Voicing of Intervocalic Fricatives in Welsh and Welsh English

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The candidate confirms that the work submitted is his/her/their own and that appropriate credit has been given where reference has been made to the work of others.

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Abstract

This thesis presents an acoustic investigation into the production of voicing in Welsh-English bilingual speakers. It contributes to previous research into devoicing and focuses on providing more research into Welsh fricatives. The study consists of analysing the production of fricatives in intervocalic position by 4 Welsh-English bilingual speakers. The amount of voicing produced, place of articulation, vowel height, and duration were investigated to make a comparative analysis between Welsh and Welsh English. The results showed no difference in the production of voicing between Welsh and English [+/-voice] fricatives, but the descriptive results did show differences demonstrating that participants were more consistent at producing voicing in Welsh than in English.

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1. Introduction

This thesis is an investigation in phonetic variation in regional minority bilingual speakers. In particular, it presents a quantitative and descriptive investigation into phonetic voicing of fricatives in the speech of Welsh-English bilinguals and compares the voicing productions and potential factors affecting voicing between the two languages.

The Welsh and Welsh English data were elicited via a set sentence task from 4 Welsh-English bilinguals from North Wales. Participants were aged between 19 and 22 years and attended Welsh-medium or Welsh-English bilingual education at primary or secondary school. The language backgrounds differed between the participants.

Welsh (*Cymraeg*) is a Celtic language that is part of the Brythonic language branch of the Indo-European family. Welsh is primarily spoken in Wales, in which it has official status from the Welsh Language (Wales) Measure 2011. This language can also be found in areas of Argentina, due to Welsh emigrants establishing a Welsh settlement in the Chubut province of Patagonia during 1865-85 (Bowen, 1966, p. 16). This thesis will, however, be focused on Welsh within Wales.

2. History of Welsh and Welsh English

This section will discuss the historical and linguistic background of Welsh and Welsh English bilingualism in Wales. Overall, Wales is rich sociolinguistically which has resulted from the uneven distribution of Welsh speakers and areas that have gone through more intense Anglicisation than others.

According to the last census in 2011 Welsh was spoken by 19% of the population (562,016 speakers) (Welsh Assembly Government, 2011), and from the latest Annual Population Survey approximately 28.3% of the population speak Welsh (855,200 speakers) (Welsh Assembly Government, 2020). Despite the increase in the number of Welsh speakers, Welsh is considered a minority language. However, in some areas of Wales (Isle of Anglesey, Gwynedd, Ceredigion, Carmarthenshire) Welsh speakers make up 50% and above of the population (Welsh Assembly Government, 2020), and therefore English can be seen as the minority language in certain communities. The number of Welsh speakers have mostly been in decline; the results from the first Welsh language census in 1891 showed that 51.2% of the population spoke Welsh and out of these speakers 55.8% were monolingual (Welsh Language Board, 2004, as cited in Morris, 2013). These statistics demonstrate that the Welsh language has been in decline for over 100 years and has largely been replaced by English and that Welsh has been maintained by Welsh and Welsh English bilingual speakers. The statistics also show that the language shift from Welsh to English has been more intense in some areas. The next sections will address the influential events and history that lead to the language shift from Welsh to Welsh-English bilingualism.

2.1 Welsh Independence and *Acts of Union*

Approximately 250 years after Wales lost its independence in 1282 and was ceded to the English crown (Carr, 1999), the process of Anglicisation was further increased with the *Acts of Union* in 1536. This act placed Wales under the legal, political, and administrative jurisdiction of the British Crown and Parliament (May, 2000), as well as some Welsh land being annexed to the English crown. As a result of the *Acts of Union* the Welsh language was proscribed from the legal system and all official government domains and replaced by the English language. From this,

English became the sole language for business and monolingual Welsh speakers were required to become bilingual with English to conduct business. While this did not force bilingualism onto the mass population, it did affect the "section of society which had previously produced the administrators, the legal advisors, the educators, and indeed the societal leaders" (C. H. Williams, 2009, pp. 204-205), which accelerated the Anglicisation within the Welsh gentry (German, 2006).

The Welsh gentry had increased contact with the English language, as official business must be conducted in English, which over time created a Welsh ruling class proficient in English (Davies, 2014). The consequence of this involved upper-class Welsh families sending their children to English-medium schools and English becoming seen as a more prestigious language than Welsh (Davies, 2014). Moreover, the attitudes towards Welsh are shown through the assimilation of the Welsh gentry into the English ruling class which "provided a constant reminder that knowledge of Welsh was divorced from any form of political power" (Davies, 2014, p. 35).

While the *Acts of Union* may be regarded as the first milestone of the erosion of the Welsh language, Jones (1993, p. 539, as cited in Morris, 2013) claims "it would be fair to say that it accelerated rather than initiated the encroachment of English on domains which had traditionally been Welsh-medium".

2.2 Industrial Revolution

In the late eighteenth century the Industrial Revolution came to Wales and remained initially in the East of Wales along the borders. The demand for skilled workers in various industries in North East Wales resulted in internal migration as well as immigration from England. The immigration of monolingual English speakers and their establishment of large English-speaking

communities in the East in addition to the low prestige of Welsh meant that the immigrants were not learning Welsh and therefore not becoming Welsh-English bilingual speakers. The consequence of English immigration and the lack of Welsh learning resulted in a divide between West and East Wales, with the West remaining largely monolingual in Welsh and the East containing both Welsh-English bilingual and monolingual English speakers. Overall the increase in industrialisation correlates with the decline of the intensity of Welsh usage in certain areas (mainly North East and South Wales) (Lewis, 1978).

2.3 Language Planning and Revitalisation

The brief history of Welsh and English as outlined above suggests an important development of the Anglicisation of Wales stems from institutional incorporation with England and language attitudes/prestige.

The revitalisation of Welsh, as stated by (May, 2000, p. 105), had three institutional developments that had an effect on Welsh language loss: firstly the establishment of the Welsh Office in 1964, which brought in the Welsh Language Act (1967), the Education Reform Act (1988), and the Welsh Language Act (1993) which built on the original act and extended the use of Welsh into public domains, secondly the 1960's political movement with the establishment of the *Cymdeithas yr Iaith Gymraeg* (Welsh Language Society) which advocated for Welsh in civic and public realms, and lastly the re-emergence of Welsh-medium education.

