortis-lenis series were the presence of voicing, breathiness, and pre-aspiration. Duration was considered in case of release duration, vowel duration, and the voiceless closure duration. As an additional step, a preliminary classification and analysis of the release realisation (affricated and/or post-aspirated) was carried out, as described above. The durational results were subject to analyses both raw and normalised (as a percentage of the word duration), with no difference between the two procedures found.

## 3. Results

The results are presented as follows. Firstly, the potential correlates of the fortis-lenis contrast are analysed individually. Next, the type of the relationship between pre-aspiration and post-aspiration is established. The role of affrication is looked into subsequently. Finally, the relationship between pre-aspiration and voicing, and that of pre-aspiration and closure duration, is demonstrated.

The statistical analyses use Fit Bayesian Models [22] for the testing of the categorical correlates because the data is such that a high number of quasi-complete separations occurs.

For the same reason, the models were run separately for the three prosodic conditions (foot-initial, foot-medial, foot-final). The independent variables were “series” (two levels: fortis vs lenis) with an interaction with “type of utterance” (two levels: isolation vs carrier sentence). “Word” and “subject” were set as random effects. The dependent variables were the potential correlates: voicing, pre-aspiration, and breathiness, each with two levels (present vs absent). The numeric dependent variables were analysed with Linear Mixed Effects Models [20] and the p-values were obtained with the lmerTest package [21]. These numeric dependent variables were release duration, vowel duration, and voiceless closure duration.

### 3.1. Release duration

The duration of the release consistently distinguishes the two series in all three contexts analysed ( $p < 0.0001$ ). Furthermore, longer values are associated with tokens uttered in isolation than in a carrier sentence ( $p < 0.01$ - $0.0001$ ), which means that the release duration difference is somewhat greater if the foot-initial plosives are preceded by a pause rather than a vowel.

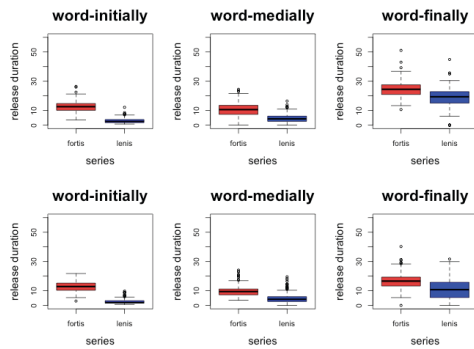


Figure 4: Release duration (normalised) by foot-position and utterance type (top: isolation; bottom: carrier sentence).

### 3.2. Vowel duration

The duration of the vowel is a very consistent correlate of the contrast. Not only is it longer before the foot-medial and foot-final lenis plosives, but also following the foot-initial lenis plosives ( $p < 0.0001$ ). Tokens in isolation show longer durations than those in a carrier sentence ( $p < 0.0001$ ).

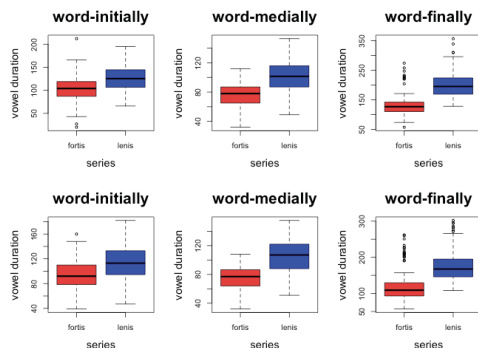


Figure 5: Vowel duration (normalised) by foot-position and utterance type (top: isolation; bottom: carrier sentence).

### 3.3. Voicing

The presence of voicing consistently distinguishes the two series in all three contexts ( $p < 0.05$ - $0.0001$ ), being more frequent with the lenis plosives. In the foot-initial position, it is more frequent if preceded by a voiced segment than a pause ( $p < 0.05$ ). It occurs in 88% of the lenis plosives foot-medially and in 91% foot-finally. Foot-initially, we find voicing in 13% of cases preceded by a pause and in 80% where a voiced segment precedes.

