# Affricated Allophones of North Welsh /t/: An acoustic Analysis

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## ABSTRACT

Welsh is a p-Celtic language spoken mostly in the British Isles. Its consonant inventory features six plosive phonemes, i.e. /p, t, k, b, d, g/. The Welsh plosives exhibit a contrast between the fortis and lenis series marked phonetically by a number of phonetic features, the most important of them being aspiration. A previous study on Welsh plosives conducted by the authors of this paper revealed that, unlike the other plosives, the Welsh /t/ has a strong tendency towards affrication in some contexts. Since affrication of plosives has received some attention in phonetic studies on other languages, it seemed striking that potential affrication of Welsh plosives has not yet been studied phonetically. The present study includes word-initial and word-final realisations of /t/ in Welsh monosyllabic lexemes. The analysis of four key spectral moments; namely, centre of gravity, dispersion, skewness and kurtosis, was conducted to confirm the assumptions regarding allophonic variation of the Welsh /t/ based on a visual inspection of spectrograms. The results suggest that the Welsh /t/ may actually have as many as four allophones, i.e. the aspirated allophone [$t^h$], the affricated allophone [ts], which can also be aspirated in two different ways; namely, aspiration can occur simultaneously with affrication [$t^{sh}$] or it can follow the affricated section [$ts^h$].

**Keywords:** Welsh; allophonic variation; centre of gravity; acoustic phonetics; spectral moments analysis

## INTRODUCTION

Plosives are usually defined as obstruents pronounced with a complete closure occurring on the course of their articulation (Carr, 2008: 39). There is, however, a considerable degree of variation that sounds classified as plosives may exhibit. Ladefoged and Maddieson (1996: 48) distinguish five main features of plosive articulation in which various types of plosives may differ.[1]

The first aspect is the laryngeal setting, i.e. description of the state of the glottis while pronouncing a given sound. Most common possibilities here are voiced, voiceless or aspirated plosives. Secondly, plosives may differ in terms of the airstream mechanism involved in providing

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[1] The theoretical model presented by Ladefoged and Maddieson (1996) is supplemented by research into phoneme mergers and splits, i.e. situations in which phonetic differences between phoneme realisations disappear or emerge respectively (see Luef 2020 as an example of such an approach). In that context, the phenomenon under review in this paper should be studied further with experiments involving speakers of different age groups to determine whether affrication of the Welsh plosive /t/ should be seen as an instance of sound change in progress.

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the air necessary for articulating a plosive. Here, the most popular mode is pulmonic egressive, but there may also be ejective or implosive sounds. Plosives also differ in terms of articulatory and respiratory force. Fortis and lenis plosives are examples of alternative physical realisations in this respect. Plosives may also differ in length. The closure phase of long plosives, or geminates, is between one and a half to three times longer than that of a short one (Ladefoged & Maddieson, 1996: 91-92). As regards the onset of a plosive, it may be pre-nasalised, as in Fijian or Fula (Ladefoged & Maddieson, 1996: 48), while the offset may be realised in several non-standard ways, e.g. nasally or laterally. Finally, plosives may also be released gradually, which results in affrication. This type of release is attested in several languages, e.g. German or Navajo (Ladefoged & Maddieson, 1996: 48).

With regard to Welsh, its consonant inventory features six plosives, i.e. /p, t, k, b, d, g/. They are organised into three fortis-lenis pairs, i.e. bilabial /p, b/, alveolar /t, d/ and velar /k, g/ (for details on the fortis-lenis distinction and its application to Welsh see for instance Asmus, Jaworski & Baran, 2020 or Baran, 2020). Welsh plosives are typically fully-released both word-initially and word-finally, and feature a certain amount of aspiration, depending on the laryngeal specification (Asmus & Grawunder, 2017; Asmus, Jaworski & Baran, 2019). As for the articulatory variation discussed in the previous paragraph, a study on the acoustic features of the release burst of Welsh plosives by Jaworski and Baran (2021) revealed that Welsh fortis plosives, especially the alveolar /t/, may occasionally be affricated.

This study constitutes a part of a research project aimed at studying Welsh consonant inventory with a particular focus on laryngeal features and related acoustic cues. The aim of this paper is to build on the foundations laid in Jaworski and Baran (2021) and explore the articulatory variation in the offset of Welsh plosives in search of potential affrication. To achieve that, theoretical background on affrication and frication of plosives is presented by giving an overview of selected studies on the matter in Section 2. Then, Section 3 describes an acoustic study conducted with a view to analysing various plosive realisations, which may include instances of affrication or frication. Section 4 presents the results of the aforementioned study focusing on allophonic variation of the sound under review and acoustic characteristics of the affricated realisations. Finally, Section 5 presents conclusions and reviews possibilities of further research in this area.

## THEORETICAL BACKGROUND

### AFFRICATION AND FRICATION OF PLOSIVES

Affrication is the focal process for this paper, because preliminary observations suggesting its existence were made in the previous study resulting from this research project (Jaworski & Baran, 2021). This study aims at confirming these observations by applying more precise measurements and methodology focused on affrication of plosives. However, frication is also relevant here as both processes, i.e. affrication and frication, are sometimes seen as similar. Therefore, in order to facilitate further discussion on the exact nature of the process under review, frication and affrication have to be contrasted first.