The Welsh Language Act (1967 and 1993) replaced all previous legislation regarding the Welsh language, including the *Acts of Union*. For the first time in legislation, Welsh was treated as having equal status as English and The Welsh Language Act provides the right to use Welsh in courts as well accessing public documents in Welsh (May, 2000). Perhaps the most significant

feature of this act was that the *Bwrdd yr Iaith Gymraeg* (the Welsh Language Board) was authorised to promote and facilitate the use of Welsh in the public sector (HMSO, 1993). The Education Reform Act established a Welsh education system and National Curriculum separate to that of England. It also formally recognised the Welsh language as a national language that should be taught as a compulsory subject within all schools in Wales, including English-medium schools (May, 2000), and not just the principle language of instruction in Welsh-medium schools. This growth of Welsh-medium education has by extension increased the number of Welsh speakers in historically anglicised and monolingual areas of Wales and the support of increasing of Welsh education has come from both Welsh and non-Welsh speakers (Lyon & Ellis, 1991). The emergence of the Welsh language political movement and creation of Welsh Language Society contributed to the establishment of Welsh language media (most notably the Welsh television channel *Sianel Pedwar Cymru* [S4C]), the Welsh Language Board, and an increase in demand for available Welsh language public services (May, 2000).

These three developments had substantial impact on reviving Welsh in the twentieth century and in the 1991 census there was a reduction in the decline of the number of speakers. While language loss occurred between the 1981 and 1991 census, the decrease was 1.4% compared to the decrease of 6.3% between the 1971 and 1981 census.

2.4 Welsh in present-day Wales

The Welsh language currently holds the highest degree of official status and equality in history since the introduction of the *Acts of Union* in 1536 and the language revitalisation efforts from the establishments such as the Welsh Language Board and Welsh Language Society means that Welsh can now be accessed over a range of domains and public services. Language planning by

the Welsh Assembly Government continues to this day with the focus of increasing the number of Welsh speakers and providing more opportunities in Welsh. The introduction of the Welsh Language (Wales) Measure 2011 confirmed Welsh as an official language within Wales and appointed a Welsh Language Commissioner to ensure public domains comply with Welsh language policies (HMSO, 2011).

With ongoing language revitalisation efforts, what remains to be seen is how the present-day attitudes towards Welsh have changed and the consequent vitality of the language. The study by S. L. Jones (2019) looked at the attitudes of 15-16 year old second language Welsh speakers towards post-compulsory Welsh-medium education. The speakers in the study mostly came from English-speaking homes (96%) and resided in a largely English-speaking community. The attitudes towards continuing Welsh-medium education were mostly directed at the lack of advantages in studying Welsh. While a minority considered the benefits of studying in Welsh in further and higher education (e.g. job prospects in Wales), the majority were concerned their careers and university education relied on using English with some speakers referring to their need of linguistic knowledge and the difficulties of changing languages within subjects (e.g. medicine, law) (S. L. Jones, 2019, p. 6). The attitudes of these speakers towards their future use and need of Welsh highlights that language planning needs to focus on providing opportunities and advantages in continuing to use Welsh after compulsory education and in the workplace. Hodges (2012) who looked at parents' attitudes to their children attending Welsh-medium education also concluded that policymakers need to acknowledge that revitalising the Welsh language cannot solely rely on education.

Following from the history of Welsh and the growth in the use of English in Wales, Section 3 will address the phonology of Welsh and Welsh English in present-day Wales.

3. Phonology of Welsh and English

This section will outline the phonological and dialectal characteristics of Welsh and Welsh English and an overview and comparison of the vowels and consonants present in both languages. Due to variation in how researchers refer to the categorisation of consonants, minimal pairs will be distinguished by phonological voicing ([+voice] and [-voice]).

3.1 Welsh

Welsh has no recognised standard form and the phonetic inventory of Welsh has significant regional variation (Hannahs, 2013, p. 13). From dialect mapping three main areas have been identified: North, South, and Midlands (Thomas, 2000). These areas can be further split into East and West varieties due to differences in grammar and lexicon which result in six dialect regions within Wales (Ball, 1988). However, as the Midlands is often described as a hybrid between Northern and Southern varieties (Mayr & Davies, 2011), Welsh is mainly categorised as Northern or Southern (King, 2015, p. 16).

3.1.1 Vowels

The Northern Welsh vowel system is comprised of 13 monophthongs and 13 diphthongs, compared to the vowel system of Southern Welsh which is comprised of 11 monophthongs and 8 diphthongs. An overview of Northern and Southern Welsh vowels is shown below.

Northern Welsh			Southern Welsh	
13 monophthongs			11 monophthongs	
Short vowels ɪ ɨ ʊ ɛ ə ɔ a	Long vowels iː ɨː uː eː oː aː		Short vowels ɪ ʊ ɛ ə ɔ a	Long vowels iː uː eː oː aː
13 diphthongs			8 diphthongs	
Front closing aɪ ɔɪ eɪ ɑɛ ɔɛ	Central closing aɨ ʊɨ eɨ	Back closing ɪʊ ɛʊ aʊ ɔʊ ɨʊ	Front closing aɪ ɔɪ ʊɪ eɪ	Back closing ɪʊ ɛʊ aʊ ɔʊ

Table 1: Northern and Southern Welsh vowels (taken from Mayr and Davies (2011, pp. 18-19))

In regards to monophthongs, both the Northern and Southern vowels show an uneven distribution between long and short vowels. The two close central vowels could be the cause of the uneven distribution as they make the vowel space more crowded in the front to central space. Mayr and Davies (2011) found that both Southern and Northern Welsh distinguish vowel pairs based on spectral properties and duration. This finding differs from previous research that found Northern Welsh distinguished monophthong vowel pairs on duration alone (Ball & Williams, 2001). For closing diphthongs, Northern Welsh is distinguished by three categories (front, central, back) whilst Sothern Welsh is distinguished by two categories (front and back).

3.1.2 Consonants

As fricatives are being investigated in this study, fricatives will be looked at in more detail in the next section (3.1.3). Phoneme inventories in Welsh that are displayed in parentheses are only

present within the phonemic inventory as a consequence of borrowing or only present in a certain variety of Welsh. An overview of Welsh consonants is shown below:

	Bilabial	Labiodental	Dental	Alveolar	Postalveolar	Retroflex	Palatal	Velar	Uvular	Glottal
Plosive	p b			t d				k g		
Nasal	m̥ m			n̥ n				ŋ̊ ŋ		
Trill				r̥ r						
Tap or Flap				ɾ						
Fricative		f v	θ ð	s (z)	ʃ				χ	(h)
Lateral fricative				ɬ						
Approximant				ɹ			j			
Lateral approximant				l						

Table 2: Northern and Southern Welsh consonant inventory (adapted from Hannahs (2013, pp. 21-22))

Welsh has three pairs of [+/-voice] plosives and nasals at a bilabial, alveolar, and velar place of articulation. The voiced nasals in Welsh are considered a part of the Welsh phonological system, however the [-voice] nasals are only present due to nasal mutations of the [-voice] stops /p, t, k/ (Hannahs, 2013). Initial Consonant Mutation (ICM) is an integral part of the Welsh language, which is linked with morphological, syntactic, and phonological features working together. Mutation is generally agreed to be a phonological change that applies to consonants that are caused by lexical and syntactic processes, although the environments for mutation are varied, unpredictable, and subject to dialect variation (Green, 2006). Nasal mutation is one of the four

types of mutation. Nasal mutation differs from soft mutation, aspirate mutation, and pre-vocalic mutation in that voiceless nasals can only appear as a process of mutation, whereas the other mutation processes mutate consonants into phonemes that are already present in the inventory.