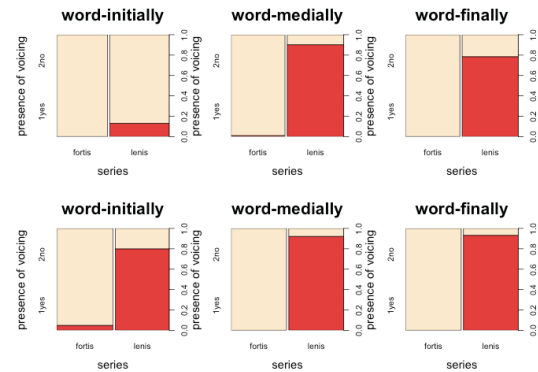


Figure 6: Presence of voicing by foot-position and utterance type (left: isolation; right: carrier sentence).

### 3.4. Pre-aspiration and breathiness

The presence of pre-aspiration is a correlate of the contrast foot-medially and foot-finally ( $p < 0.0001$ ), where it is found in 80-91% of the cases. Although it occurs foot-initially, the frequency is not high enough for it to reliably distinguish the two series (32%). Foot-initially, pre-aspiration occurs only if preceded by a voiced segment rather than a pause ( $p < 0.0001$ ). In all three positions, pre-aspiration is more frequent when the token is uttered in a carrier sentence than in isolation ( $p < 0.05$ - $0.01$ ).

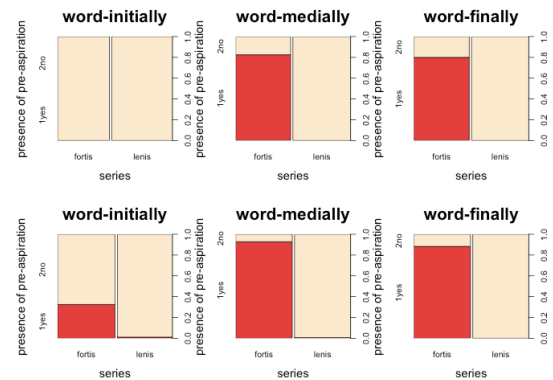


Figure 7: Presence of pre-aspiration by foot-position and utterance type (left: isolation; right: carrier sentence).

Breathiness was analysed only for the foot-medial and the foot-final contexts and similar patterns were found: the presence of breathiness distinguishes the two series both foot-medially ( $p < 0.0001$ ), where it occurs in 93% of the fortis cases, and foot-finally ( $p < 0.0001$ ), where it is found in 92% of the fortis cases ( $p < 0.0001$ ). However, breathiness is also found in the lenis series in both conditions, with 8% and 7%

occurrences foot-medially and foot-finally respectively. Thus, we can assume that it may be less reliable than pre-aspiration in cuing the contrast. Similarly to pre-aspiration, breathiness is more frequent in tokens uttered in a carrier sentence rather than isolation in the foot-final position ( $p < 0.01$ ), although this tendency is stronger for the fortis than the lenis plosives ( $p < 0.001$ ).

### 3.5. Closure duration

Excepting one speaker (ABE37), the duration of the voiceless closure duration distinguishes the two series foot-finally ( $p < 0.0001$ ), where longer values are associated with the fortis than the lenis series. For this one speaker, glottalisation rather than closure duration, pre-aspiration, or breathiness distinguishes the series.

### 3.6. /t/ and /d/ affrication

The speakers show a mixture of consistent and inconsistent patterns related to affrication. The results confirm that /t/ is affricated in all the prosodic conditions; however, /d/ is similarly realised with affrication fairly frequently, depending on the speaker. The presence of affrication then cannot be taken as an acoustic correlate of the contrast. Post-aspiration occurrence is thus more reliable than affrication in this regard. Nevertheless, the durational aspects of the release of /t/ and /d/ are more consistent than the presence or absence of affrication or post-aspiration.