Frication is defined here as a process changing plosives into fricatives. This means that a plosive sound, that normally features a complete closure in the oral cavity that is later released, is pronounced with an incomplete closure similar to that in fricatives, which turns it into a fricative that exhibits constant turbulent noise. It should, however, be mentioned that an incomplete closure is not sufficient to cause frication. Acoustic studies of frication suggest that an incomplete closure

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results in a fricated realisation only if it is accompanied by the right positioning of articulators (sounds involving high jaw or tongue position exhibit higher possibility of frication) and appropriate intraoral pressure (for details see Nicolaidis, 2001: 70; Jones & McDougall, 2009: 266).

Frication of plosives is cross-linguistically common in casual speech (Beckman, de Jong, Jun & Lee, 1992; Jones & Llamas, 2008). The link between frication and casual speech seems to be logical as less careful articulation, characteristic of casual speech, is likely to result in plosive closures being incomplete, which, in turn, facilitates frication. However, except for being a low-level phonetic effect of casual speech, frication has the potential of being phonologised. Jones and McDougal (2009: 267) point to Spanish (for details see González, 2002), Tuscan Italian (for details see Villafaña-Dalcher, 2008), Irish English (for details see Jones and Llamas, 2008) or Liverpool English (for details see Watson, 2007) as examples of languages in which frication of plosives is more than just a phonetic process, but functions as a phonologised paradigm of regular alterations.

A phonetic study of the fricated /t/ in Australian English conducted by Jones and McDougall (2009) is summarised here as an example of an experimental analysis of frication of plosives. The acoustic features of the fricated Australian English /t/ as described by Jones and McDougall (2009) may also be used in comparison with the findings of this study.

As Jones and McDougal (2009) set out to analyse the acoustic features of fricated /t/ in Australian English, their study required generating a considerable number of fricated realisations. To achieve this goal, the authors adjusted the methodology of the study to increase the likelihood of frication occurring in the recordings. First of all, literature revision suggested that frication of /t/ in Australian English happens most frequently in intervocalic or prepausal/word-final position, so Jones and McDougal (2009) placed /t/ in these two positions in target words and used a carrier phrase that provided intervocalic context. Secondly, it is known that frication in Australian English happens more often in speech of higher and middle-class speakers, so the speakers recorded for the study were chosen accordingly. These two adjustments allowed Jones and McDougal (2009) to record fricated realisations of /t/ in the majority of cases for all the speakers chosen for their study.

The acoustic analysis in Jones and McDougal's paper was only conducted on the realisations of the fricated /t/ that were 'true fricatives', i.e. did not exhibit any acoustic signs of a complete closure being formed (2009: 269). The authors measured frequency location and amplitude of the two major spectral peaks in the central 50ms of friction and frequency range of energy falling within 12 dB of the major spectral peak. Statistical measures of the frication spectrum were also taken, with focus on the centre of gravity (COG), dispersion, skewness and kurtosis.

Jones and McDougall compared the measurements of fricated /t/ realisations described in the previous paragraph to /ʃ/ and /s/. The results of that comparison suggest a similarity between fricated /t/ and /ʃ/ as there was no significant difference in COG between the two sounds. Additionally, major spectral peak frequencies and skewness measurements rendered differences that were significantly different for fricated /t/, /ʃ/ and /s/, but the values for fricated /t/ were closer to those of /ʃ/ than those of /s/. Relative duration, however, shows a clear difference between fricated /t/ that was regularly shorter than /ʃ/ and /s/.

The study by Jones and McDougal (2009) is relevant for this paper as it complements the definition of frication established above. Frication in Australian English was proven to be responsible for generating a fricated /t/ that is a true fricative and becomes acoustically similar to another phonemic fricative, i.e. /ʃ/ (Jones & McDougal, 2009). On the basis of this, frication may be differentiated from affrication, which is key for the rest of this study.

With respect to affrication, the term is understood here as a process changing the manner of articulation of a given sound from plosive to affricate. This is achieved by changing the characteristics of the release of the sound, i.e. affricated plosives exhibit fricative-like friction after the release. Affrication, understood in this way, is then clearly different from frication. While fricated plosives exhibit no hold phase and release burst, affricated plosives still feature these two stages in articulation (Buizza & Plug, 2012). It should be mentioned that plain plosives do not differ significantly from affricated plosives in terms of characteristics of hold phase or release burst. The most significant difference between the two variants is, as aforementioned, in what happens after the release (Buizza & Plug, 2012).

The phenomenon of affrication may be studied phonetically in a number of ways. The phonetic cues most relevant here are segment duration, aspects of sound amplitude and sound intensity. As regards duration, analyses of phonemic plosives and affricates reveal that the former are usually shorter than the latter (Lengeris & Kappa, 2016). Thus, it may be expected that the same pattern should appear in comparison of plain and affricated plosives. A study of RP English /t/ and its aspirated, affricated and fricated allophones conducted by Buizza and Plug (2012) confirms this assumption as it shows that realisations of affricated /$t^s$/ are longer than realisations of aspirated /$t^h$/. This results from the difference in duration of the post-release phase because the hold phase and burst stage are of comparable length (Buizza & Plug, 2012).

Amplitude measurements may also be used in distinguishing affricated plosives from other variants. The amplitude of the post-release stage seems to be most useful here. The aforementioned study by Buizza and Plug (2012) reveals that, in RP English, the amplitude of the post-release phase of affricated /t/ is higher than the amplitude of the post-release phase of aspirated /t/ and friction amplitude in fricated /t/.