The distribution of /l/ in Welsh is that in Northern Welsh /l/ is dark in all word positions whereas Southern Welsh it is clear in all word position (Penhallurick, 2004). Welsh has two alveolar trills ([+voice] and [-voice]). The [+voice] alveolar trill can also be realised as a flap, and, particularly in Bala North Wales, as a uvular rolled /ʀ/ or a uvular fricative /ʁ/ (Penhallurick, 2004, p. 118).

3.1.3 Fricatives

Fricatives in Welsh are predominately made up of [-voice] fricatives, including the [-voice] lateral fricative. Northern Welsh has six places of articulation for fricatives: labiodental, dental, alveolar, postalveolar, uvular, and glottal, which is shown in the table above. This is considered relatively unusual to have [-voice] fricatives at six places of articulation (M. J. Jones & Nolan, 2007). The glottal fricative [h] is only present in Northern varieties of Welsh (Hannahs, 2013). The [+voice] alveolar fricative /z/ is a borrowed phoneme from English and is present in southern varieties from English loanwords e.g. /'babɪz/ ‘babies’, however, speakers of northern Welsh lack this borrowed phoneme. The uvular voiceless fricative /χ/ is present in north Welsh varieties, but it is realised as /x/ in south Welsh (Ball & Müller, 1992).

The fricatives /f, θ, s, ʃ, χ, ɬ/ occur word initial, word medial, and word final, whereas the [-voice] glottal /h/ only occurs in word initial and word final position. The [+voice] fricatives /v, ð/ also occur word initial, word medial, and word final, but are prone to deletion in word final position in all dialects of Welsh (Hannahs, 2013, p. 18). Fricatives are also mutate correlates of plosives

and nasals which occur as a result of ICM, for example [+voice] stops /b/ and /d/ become the [+voice] fricatives /v/ and /ð/ and the [+voice] nasal /m/ changes to the [+voice] labiodental fricative /v/ (examples of soft mutation).

3.2 Welsh English

Welsh English is an umbrella term used to describe the varieties of English which are spoken in Wales (Morris, 2013). Welsh English is split into various regional varieties based on the extent to which Welsh is, or previously was, spoken in a particular area. Three areas types are proposed by Mees and Collins (1999): the first is an area where Welsh is the dominant language (North West, South West, and some areas in Mid Wales), the second is an area where Welsh use to be dominant until a language shift to English during the 1850s (North East and South East), and the final area has been English dominant for centuries (the border of Wales and England and parts of South East).

However, varieties of Welsh English are not solely defined by the extent to which Welsh is spoken in the area. Whilst many researchers focus on the influence that Welsh has on English (Penhallurick, 2004), it has been found that dialects of English in England have also influenced varieties of English spoken in Wales. North east varieties of Welsh English are influenced by dialects spoken in north west counties of England, such as Merseyside. The accent perceptual study by A. Williams, Garrett, and Coupland (1996) found English speakers in north east Wales that were perceived as having non-Welsh accents were instead associated with accent/dialects from Liverpool. This can also be seen phonetically with the merge of STRUT and FOOT vowels in north east Wales, which differ from other Welsh English varieties, but are identical to neighbouring areas in England.

3.2.1 Vowels

The most comprehensive study of Welsh English comes from the *Survey of Anglo-Welsh Dialects* collected by Parry (1977, 1979). As the data was collected predominantly from rural areas in Wales this will therefore show some variation in the phonology of Welsh English for vowels. The below table shows the realisation of rural Welsh English vowels:

Welsh English	
16 monophthongs	
Short vowels ɪ i ʊ ɛ ə ʌ ɔ a	Long vowels iː uː ɛː eː æː oː ɔː aː
6 diphthongs	
Front closing oə iə ai ɔi	Back closing au ɪu

Table 3: Welsh English vowel inventory (adapted from Parry (1977, 1979))

In regards to monophthongs, there is an uneven distribution between long and short vowels. Both long and short vowels have eight vowels present, but only share four vowel phonemes. The diphthongs also show an uneven distribution with front closing vowels having four vowels and back closing vowels having two vowels.

3.2.2 Consonants

As fricatives are being investigated in this study, fricatives in Welsh English will be looked at in more detail (see Section 3.2.3). An overview of Welsh English consonants is shown below:

	Bilabial	Labiodental	Dental	Alveolar	Postalveolar	Retroflex	Palatal	Velar	Uvular	Glottal
Plosive	p b			t d				k g		
Nasal	m			n				ŋ		
Trill										
Fricative		f v	θ ð	s z	ʃ ʒ					h
Lateral fricative										
Approximant				ɹ			j			
Lateral approximant				l						

Table 4: Welsh English consonant inventory

Welsh English has three sets of [+/-voice] plosives at a bilabial, alveolar, and velar place of articulation. The nasal phonemes are also produced at a bilabial, alveolar, and velar place of articulation, but only have a [+voice] nasal at each place. Welsh English has two approximant phonemes: the [+voice] alveolar /ɹ/ and the [+voice] palatal /j/. Welsh influence can be seen on Welsh English in bilingual speakers from Welsh-speaking homes; Morris (2013) found the Welsh variants [r] and [r], allophones of /ɹ/, in non-coda position in English speech in North West Wales.

3.2.3 Fricatives

Fricatives in Welsh English are predominately made up of [+/-voice] pairs. Welsh English has four places of articulation for fricatives which have a [+/-voice] pair: labiodental, dental, alveolar, postalveolar, and one place of articulation which has a [-voice] phoneme: glottal, which is shown in the table above (Table 4).

3.3 Comparison of Welsh and Welsh English

The data used within this study will be from bilingual speakers from North Wales, therefore the comparison will focus on the North Welsh variety compared to Welsh English.

3.3.1 Vowels

Welsh English has fewer diphthongs than Welsh and shows few categorical differences for the monophthongs. Welsh English has 16 monophthongs and Welsh has 13; Welsh English has the short vowel /ʌ/ and the long vowels /ɛː, æː/ that is not present in Welsh and Welsh has the long vowel / ɨː/ that is not present in Welsh English. Welsh English has 6 diphthongs and Welsh has 16. The main difference between Welsh English and Welsh is the presence of central closing vowels for Welsh.