### 3.7. Relationship between voicing and pre-aspiration

As Figure 8 shows, it is not the case that the less voicing there is in the lenis series, the more pre-aspiration there is in the fortis series. On the contrary, if there is a relationship at all, it is that of a positive correlation.

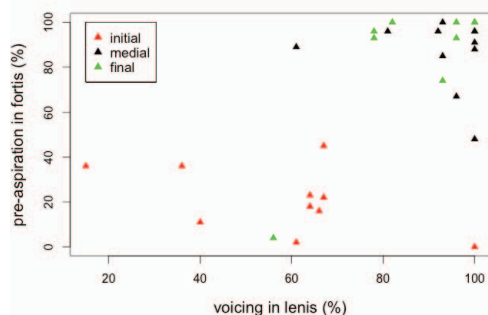


Figure 8: *Co-occurrence of voicing in lenis and pre-aspiration in fortis series.*

### 3.8. Relationship between closure duration and pre-aspiration

The degemination scenario whereby lengthened closure duration gets replaced with pre-aspiration in conjunction with shorter closure duration predicts a negative correlation between the duration of pre-aspiration and that of closure duration within the fortis series. However, when correlational results are significant within the present dataset, the correlations are positive and very weak ( $r = 0.11$ - $0.13$ ;  $p < 0.01$ ; Spearman and Pearson correlation tests).

## 4. Discussion

This study set out to shed light on a number of questions.

Firstly, it has been shown that release duration distinguishes the fortis-lenis contrast consistently in all three positions in Aberystwyth English.

Secondly, it has been found that vowel duration is consistently longer before the lenis plosives in the foot-medial and the foot-final positions. However, it has also been observed that the foot-initial lenis plosives are associated with longer duration of the following vowel. The latter finding is in line with those of [23, p. 2031] for American English plosives and [24, p. 19 and pp. 23–4] for Seoul Korean fricatives. These findings suggest that the affiliation of post-aspiration with respect to the plosive as opposed to the vowel is as ambiguous as the segmental affiliation of pre-aspiration (see also [25]).

Thirdly, it has been demonstrated that pre-aspiration and breathiness are both acoustic correlates of the contrast foot-medially and foot-finally, which so far has not been shown for any accent of English, although similar evidence is available for other languages ([14], [15], [26], [27], [28], [29], [30]). More rarely, pre-aspiration can distinguish the two series even if found in both of them ([11], [31], [32]).

Fourthly, a high variability has been found in the presence of affrication and post-aspiration, both for /t/ and /d/. Both phenomena are very frequent in the data and post-aspiration rather than affrication is more consistent in distinguishing the two series. Nevertheless, I propose that the contrast would appear to rely on the duration of the release, irrespective of whether this is realised as affrication or post-aspiration. This provides support to the proposal by [33] that there may be a phonological feature [long VOT]. However, whilst the high degree of variability may truly reflect the production of the speakers, this could also be due to the difficulties associated with reliable identification of affrication and post-aspiration in a language where the two are not contrastive and form a cline.

Fifthly, it is not the case that higher presence of pre-aspiration in the fortis series would be concomitant with higher absence of voicing in the lenis series. If there is a correlation between the two, this correlation is not a negative one. Indeed, both voicing and pre-aspiration are found more frequently in the lenis and fortis series, respectively, in the following order: foot-initial < foot-medial < foot-final. This hierarchy reflects that of vowel duration, which is most different across the series foot-finally, then foot-medially, then foot-initially. The release duration shows the opposite pattern.

Finally, there is no negative correlation between the duration of pre-aspiration and the voiceless closure duration. Whilst this may be interpreted as evidence that pre-aspiration does not serve as a step in the degemination pathway, this needs to be approached with caution. It may be the case that different results would be obtained in a different style: although the speakers often lengthen their plosives in conversational data, this lengthening is gone for all but one (ABE24) in the wordlist data analysed here. Furthermore, if a degemination change has been finalised, we would not expect there to be a correlation even though the change actually happened via this route.

Analyses of the correlates in conversational data should complement those presented here to establish whether the same patterns are found in more natural situations.

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