Intensity is the last of the major phonetic cues used in distinguishing affricated plosives from other variants. Again, the decision to study it is based on the observation on relationships between phonemic plosives and affricates. It is commonly accepted that affricates exhibit higher relative intensity than plosives (Lengeris & Kappa, 2016), so it seems reasonable to expect that affricated plosives will feature post-release stage friction of higher intensity than that in plain plosives. Such a pattern is visible in the results of the study by Lengeris and Kappa (2016), which shows that the relative amplitude of the release burst is higher in the affricated realisation of /k/ of western Cretan than in the plain one.

All in all, it seems reasonable to consider affrication of plosives a separate phenomenon from frication of plosives. The difference between the two is one of the manner-related acoustic features, i.e. fricated plosives do not feature a hold phase and release burst as they become fricatives, while affricated plosives retain a hold phase and release burst, but change the way they are released, i.e. they become affricates. Affricated, fricated and plain plosives may be contrasted on acoustic grounds by studying their duration, amplitude and intensity.

## AFFRICATION OF PLOSIVES IN WELSH – STATE OF THE ART

It appears that the issue of affrication of plosives in Welsh has not been a focal point of any study so far. Literature review conducted for this paper reveals only one publication that briefly mentions affrication in the context of Welsh. In their description of the North Welsh dialect, Bell, Archangeli, Anderson, Hammond, Webb-Davies and Brooks (2021: 6) observe that "release of fortis plosives may verge on affrication". Interestingly, the examples of such affricated realisations given by the authors only include lexemes with /t/, which confirms the preliminary findings regarding affrication in Welsh from the study by Baran and Jaworski (2021).

As noted above, the idea to pursue the acoustic analysis of the potential affrication of plosives in Welsh resulted from working on a paper on the acoustic features of the release burst of Welsh plosives (Jaworski & Baran, 2021). The authors noticed a tendency of the Welsh fortis /t/ to exhibit post-release phases that included a period of fricative-like friction, instead of the aspiration friction visible in typical realisations. As the question of whether or not Welsh /t/, and potentially other plosives, exhibit occasional or regular affrication was outside the scope of the aforementioned release burst study, the decision was made to make it a subject of a separate phonetic investigation.

As there are no previous phonetic studies of Welsh plosive affrication, the theoretical framework has to be built on general acoustic knowledge and on studies on plosive affrication in other languages. As established in Section 2.1., it is expected that potential affricated realisations of plosives in Welsh and typical plosive realisations form a pattern of acoustic similarities and differences comparable to those of phonemic affricates and plosives cross-linguistically. However, one notable feature of Welsh to mention here is that its consonant inventory features no phonemic affricates. Affricates /tʃ, dʒ/ are not found in the sound inventory of Welsh. Words containing them are almost exclusively borrowings from English, Latin or effects of vowel-triggered palatalisation of /t/ and /d/ (Jones, 1984: 44; Hannahs, 2013: 15). There is, however, dialectal evidence suggesting that /tʃ, dʒ/ may have started the process of being integrated into the Welsh consonant inventory. Some studies of Welsh mICM system suggest that Northern Welsh mICM includes affricates in its paradigm (see, for instance, Griffen, 2015 for a detailed analysis). Nevertheless, as the status of affricates in Welsh remains questionable, they will not be used in the phonetic comparison presented in this study.

## METHOD

### THE OBJECTIVES

Even though, on the whole, the article focuses on the allophonic variation of the Welsh /t/, its primary objective is to describe the acoustic features of the affricated allophone of the sound. The idea for writing this article emerged while working on a different paper, when we noticed that numerous realisations of the plosive /t/ resembled and, in fact, sounded like the affricate [ts] rather than [tʰ]. Since, to the best of our knowledge, this particular variant has not attracted much attention to date, some of the decisions regarding the classification of the allophones of the Welsh /t/ had to be made on the basis of their acoustic and spectral properties. More specifically, we needed to distinguish affricated unaspirated allophones [tˢ] (see Figure 1) from affricated aspirated ones [tˢʰ] (see Figure 2), whose spectra differ primarily with respect to the distribution of frequencies.

### THE PARTICIPANTS AND DATA COLLECTION METHOD

In order to collect data for analysis, six native speakers of Welsh were asked to read a list of monosyllabic words embedded in the carrier phrase *Dw i heb ddweud X ond Y!* ‘I didn’t say X but Y’[2]. X and Y represent the slots occupied by the target words. The plosive /t/ was placed in word-initial and word-final position. Altogether each participant produced 40 tokens of /t/ in word-initial

[2] Literally, ‘I am without say(ing) X, but Y’.

position and 20 realisations word-finally. Thus, each speaker pronounced 60 target words, which means that the study includes 360 realisations of the plosive, of which 16 were excluded from the analysis due to being realised either as a spirant or an approximant. The recordings sessions were held in Aberystwyth in 2018. All the participants are female native speakers of the northern dialect of the Welsh language. At the time of the recording they were between 39 and 73 years of age. The average age of the participant was 53 (±16). The speakers were naïve as to the objectives of the study and they did not report any hearing or speech impediments.

During the recording sessions, the participants sat at a table with a Sinn7 mPod USB Studio microphone, connected to a Sony Vaio laptop. The microphone was placed approximately twenty centimetres from the speakers. The Praat software (version 4.2.21) was used to make the recordings, digitise the data and determine the spectral parameters of the intrusive vocalic elements, as well as produce the spectrograms and oscillograms. As suggested by the authors of Praat (Boersma & Weenink, 2022), the original sampling rate was set at 44,110 Hz.