3.3.2 Consonants

A comparison between Welsh and Welsh English shows that Northern Welsh has six phonemes that are not present for Welsh English: the [-voice] alveolar lateral fricative, the [-voice] uvular fricative, the [-voice] bilabial, dental, and velar nasals, and the [-voice] alveolar trill. Welsh

English has one phoneme that does not appear in Northern Welsh: the [+voice] alveolar fricative.

Both Welsh and Welsh English have three pairs of [+voice]/[-voice] plosives at the same places of articulation. For Welsh, pre-aspiration is the distinguishing factor between plosive pairs at the same place of articulation (Wells, 1979). Pre-aspiration is also found in the production of plosives for both Welsh and Welsh English in bilingual speakers (Morris, 2010).

3.3.3 Fricatives

Comparing Northern Welsh to Welsh English there are three phonemic differences. Northern Welsh contains the [-voice] lateral fricative and the [-voice] uvular fricative while Welsh English does not, and Welsh English contains the [+voice] alveolar fricative while Northern Welsh does not. Although the lateral and uvular fricatives are not present in Welsh English, they may still occur in the speech of monolingual English speakers in the pronunciation of Welsh place names and personal names.

4. Voicing Studies

4.1 Overview of Voicing

This section will outline the production of voicing and how consonants are categorised in Welsh and English.

Voicing is produced in the larynx through vocal fold manipulation. This manipulation changes the shape of the glottis, which is the space between the vocal folds through which the air stream passes, and thus creates different voicing productions. Two types of shape that are

linguistically significant for English and Welsh, and will be looked at in this study, are a narrow glottis and an open glottis (Giegerich, 1992). A narrow glottis describes the vocal folds coming together to create a narrow passage for the air to pass through which causes a suction effect (Bernoulli principle) and the vocal folds close together. When the vocal folds are together there is no suction effect and the vocal folds then open back to the narrow position which reinitiates the suction effect, and the cycle repeats (Yavas, 2011, p. 17). The vibration of the vocal folds in turn causes vibration above the glottis resulting in the production of voiced sounds (e.g. [b] [v]) (Giegerich, 1992). For an open glottis, the vocal folds are spread apart and do not vibrate; the glottis is open to allow air flow without obstruction (Giegerich, 1992). An open glottis is the shape required to produce voiceless sounds (e.g. [p] [f]).

Consonant categorisation in English uses the presence ([+voice]) or absence ([-voice]) of voicing to differentiate between sets of sounds, commonly referred to as 'voiced' and 'voiceless' (Lisker, 1970). Voicing contrasts only occur in [-sonorant] phonemes or 'obstruents', such as plosives (/p/-/b/) and fricatives (/f/-/v/), as the voicing produced in [+sonorant] phonemes tend not to be lexically distinctive and therefore no contrast can be made (Giegerich, 1992). In English, Voice Onset Time (VOT) has typically been identified as a primary cue to the voicing contrast of plosives. Lisker and Abramson (1964) defined VOT "as the temporal relation between the moment of the release of the stop and the onset of glottal pulsing" (Abramson & Whalen, 2017) and two main measurements to distinguish obstruents were defined as voicing lead and voicing lag. Voicing lead was found to be present in 'voiced' plosives, where the glottal pulsing starts in the consonantal closure and continues to the release of the stop, and voicing lag was found to be present in 'voiceless' plosives, where the glottal pulsing started after the release of the stop (Abramson & Whalen, 2017).

Other linguistic correlates, such as preceding vowel duration and fricative noise duration, are considered additional correlates to the voicing distinction between 'voiced' and 'voiceless' obstruents in English (Behrens & Blumstein, 1988; Chen, 1970). Preceding vowel duration is seen as a feature for distinguishing stops, fricatives, and affricates throughout languages such as English, Chinese, Japanese, and French (Chen, 1970; Crowther & Mann, 1992; Lee & Choi, 2012). Chen (1970) suggests a universal trend for vocalic duration before consonants, in which vowels are longer before 'voiced' consonants and shorter before 'voiceless' consonants. Fricative noise duration has been found to distinguish sibilant and non-sibilant English fricatives and provide a voicing cue to 'voiced' and 'voiceless' syllable initial fricatives. The 'voiceless' English sibilant fricatives /s, ʃ/ have longer fricative durations than /f, θ/ (Behrens & Blumstein, 1988), as well as having a higher amplitude and more prominent spectral peaks. 'Voiceless' fricatives, overall, are found to have longer noise durations than their 'voiced' counterparts in both isolated (Baum & Blumstein, 1987) and connected speech (Crystal & House, 1988).

Regarding voicing and consonant categorisation in Welsh, some scholars describe a fortis/lenis contrast and others a voiced/voiceless contrast. Scholars such as Grawunder, Asmus, and Anderson (2015); Jonathan Morris and Hejná (2019), and M J Ball and Müller (1992) use a fortis/lenis contrast which is motivated by findings of their studies (see below for further discussion), whereas Hannahs (2013) uses a voiced/voiceless contrast to categories consonants in Welsh but does not provide motivation for this categorisation. The claim that Welsh has a voicing contrast may result from the idea that a voiced/voiceless distinction is often considered to be universal. However, as Welsh is not the only language that does not have a voiced/voiceless voicing contrast this view has been challenged. Kiparsky (2006) suggests different laryngeal contrasts in regard to voicing and non-voicing languages. Non-voicing languages, such as Welsh, may exhibit a laryngeal contrast that is not based on the presence of

phonetic voicing and instead utilise a fortis/lenis contrast distinguished by other linguistic factors (e.g. vowel duration, aspiration, and friction noise duration).