In order to provide a comprehensive description of the allophones of the Welsh /t/, we took measurements of the following acoustic parameters: the centre of gravity (CoG), dispersion, skewness and kurtosis. The CoG measure can be thought of as frequency that divides the spectrum into two halves (Chodroff & Wilson, 2019). The amount of energy in the top half, i.e. higher frequencies, is equal to that in the bottom half, i.e. lower frequencies. Thus, sounds with a lot of high-frequency energy, such as [s] or [z], will have a higher CoG than ones with low-frequency energy, e.g. [x] or [ɣ], or the glottal [h].

Dispersion, alternatively referred to as standard deviation, specifies the range of frequencies within which the energy of a sound is concentrated. Low values of this measure indicate that the frequencies are close to the CoG, while high values mean that the energy is dispersed over a large frequency range.

Skewness describes numerically whether or not the distribution of frequencies on both sides of the CoG is symmetrical. Since it is never the case, the distribution of frequencies is skewed either to the right or the left. In the case of a negative skew, the mean and median are smaller than the mode, i.e. the most common score. In other words, if skewness is negative, more scores are to the left of the CoG, while a positively skewed distribution has more scores to the right of the CoG.

Finally, kurtosis is a measure of how much the shape of the spectrum around the centre of gravity is different from the mathematically defined normal curve in terms of steepness or shallowness. A positive value of kurtosis means that the curve is steep, while a negative value indicates that a curve is flat (Howitt & Cramer, 2005; Boersma & Weenink, 2019).

## STATISTICAL ANALYSIS OF THE DATA

In this study, two types of data were collected; namely, nominal and continuous. For this reason, different statistical procedures had to be employed to establish whether or not there are significant differences between the data produced by the participants. Since all the physical realisations of the Welsh plosive /t/ were assigned to one of the four allophone types, they constitute nominal data. While analysing the incidence of different allophones of the plosive in a given context, one deals with percentages. Therefore, in order to establish whether there exist statistically significant differences in the distribution of allophones in the speech of the participants, contingency tests were performed, which can be regarded as more complex versions of the chi square test in that they include more rows and columns of data. In contingency tests, the equal frequencies model is

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normally used. In terms of this study, the model predicts that the allophones of the Welsh /t/ occurring in a specified environment are equally distributed.

In quantitative research, one also deals with continuous data, in which the dependent variable can take any value within a certain range. CoG values of periods of friction are a good example of continuous data. Whenever more than two groups of data need to be compared, different variants of the one-way ANOVA test are usually used. In this study, we applied the procedure to ascertain whether the CoG values of the allophones are affected by the speaker.

## RESULTS

### ALLOPHONIC VARIATION

As noted above, the study included 464 realisations of the Welsh /t/ in word-initial position. Since only monosyllabic words were examined, the sound was expected to be fully aspirated as it occurred in prosodically strong position. However, the analysis revealed a certain amount of allophonic variation which strongly suggests that the aspirated allophone, defined as a closure release followed by a period of glottalic friction, is in fact a minority variant (8%). A typical realisation of the Welsh /t/ should probably be classified as an affricated plosive, i.e. one that involves a period of friction produced at the place of articulation. Instances of affricated /t/ can also be aspirated to various degrees. Our analysis shows that glottal friction may occur simultaneously with the affrication, considerably lowering the CoG of the friction, or it can follow the affricated component as a separate period of friction. Thus, we distinguish four allophones of /t/, namely, aspirated [tʰ], affricated [ts], affricated and aspirated [tˢʰ] and affricated followed by a period of voiceless friction [t͡s ʰ].

With regard to the least frequent aspirated variant, an example of such an allophone, produced in the word *tan* 'until', is depicted in Figure 1. As the spectrogram shows, the release of the hold phase of the plosive is rather weak in that the amplitude of friction of the burst hardly differs from that of the following period of voicelessness. The intensity of friction remains relatively stable and it is virtually impossible to determine which range of frequencies is the most salient. Given this fact, one should expect the CoG of the friction period to be relatively low. The assumption was confirmed by the acoustic examination of this token as its centre of gravity of is 458 Hz, while the dispersion is 1284 Hz. Such realisations also tend to have very high values of skewness and kurtosis. In this particular case they reached 3.655 and 21.087 respectively.