Pre-aspiration could potentially be a correlate in the categorisation of Welsh consonants. Ball and Müller's (1992) analysis of stops in Welsh showed little voicing occurred during the closure stage for 'lenis' stops /b, d, g/ and produced small amounts of pre-aspiration, whereas 'fortis' stops /p t k/ showed considerable pre-aspiration during production. Morris and Hejná's (2019) work on Bethesda Welsh also found similar results in that pre-aspiration is a "variable feature in both fortis and, to a lesser extent, voiceless lenis contexts" (p.26). The research on Welsh plosives by Asmus, Jaworski, and Baran (2020) investigated phonetic voicing and aspiration to determine whether a voiced/voiceless contrast or fortis/lenis contrast is best to describe the contrast in Welsh. An acoustic analysis was conducted of the plosives /p, b, t, d, k, g/ in word initial and word final position taken from 31 native speakers of Welsh in North and South Wales aged 19-71. Both voicing and aspiration was found to contribute to distinguishing between 'fortis' and 'lenis' plosives; (i) aspiration following 'lenis' plosives was significantly shorter than 'fortis' plosives and while there were differences in voicing, they did not form a consistent pattern, (ii) the ratio between the duration of the aspiration and total duration was significantly higher for 'lenis' plosives, and (iii) the voicing in the hold phase is longer for 'lenis' plosives than 'fortis' plosives. From these results the authors conclude that the fortis/lenis distinction is more appropriate than a voiced/voiceless distinction to describe the phonological system of Welsh. Baran (2020a) on the other hand, when combining the results of two studies using the same data but analysing different obstruents Asmus, Jaworski, and Baran (2019) for plosives and Baran (2020b) for fricatives), did not find phonetic voicing to be a distinctive factor in distinguishing between fortis/lenis plosives and fricatives in Welsh, but did find aspiration and frication period to be a more reliable factor. The analysis was taken from monosyllabic lexemes

in onset and coda position from 31 male and female native Welsh speakers aged 19-71 who used Welsh at home and at work. The analysis measured phonetic voicing and hold phase duration in plosives and friction and voicing length were measured in fricatives and the results confirmed that phonetic voicing is not conclusive at differentiating Welsh obstruents; differences in voicing vary from situations such as /g/ vs /k/ where the lenis sound had a significantly longer voicing period and /p/ vs /b/ where the fortis sound had more voicing on average. However, voicing differences were found to be clearly visible for /f/ and /v/ but not /θ/ and /ð/ or plosives. Aspiration and fricative length were found to be conclusive for all plosive and fricative contrasts analysed, with the pattern that 'fortis' obstruents have longer aspiration/frication than the 'lenis' obstruents.

Hannahs (2013) further describes the presence of pre-aspiration in Welsh by word position. 'Voiceless' stops /p t k/ are pre-aspirated in word initial and word medial positions, however word finally they remain fully voiceless and unaspirated. The opposite is described for the 'voiced' stops /b d g/; they are unaspirated and partially voiced word initially and finally. 'Voiced' stops word medially and intervocalic appear to be fully voiced, showing that 'voiced' obstruents in Welsh have variation with the production of voicing and aspiration depending on word position (M. J. Ball, 1984).

In sum, voicing productions in Welsh are found to be inconsistent with some studies finding phonetic voicing to be conclusive and others finding it to be inconclusive at distinguishing between [+voice] and [-voice] obstruents. Aspiration on the other hand is found to form consistent patterns and is therefore a more reliable factor in distinguishing Welsh [+voice] and [-voice] obstruents. Previous studies have predominantly focused on plosives when investigating

the contrast best suited for Welsh, therefore this study aims to add to literature on the voicing of fricatives in Welsh and Welsh-English bilinguals.

4.2 Devoicing

Following on from the categorisation of obstruents in Welsh and Welsh English this section will look at the realisation of voicing in obstruents and factors that affect the production of voicing such as place of articulation, vowel height, and word position.

The most generally accepted explanation for the devoicing of phonologically [+voice] fricatives is that producing and sustaining voicing and frication simultaneously is difficult ~~the production of voicing and frication simultaneously is difficult to produce and sust~~(J. Ohala, 1983).

This production based hypothesis is based on the recognition of~~has~~ two competing aerodynamic factors within a [+voice] fricative: (1) in order to maintain vocal fold vibration subglottal pressure must be greater than the oral pressure, and (2) to produce the turbulent noise characteristic of fricatives there must be high air flow through the oral constriction (Smith, 1997). These two necessary aerodynamic requirements to produce a [+voice] fricative compete due to their specific and opposing ~~contrasting~~ conditions~~requirements~~.

To maintain voicing oral pressure must be lower than the subglottal pressure, however the narrow constriction of the articulators (as to produce the frication) tends to increase the pressure in the oral cavity. This increase may result in an oral pressure that is higher than subglottal pressure, thus voicing cannot be maintained and devoicing occurs. However, if the constriction of the articulators is widened to keep a lower air pressure in the oral cavity to retain voicing, the pressure will be too low to produce the turbulent air flow, which is necessary for a

fricative. If devoicing occurs during a fricative it may be caused by the size of the constriction in the oral cavity or the aerodynamic conditions of the vocal tract (Smith, 1997) and if the "segment retains voicing it may become less of a fricative" (J. Ohala, 1983, p. 201) due to the lack of high air flow through the oral cavity. Due to the difficulty in producing simultaneous voicing and frication, devoicing may therefore occur as a simplification of a difficult sound to produce in the form of the loss of voicing (Docherty, 1992; Haggard, 1978).

An alternative hypothesis to the production hypothesis, the perception hypothesis (Balise & Diehl, 1994), suggests that voicing for fricatives, in particular sibilants, is perceptually favoured because it reduces the characteristic turbulent air flow of fricatives. J. Ohala (1983) states that there needs to be sufficient air velocity to satisfy both voicing and frication aerodynamics; Balise and Diehl (1994) suggests that 'sufficient' can be interpreted as either a physical constraint of articulators in production or alternatively as whether the air velocity has to be sufficient enough to convey intended perceptual linguistic information to the listener. However, other perception studies of fricatives indicate that listeners may use other factors to distinguish between fricatives and when deciding whether a segment is voiced or voiceless. Listeners may use the duration of post and preceding vowels, spectral properties, and segment duration to categorise fricatives (Jongman, Wayland, & Wong, 2000; Mitani, Kitama, & Sato, 2006; Wells, 1979; Whitehead, Whitehead, Schiavetti, Metz, & Farinella, 1999), and not just the presence or absence of glottal vibration.

4.2.1 Factors that affect devoicing

The following sections will address three factors that potentially affect voicing in fricatives: place of articulation, word position, and vowel height.

4.2.1.1 Place of articulation

Place of articulation is seen to have an effect on the voicing of phonologically [+voice] fricatives; fricatives with a more posterior place of articulation are subject to devoicing at a higher rate than anterior articulations (Pape, Mooshammer, Hoole, & Fuchs, 2003; Westbury, 1983; Westbury & Keating, 1986). This effect is caused by a reduced cavity size behind the place of constriction, which limits the capacity for passive enlargement of the vocal tract that is required to keep pharyngeal pressure low, and therefore affects voicing being sustained (J. J. Ohala & Riordan, 1979).

The studies by Verhoeven, Hirson, and Basavaraj (2011) and Haggard (1978) of Southern British English found that place of articulation had a significant effect on devoicing of fricatives. The result followed the previously assumed hierarchal structure with alveolar fricatives devoicing at a higher rate than labiodental fricatives. In Verhoeven et al.'s (2011) study alveolar fricatives were devoiced 58% of the time and labiodental fricatives devoicing 45% of the time, and Haggard (1978) found that 20% of labiodental fricatives were devoiced and 26% of alveolar fricatives were devoiced, which demonstrate that the rate of devoicing noticeably varies between place of articulation with a greater rate of devoicing for a more posterior place. These results can be accounted for by cavity size between location of the constriction and glottis. The alveolar /z/ has an overall smaller oral cavity size than the labiodental /v/, and with having a smaller vocal tract, the pressure between the subglottal and supraglottal "equalizes faster so that the vocal folds naturally stop vibrating somewhat earlier than in fricatives with a bigger vocal tract cavity" (Verhoeven et al., 2011, p. 2070). The results presented by J. Ohala (1983) for voicing of English stops suggests that the "farther forward in the vocal tract a stop is, the better it is to accommodate voicing" (J. Ohala, 1983, p. 199).

The difference in the amount of devoicing in labiodental and alveolar fricatives in Haggard (1978) and Verhoeven et al.'s (2011) studies may be due to Verhoeven et al.'s stricter definition of devoicing. Haggard (1978) defined devoicing "as presence of measurable friction in the absence of continued glottal vibration" (Haggard, 1978, p. 96). This definition does not define what 'measurable frication' is, nor give a base time to the minimum length needed of friction without glottal vibration present. It also does not provide any exact measurements as to the duration of the fricative with the absence of glottal vibration compared to the overall duration of the fricative. Verhoeven et al., however, provided a clearer definition to how they defined devoicing in their study: "fricatives were regarded as phonetically devoiced if vocal fold vibration was not sustained for less than two thirds of the duration of the fricative" (2011, p. 2072).

4.2.1.2 Word Position

Another factor that influences devoicing is word position. Devoicing is highly prevalent in word final position in Haggard's (1978) study of British English voiced fricatives. The mean percentage of devoicing for word final position ranges from 92% - 100% i.e. completely devoid of voicing for 100%. /v/ has the lowest amount of devoicing from 92-95%, /z/ had 99% devoicing, /ʒ/ had 100% devoicing, and the affricate /ʤ/ had 99-100% devoicing. The slight difference in the amount of devoicing for /v/ and /z, ʒ, ʤ/ was not found to be a statistically significant difference. Word initial and word medial fricatives, however, did find place of articulation to be a significant factor in the amount of devoicing, which follow on from the previously assumed hypothesis in which fricatives with a more posterior articulation are devoiced more. For word initial and word medial fricatives /v/ had the most voicing present, followed by /z/, and then

/ʤ/ with the lowest amount of voicing, and thus devoiced the most. The devoicing of word medial fricatives had the most variation between the vowel contexts studied (before a stressed vowel, before an unstressed vowel, and specific to the intervocalic position -between stressed vowels). The below table presents the mean percentage of devoicing for intervocalic position:

	v	z	ʒ	dʒ
Before stressed vowel	23	30	n/a	68
Before unstressed vowel	8	39	29	61
Between stressed vowels	37	90	n/a	n/a

Table 5: Percentage of devoicing for fricatives (results taken from Haggard (1978))

As shown in Table 5 the percentage of devoicing varies between vowel contexts, which differs from word medial and word final position where the biggest difference in vowel contexts is 3%. The alveolar fricative /z/ shows a large amount of devoicing when between stressed vowels compared to the amount of devoicing before a stressed and unstressed vowel. The 90% devoicing is also close to the mean percentages of /z/ produced in word final position (99% for both vowel contexts). /z/ shows similar means of devoicing for stressed and unstressed vowels with unstressed vowels devoiced more, whereas /v/ has a bigger difference in devoicing and devoices less with unstressed vowels. These results show variation and a difference in devoicing patterns between fricatives and the vowel contexts.

Lastly, the fricatives /v/, /z/, and /ʤ/ were devoiced less often when in word initial position than in word final position. Smith's (1997) study of /z/ in American English indicated a similar pattern; there was a greater likelihood for devoicing in final position and in word initial position /z/ was not devoiced. This pattern of devoicing, whereby word final fricatives are devoiced at a

higher rate, is also found in Docherty's (1992) investigation of phonation in word initial and word final Southern British English fricatives. The target [+voice] and [-voice] fricatives were elicited in three different read environments: in isolation, in a voiced carrier phrase (vowel adjacent), and a voiceless carrier phrase (voiceless obstruent adjacent). Fricatives were then split across three categories according to how much voicing was produced: completely voiced, completely voiceless, and partially voiced. For word initial position, fricatives were mostly categorised as partially voiced and completely voiceless and had the fewest fricatives in the completely voiced category. The completely voiced category included mostly post-pausal and intervocalic fricatives that were predominantly within a voiced carrier phrase. The partially voiced category was most often observed in post-vocalic [-voice] fricatives potentially caused by edge vibrations; a process where partial phonation carries over from the preceding voiced sound into the beginning production of the adjacent sound (Lisker & Abramson, 1964). The completely voiceless category contained predominantly [-voice] fricatives, however some [+voice] fricatives also occurred in this category. The [+voice] fricatives that were devoid of phonation were all produced in the voiceless carrier phrase; the anticipation of the following voiceless sound combined with a preceding voiceless sound could affect the production of voicing due to the aerodynamic effort to produce and sustain voicing between two sounds that do not require glottal vibration~~, which contrast with a voiced sound that requires oral pressure to be lower than subglottal pressure to maintain voicing~~ .

For word final position, fricatives were mostly categorised as partially voiced and included both [+voice] and [-voice] fricatives. The [-voice] fricatives that produce some voicing could be explained as above by edge vibrations. The completely voiceless category, similar to word initial position, included mostly [-voice] fricatives with a small number of [+voice] fricatives that were

produced in the voiceless carrier phrase. The completely voiced category accounted for the least amount of fricatives and only included [+voice] fricatives.

From these results Docherty concludes that the phonological categorisation of [+voice] and [-voice] is more complex than previously assumed and that "many aspects of the realization of voicing timing are not predictable from the nature of the voicing category [and] the frequency with which VOICED obstruents are "devoiced" means that there is a good deal of overlap in voicing timing patterns between sounds which would typically be labelled differently as "voiced" or "voiceless"" (Docherty, 1992, p. 129).