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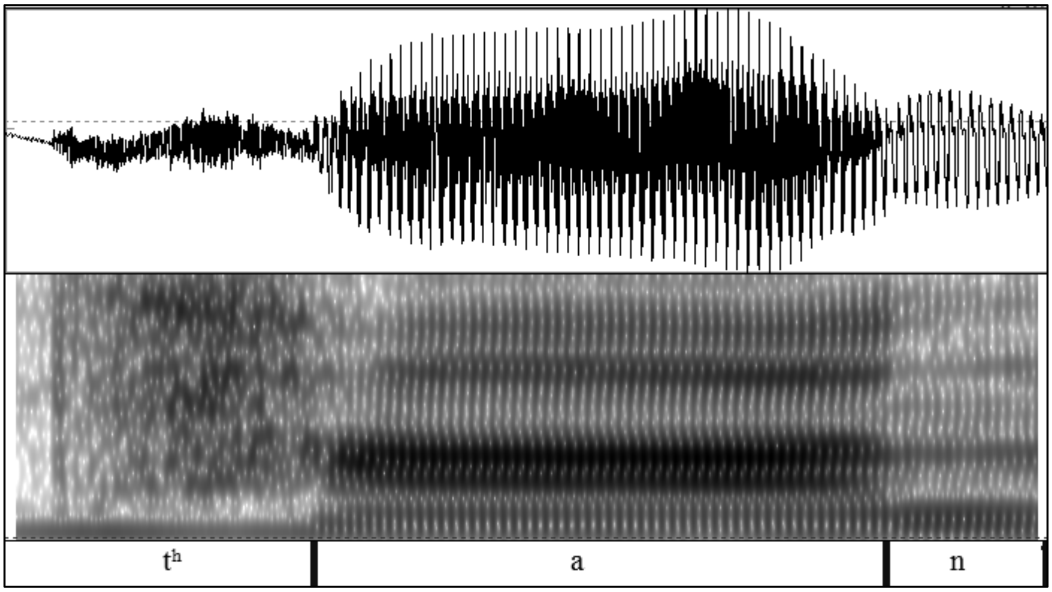


FIGURE 1. An aspirated allophone of the Welsh /t/ produced in the word *tan* 'until'

An example of an affricated allophone without glottal friction is presented in Figure 2, which depicts the spectrogram and oscillogram of the word *tir* 'land'. The section of the oscillogram that represents the realisation of the plosive sound shows a typical affricate. The sound is definitely a stop, released gradually, with the amplitude of friction increasing till approximately the middle of its duration and then it decreases before the sound is released into the following vowel. The corresponding section of the spectrogram shows that the friction occurs in the upper half of the frequency range. As a matter of fact, the CoG of the whole period of friction of this affricated plosive is 3597 Hz, with the dispersion parameter reaching the value of 4688 Hz. Given that its skewness and kurtosis are 0.736 and -1,107 respectively, it may be assumed that the described realisation of /t/ meets all criteria of an affricate.

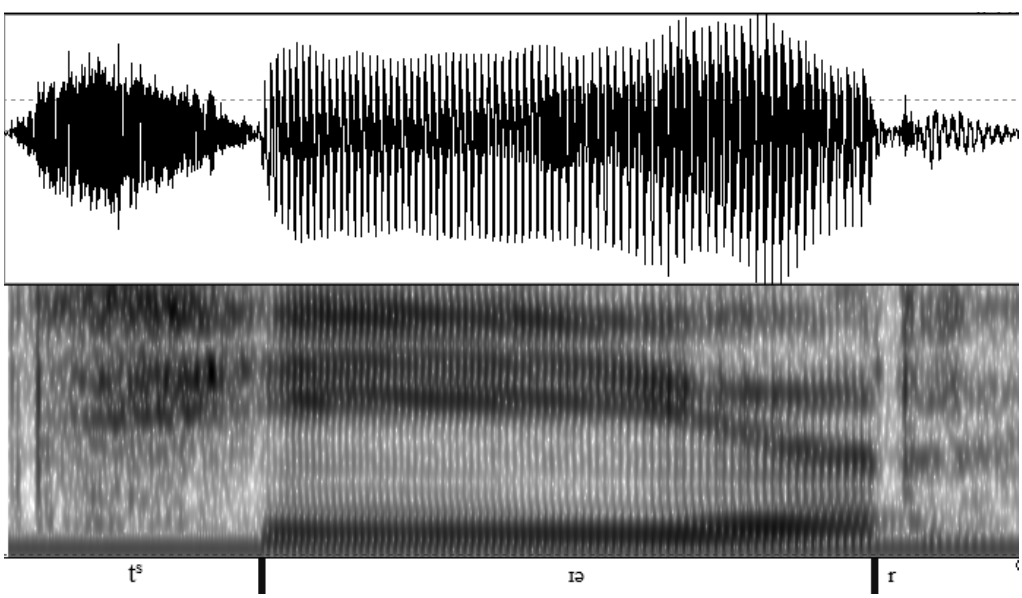


FIGURE 2. An affricated allophone of the Welsh /t/ produced in the word *tir* 'land'

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A realisation of the Welsh /t/ that includes a relatively large amount of glottal friction is presented in Figure 3. The most striking difference between this spectrogram and the one in Figure 2 is that affricated aspirated plosives have a relatively strong friction component in the lower part of the spectrogram, which consequently lowers the CoG of the whole period of friction. Indeed, the spectrogram shows that the sound is a stop with a clearly marked hold phase, followed by a period of friction that is intensive in the upper part and, to a lower extent, in the low frequency region of the spectrum. As a consequence, despite looking similar to the spectrogram in Figure 2, this period of friction has acoustic features that differ significantly from those of the affricated plosive in Figure 2. To begin with, the CoG is much lower as its value is only 874 Hz, with a dispersion of 1389 Hz. Predictably, the skewness and kurtosis of this token resemble those of non-sibilants, i.e. they tend to be considerably higher than in the case of affricated plosives. In this particular case, they are 3.569 and 19.949 respectively.