Studies in German (Pape & Jesus, 2015), Southern British English (Gonet & Święciński, 2012), and American English (Davidson, 2016) show a pattern of devoicing in that word initial position has the most devoiced tokens, then word final, and lastly word medial which has the least devoiced tokens. However, this pattern is not observed universally. Haggard's (1978) study found that the most devoiced position was word final, then word initial and the least devoiced position word medial. Despite the results differing for the amount of devoicing in word final and word initial position, it is seen that word medial retains the highest amount of voicing and is the least devoiced. The higher likelihood for the retention of voicing for word medial position could be due to the voicing being more easily reached and maintained when positioned between sounds that are voiced.

4.2.1.3 Vowel Height

Vowel height may influence devoicing when preceding a voiced consonant. High vowels are associated with high oral air pressure and thus would be more prone to devoicing adjacent consonants than low vowels (Jaeger, 1978; Yavas, 1997). As voicing can only be maintained

when subglottal air pressure is higher than supraglottal air pressure, when there is a partial blockage in the oral cavity such as the narrow constriction of high vowels, the air pressure in the oral cavity will increase; if this increase in oral air pressure becomes equal to subglottal pressure, voicing stops (Jaeger, 1978).

The study by Yavas (1997) showed that high vowels have an 'accelerating' effect for the devoicing of word final stops that are predisposed to devoicing in posterior places of articulation. From a comparative analysis with low vowels, Yavas found that the more posterior the articulation the greater the effect high vowels have on devoicing. Bilabial stops devoiced the same amount when preceded by low and high vowels, but alveolar and velar stops were devoiced significantly more when preceded by a high vowel than a low vowel. A potential reason for this is that as the cavity size for velar and alveolar stops are smaller than bilabial stops the supraglottal air pressure tends to be higher and consequently voicing stops earlier (Yavas, 1997, p. 122).

5. Bilingualism Studies

This present study aims to investigate voicing productions in Welsh-English bilingual speakers who speak Welsh and Welsh English. This section reviews previous work on bilingual language acquisition.

5.1 Bilingual Language Acquisition

5.1.1 Bilingual Speaker Classification

There are different ways of categorising bilingual speakers such as the level of proficiency in each language (e.g. dominant/balanced), functional ability (e.g. incipient/receptive), and effects of second language (L2) learning on first language (L1) retention (additive/subtractive) (Bhatia & Ritchie, 2014)

Bilingual speakers can also be characterised based on the age of acquisition of the second language. Following Hamers and Blanc (2000) there are four categories of bilingual speakers: childhood simultaneous, childhood consecutive (also commonly known as sequential), adolescent, and adult. Childhood consecutive is defined as the first language learnt from birth and the second language acquired before age 11, adolescent is defined as the second language acquired between age 11 and 17, and adult is defined as the second language acquired after age 17 (Hamers & Blanc, 2000, p. 26). Childhood simultaneous, however, does not have a clear definition, as researchers propose different time constraints to when the second language is acquired. De Houwer (1995) suggests that exposure to the two languages should be within one month of birth, whereas McLaughlin (1984) suggests a cut-off point at age 3.

Categorising Welsh-English bilingual speakers using the system proposed by Hamers and Blanc (2000) is not straightforward. As previously mentioned (see Section 2), different areas of Wales have developed different dominant societal languages due to the migration of monolingual English speakers into Wales, and residing in a certain area will therefore determine the speakers' acquisition of Welsh and English. The language background of Welsh-English bilingual speakers consist of three predominant factors: home language (Welsh, English, or both), school language (Welsh, English, or both), and societal language (Welsh dominant or English

dominant), which create complex and varied language backgrounds for bilingual speakers throughout Wales.

Further to the complex language backgrounds, many Welsh-English bilingual speakers who come from Welsh speaking homes state they did not acquire English until compulsory education. However, as English is a dominant language within areas of Wales, those from Welsh speaking homes may be exposed to English simultaneously (e.g. from the wider community, media, extended family) and therefore they could be categorised as childhood simultaneous rather than childhood consecutive. Evidence for this can be seen in the study by Munro, Ball, Müller, Duckworth, and Lyddy (2005). This study examined phonological acquisition in Welsh-dominant and English-dominant Welsh-English bilingual children from South East Wales. Munro et al. (2005) defined the dominant language as the language used most frequently, which was determined by language background questionnaires. The results showed that the youngest speakers (aged 2;6 to 3;0) who came from Welsh speaking homes had acquired the sound systems of both Welsh and English (Munro et al., 2005, pp. 34-35). Whilst these results do provide evidence for categorising Welsh-English bilingual speakers as childhood simultaneous, the speakers resided in an English dominant area of Wales. For the acquisition of English for children from Welsh speaking homes who grew up in a Welsh dominant area, these speakers may also be categorised as simultaneous. Evidence for this can be seen in the study by Mayr, Howells, and Lewis (2015). This study examined the acquisition of word-final consonant clusters in English-dominant and Welsh-dominant Welsh-English children in Pembrokeshire (West Wales). The results showed that the Welsh-dominant bilinguals acquired the Welsh word-final consonant clusters with a greater accuracy than the English-dominant bilinguals. Moreover, the English-dominant bilinguals did not acquire the English word-final consonant clusters at a greater accuracy than the Welsh-dominant bilinguals and were found to acquire the English

clusters at a similar rate. These results again provide evidence for categorising Welsh-English bilingual speakers as childhood simultaneous.

For speakers who acquired Welsh from compulsory education and have an English home language, those living in an English dominant society would have little exposure to Welsh until education and it would therefore be hypothesised that they would be categorised as consecutive bilinguals. But those living in a Welsh dominant society would be exposed to Welsh (e.g. the wider community, extended friends and family) and therefore it would be hypothesised that they would be categorised as simultaneous bilinguals.

Following on from Hamers and Blanc (2000) four categories of bilingual speakers, researchers have further investigated bilingualism and the socio-economic connections of 'new speakers'. New speakers refer to individuals who have little or no exposure to a minority language and acquired the language through revitalization projects or as adult learners (O'Rourke, Pujolar, & Ramallo, 2015). In the context of Welsh, 'new speakers' has also been used to refer to individuals that access the language through Welsh medium education (SELLECK 2018) instead of through familial transmission (HORNSBY 2015B).

Specific to Welsh-English bilinguals, Musk (2006) created language profiles based on speakers' language use and language attitudes of Welsh and English. Using a conversation analysis framework to investigate attitudes towards bilingualism in school pupils, Musk (2006) created three categories to distinguish Welsh-English bilinguals: Welsh dominant, floaters, and English dominant.