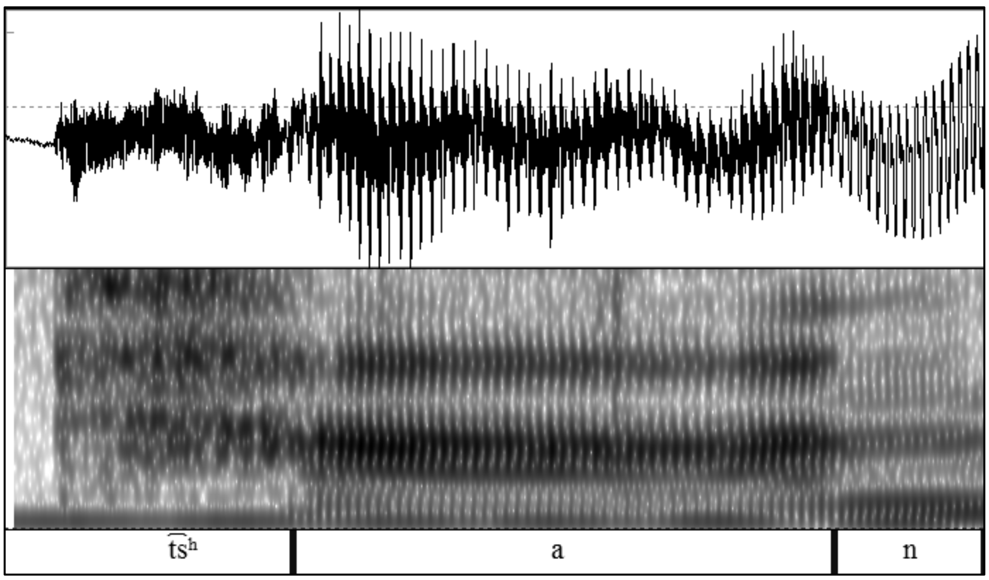


FIGURE 3. An aspirated affricated allophone of the Welsh /t/, produced in the word *tan* ‘until’

The last allophone of /t/ distinguished in this study is complex as it consists of two distinct components. The post-release component is an affricate-like segment that is followed by a period of voicelessness. A realisation of this type, pronounced in the word *tir* ‘land’ is presented in Figure 4. The temporal parameters of the two components vary to a great extent and they also differ with respect to their acoustic features, of which the CoG indicates clearly that the two periods of friction are produced in different places of articulation. The CoG of the affricated component reached the value of 3847 Hz, with a dispersion of 4520 Hz, while that of the period of voicelessness is only 252 Hz, with a dispersion of 1045 Hz. Also the skewness and kurtosis parameters of the two components differ to a very great extent. As for the former component, its skewness and kurtosis are 0.566 and -1.201 respectively, whereas the same parameters of the latter reached the values of 6.725 and 63.097.

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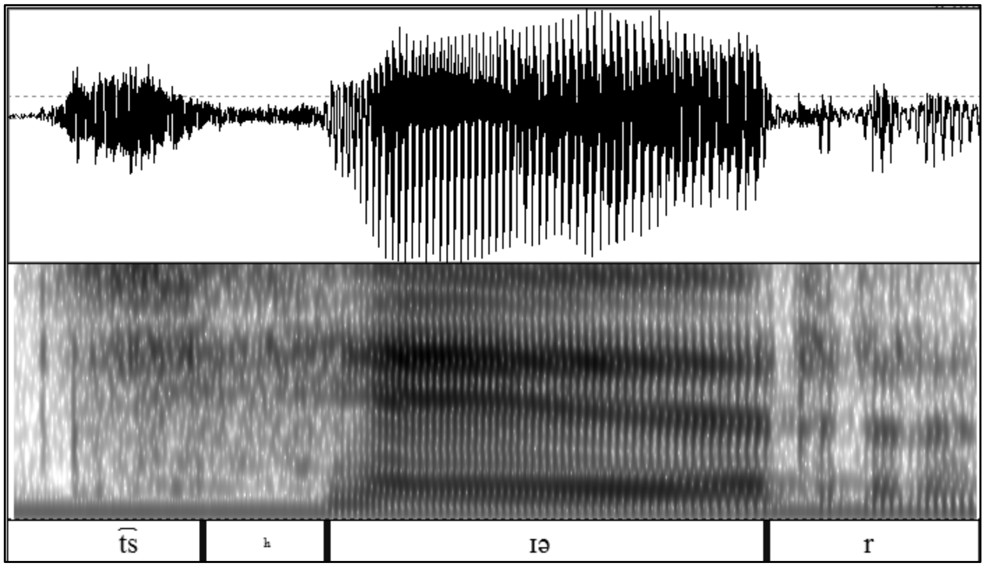


FIGURE 4. An affricated aspirated allophone of the Welsh /t/, produced in the word *tir* ‘land’.

In order to establish whether or not there are statistically significant differences in the distribution of allophones in the speech of the participants, contingency test was performed, using the data presented in Table 1. In contingency tests, the equal frequencies model is employed. In terms of this study, the null hypothesis ($H_0$) predicts that the four allophones of the Welsh /t/ are equally distributed in a given environment.

TABLE 1. Distribution of the four allophones of Welsh /t/ in word-initial and word-final position

| | **Word-initial position** | | | | **Word-final position** | | | |
|---|---|---|---|---|---|---|---|---|
| | $t^{h}$ | $t^{sh}$ | ts | $\widehat{ts}^{h}$ | $t^{h}$ | $t^{sh}$ | ts | $\widehat{ts}^{h}$ |
| S1 | 11 | 14 | 11 | 4 | 10 | 5 | 5 | - |
| S2 | 3 | 4 | 17 | 16 | 4 | 9 | 7 | - |
| S3 | 20 | 6 | 9 | 5 | 12 | 8 | - | - |
| S4 | 10 | 12 | 18 | - | 4 | 10 | 6 | - |
| S5 | 4 | 22 | - | 14 | 5 | 9 | 6 | - |
| S6 | 11 | 24 | 5 | - | 15 | 5 | - | - |

The distribution patterns produced by the speakers in word-initial position differ significantly from one another due to the fact that some of the speakers appear to have less allophonic variation in their speech. By contrast, the patterns occurring in word-final position, which include fewer allophones, do not vary to the same extent. The impressions were fully confirmed when the distribution patterns were compared in a contingency table as the differences turned out to be significant in word-initial position ($F = 46.837$, $df = 23$, $p = 0.00235$), while they were not in word-final position ($F = 30.2673$, $df = 17$, $p = 0.244$). This finding is hardly surprising given that there were fewer allophone types and fewer realisations in the latter context.

**ACOUSTIC PROPERTIES OF AFFRICATED ALLOPHONES OF THE WELSH /t/**

Since affricated allophones differ substantially from affricated aspirated allophones, it seems necessary to adopt a set of acoustic criteria that will allow us to distinguish the former group of allophones from the latter. One of the objective criteria that can be used in order to distinguish the allophones is the value of the CoG, and to a certain extent the related parameters of skewness and kurtosis. Since, to the best of our knowledge, there are no guidelines in the literature as to the acoustic properties of affricated allophones of /t/, a decision was made to classify those four allophones according to the criteria presented in Table 2.

Table 2 does not include the acoustic parameters of affricated allophones followed by a period of glottal friction, like the token in Figure 4 above. However, the data examined for the purposes of the study indicate that affricated parts of such allophones and [ts] variants do not differ significantly with respect to their CoG. Likewise, the periods of friction following the affricated parts of the plosive have acoustic features that do not differ from those of glottal friction following aspirated allophones [$t^h$]. It is worth stressing that the [$\widehat{ts}^h$] allophone was not attested in word-final position.

TABLE 2. The acoustic parameters of the allophones of the Welsh /t/

| Allophone | CoG | Dispersion | Skewness | Kurtosis |
|---|---|---|---|---|
| $t^h$ | 0–1,000 Hz | 712–1,587 Hz | 3.8 – 10.2 | 18.9 – 141 |
| $t^{sh}$ | 1,000–2,000 Hz | 1,351 – 2,424 Hz | 2 – 3.9 | 5.3 – 22.8 |
| ts | > 2,000 Hz | 3,087 – 5,188 | 0.02 – 1.7 | -1.9 – 1.5 |

Having established the thresholds, a one-way ANOVA test was performed on the data to determine whether or not there exist statistically significant differences between the CoG values of the allophones produced by the six speakers. The differences turned out to be significant at the 5% level with respect to the [$t^h$] allophone (F = 4.235, df = 57, p = 0.004842) and very highly significant as far as [$t^{sh}$] is concerned (F = 6.598, df = 80, p = 0.00013). However, they did not reach the level of statistical significance when the centres of gravity of the affricated allophones were compared (F = 1.337, df = 58, p = 0.268).

The analysis of variance yielded different results for word-final position. The CoG values of the periods of friction of the aspirated allophones do not differ significantly (F = 1.528, df = 48, p = 0.211), nor do those of affricated allophones (F = 1,255, df = 24, p = 0.332). However, the test produced statistically significant results when the same parameters of the word-final [ts] allophones were compared (F = 5.509, df = 44, p = 0.00125). Given the insignificant number of tokens that were produced in context, the results should be treated with caution.

## CONCLUSION

The analysis performed for the purposes of the study allows us to draw conclusions as to the amount of allophonic variation of the Welsh /t/, and the acoustic features of the allophones. The allophone types were distinguished on the basis of visual inspection of spectrograms, further supported by the CoG values of the periods of friction following each realisation of /t/. The CoG cut-off points for each allophone type had to be set according to their acoustic and spectral properties due to total lack of guidelines in the literature on Welsh (but see Section 2.1.).

With respect to allophonic variation, we distinguish four variants of the sound in question, which are hardly ever mentioned in the literature (see Bell et al. 2021: 6). These include: the aspirated allophone [$t^h$], the affricated allophone [ts], which can also be aspirated in two different ways; namely, aspiration can occur simultaneously with affrication [$t^{sh}$] or it can follow the affricated section [$\widehat{ts}^h$]. It is worth stressing that there are statistically significant interspeaker differences regarding the distribution of the allophones despite the fact that, word-initially, the [t$^{sh}$] and [ts] allophones appear to constitute the majority of realisations in most speakers.

The analysis also revealed that the other spectral moments examined in the paper are correlated with the value of CoG in that high values of CoG resulted in relatively low values of skewness and kurtosis. Our study shows clearly that all the realisations that we classified as affricated allophones [ts] on the basis of visual inspection are characterized by CoG values higher than 2,000 Hz and low values of both skewness and kurtosis. In the case of [t͡s$^{h}$], the CoG of the affricated part is similar to that of [ts], but the glottal friction following it has a much lower CoG, characteristic of aspirated realisations [t$^{h}$], which tend to have a CoG lower than 1,000 Hz and relatively high values of skewness and kurtosis. The affricated aspirated allophone [t$^{sh}$] has intermediate values of all the acoustic parameters.

Even though the findings are interesting, they should be treated with caution due to the limitations of the study. Before stating decisively that affrication of the Welsh /t/ is a fact, one needs to conduct large scale research involving speakers belonging to different social groups[3] (e.g. age, gender, education level, etc.) and coming from all areas of Wales. This would allow us to determine whether the phenomenon is widespread or should it rather be treated in terms of speaker or dialect-specific features. Finally, it may also be interesting to investigate if the existence of affrication of the North Welsh /t/ results from, or is influenced by, transfer from English where it affects not only /t/, but also /d/.

## REFERENCES

Asmus, S. & Grawunder, S. (2017). *Vowel length in Welsh monosyllables – consonant-mutation dependence, Irish cognation and related theoretical problems. An acoustic study and its didactic implications.* Lampeter: The Edwin Mellen Press.

Asmus, S., Jaworski, S., Baran, M. (2019). Fortis-lenis or voiced-voiceless – features of Welsh consonant. *Proceedings of the 19th International Congress of Phonetic Sciences.* Canberra: Australasian Speech Science and Technology Association Inc.

Asmus, S., Jaworski, S., Baran, M. (2020). Fortis-lenis vs voiced-voiceless plosives in Welsh. *Linguistics Beyond and Within*. *6*, 5-16.

Baran, M. (2020). Fortis-lenis distinction of fricatives and plosives in Welsh – Phonetically distinctive factors. *Linguistics Beyond and Within. 6,* 47-59.

Beckman, M. E., de Jong, K., Jun, S., Lee, S. (1992). The interaction of coarticulation and prosody in sound change. *Language and Speech*. *35*, 45–58.

Bell, E., Archangeli, D., Anderson, S., Hammond, M., Webb-Davies, P., Brooks, H. (2021). Northern Welsh. *Journal of the International Phonetic Association.* First View, 1-24.

Boersma, P. & Weenink, D. (2022). *Praat: doing phonetics by computer [Computer program].* Version 6.3.03, retrieved 17 December 2022 from http://www.praat.org/

Buizza, E. & Plug, L. (2012). Lenition, fortition and the status of plosive affrication: The case of spontaneous RP English /t/. *Phonology. 29*(1), 1-38.

Carr, P. (2008). *A Glossary of Phonology.* Edinburgh: Edinburgh University Press.

[3] Investigating the distribution of the allophones of the Welsh /t/ in various social groups would also be useful in the context of the aforementioned study by Jones and McDougal (2009) who linked the occurrence of the fricated allophones with the speech of people from a certain social group. We did not take this aspect into consideration in this paper, but it will be addressed in a follow-up study as we would like to determine whether or not affrication of the Welsh /t/ constitutes a change in progress.

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Chodroff, E. & Wilson, C. (2019). Acoustic–phonetic and auditory mechanisms of adaptation in the perception of sibilant fricatives. *Attention, Perception & Psycholinguistics. 82,* 2027-2048.

González, C. (2002). Phonetic variation in voiced obstruents in North-Central Peninsular Spanish. *Journal of the International Phonetic Association. 32*(1), 17–31.

Griffen, T. D. (2015). Welsh alveopalatals: Functional pattern attraction. *Word. 48*(3), 353-366.

Hannahs, S. J. (2013). *The Phonology of Welsh.* Oxford: Oxford University Press.

Howitt, D. & Crammer, D. (2005). *Introduction to Statistics in Psychology*. London: Pearson Education.

Jaworski, S. & Baran, M. (2021). Acoustic features of burst release: A study of Welsh plosives. *Roczniki Humanistyczne.* 69(11), 89-105.

Jones, G. E. (1984). The Distinctive Vowels and Consonants of Welsh. In M. J. Ball & G. E. Jones (Eds.) *Welsh Phonology.* (pp. 40-64). Cardiff: University of Wales Press.

Jones, M. J. & Llamas, C. (2008). Fricative realisations of /t/ in Dublin and Middlesbrough English: An acoustic study of plosive frication rates and surface fricative contrasts. *English Language and Linguistics*. *12*(3), 419–443.

Jones, M. J. & McDougall, K. (2009). The acoustic character of fricated /t/ in Australian English: A comparison with /s/ and /ʃ/. *Journal of the International Phonetic Association. 39*(3), 265-289.

Ladefoged, P. & Maddieson, I. (1996). *The Sounds of the World's Languages*. Oxford: Blackwell Publishers.

Lengeris, A. & Kappa, I. (2016). *Palatalization and affrication of velar stops in the (western) Cretan dialect. Selected Papers of the 21st International Symposium on Theoretical and Applied Linguistics* (ISTAL 21).

Luef, E. M. (2020). Development of voice onset time in an ongoing phonetic differentiation in Austrian German plosives: Reversing a near-merger. *Zeitschrift für Sprachwissenschaft. 39*(1), 79-101.

Nicolaidis, K. (2001). An electropalatographic study of Greek spontaneous speech. *Journal of the International Phonetic Association. 31*(1), 43-62.

Villafaña-Dalcher, Ch. (2006). *Consonant weakening in Florentine Italian: An acoustic study of gradient and variable sound change.* Ph.D. thesis, Georgetown University.

Watson, K. (2007). Illustration of the IPA: Liverpool English. *Journal of the International Phonetic Association*. *37*(3), 351–360.

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