Group	Main Attributes	Links with discourse surrounding language matters
Welsh-dominant Bilinguals	• Speak Welsh at home. • May be more confident speaking Welsh. • Speak Welsh to other members of the group and floaters but usually speak English with English-dominant bilinguals.	• Likely to condemn pupils who refuse to speak Welsh. • Approve of the school's attitude to Welshness. • Tend to show a commitment to maintaining Welsh.
Floaters	• Speak Welsh, English, or both at home. • Less likely to have a lack of confidence in either language. • Most likely to accommodate to the dominant language of the other groups.	• May condemn those who refuse to speak Welsh. • Tend to criticise some teachers' methods of enforcing bilingualism. • Tend to show a commitment to maintaining Welsh.
English-dominant Bilinguals	• Speak English at home. • Tend to lack confidence in Welsh. • Prefer to speak English with all other groups. • Less likely to use Welsh after school.	• Tend to criticise any attempts to curb their use of English.

Table 6: Attributes of Welsh English bilingual speakers categorised by Musk (2006) (table taken from (J Morris, 2013).

Musk's research focused on bilingual schools in Welsh dominant areas where there was an equal proportion of students from Welsh-speaking homes and English-speaking homes. It remains to be seen whether these language profiles can be used and correspond to the language backgrounds and attitudes of students in English dominant areas where the majority of students in Welsh medium education come from English-speaking homes.

Research has shown that the dominant societal language and home language of Welsh-English bilinguals correlate with language use. H. M. Jones (2008) found that speakers were more likely to use Welsh daily from a Welsh speaking home and living in an area where 60% of the population speak Welsh. In turn, those from English speaking homes and an English dominant society do not use Welsh frequently outside of school. This research shows that the dominant language of a speakers' area increases the likelihood that they will use that language daily and potentially positively influence attitudes towards that language.

In the studies above Munro et al. (2005) defines dominance as the most frequently used language but Musk (2006) defines dominances as a combination of language use and language attitude. These studies demonstrate that language dominance in bilingual speakers can be indicative of a variety of linguistic and sociolinguistic factors, and there is no census on a definition of 'dominance'. Dominance has primarily been assessed by self-reported proficiency, with the most proficient language corresponding to the dominant language. There are various self-report instruments that use proficiency and language experience to determine language dominance, such as the Bilingual Dominance Scale (Dunn & Tree, 2009), the Self-Report Classification Tool (Lim, Liow, Lincoln, Chan, & Onslow, 2008), and The Language Experience and Proficiency Questionnaire (Marian, Blumenfeld, & Kaushanskaya, 2007) which also measures language attitude. Birdsong's Bilingual Language Profile combines four language dimensions (language history, language use, proficiency, and attitudes) to determine a speaker's dominant language (Birdsong, 2014). These four questionnaires demonstrate that researchers use a combination of different linguistic variables to determine language dominance. When using proficiency to determine a speaker's dominant language, it is important to note that different linguistic variables tested to determine proficiency will produce different results. The research by Bedore et al. (2012) on the language dominance and proficiency of Spanish-English bilingual

pre-kindergarteners found that when proficiency tests weight semantics or morphosyntax more heavily it will result in different languages classed as the dominant and non-dominant language. While there is no census on the variables used to define dominance, researchers define the term best suited for the type of bilingual speakers studied; for example, in heritage language research many researchers (e.g., Rothman, 2009) refer to the majority language of the larger society as the dominant language and the heritage language as the non-dominant language.

5.1.2 Acquisition Hypotheses

Previous studies have shown a tendency to perform more 'native like' in speech production and perception when the second language is acquired in early childhood, compared to those who acquired the language in adolescence (Antoniou, Best, Tyler, & Kroos, 2010; Kang & Guion, 2006). The Critical Period Hypothesis (Lenneberg, 1967), which states that neural plasticity decreases with age and inhabits second language learning, has been used as an explanation for the tendency to perform 'native like' in speech production and perception when the language is acquired in early childhood. However, the age in which the Critical Period ends has been subject to debate; De Houwer (1995) suggest a cut-off point at one month old whereas McLaughlin (1984) suggests a cut-off point at three years old. Several researchers also suggest several Critical Periods with each period affecting a different linguistic ability, and the first period and ability to be lost would be the development of a native like pronunciation of a second language.

Studies that provided evidence against this hypothesis still find that age of acquisition is a significant factor in acquiring a second language, however age of acquisition is not the only factor found to affect second language (L2) acquisition. For instance, Guion, Flege, and Loftin (2000) investigated how the use of a speaker's first language (L1) affects their L2. They studied

Quichua-Spanish bilingual adults from Otavalo, Ecuador (along with monolingual Spanish speakers and near-monolingual Quichua speakers as control groups) and grouped speakers by their use of Quichua. Participants produced sentences in both Quichua (L1) and Spanish (L2) which were then rated by listeners for degree of foreign accent. For the Spanish sentences produced by the Spanish monolingual and Quichua-Spanish bilingual speakers they found that the mean foreign accent scores increased with higher use of Quichua. The majority of Quichua-Spanish bilinguals that received a native-like accent rating had the lowest use of their first language. For the Quichua sentences produced by Quichua near-monolingual and Quichua-Spanish bilingual speakers, they found no significant effects or correlations, and the mean foreign accent ratings did not differ. These results show that age of acquisition "at the time of first L2 exposure is not the only factor to influence success in L2 learning" (Guion et al., 2000, p. 39) and the amount of L1 use determines the strength of influence on the L2. Piske, MacKay, and Flege (2001) also showed that those who acquire a second language during early childhood can differ from native monolingual speakers. They investigated perceived foreign accent of Italian-English bilinguals in Canada. The speakers were separated into four categories based on whether they were an early or late learner and if they had high use of their L1 (Italian) or low use. The results match that of Guion et al. (2000); speakers who use their L1 frequently had significantly strong perceived foreign accents in their L2 than speakers who use their L1 infrequently. This effect of the use of L1 was shown to exist for both early and late learners. These results show that early learners of a second language do not always achieve native like pronunciation despite being within the threshold of the Critical Period for the tendency to perform native-like.

These studies show that acquisition cannot be fully explained by the neural plasticity at the age of acquisition and the effects of age can instead be explained by L1 interference. Including other

factors besides the age of acquisition, Flege (1995) proposes the Speech Learning Model as an alternative to the Critical Period Hypothesis. This model aims to account for the age-related limits on the ability to produce L2 vowels and consonants and is primarily concerned with the ultimate acquisition of L2 pronunciation (Flege, 1995, pp. 237-238). The model assumes that the L1 and L2 exist in the same phonological space and that both languages can influence each other. Influence between the L1 and L2 will vary with cognitive, social, and input factors (see Moyer (2004, p. 15) for a full list of factors affecting second language acquisition), as well as age of acquisition.

While SLM is based on speech perception, it also makes predictions about speech production. The model claims that without accurate perceptual 'targets' in the learning of L2 sounds, the production of these L2 sounds will therefore be non-native like (Flege, 1995, p. 238). This model does not claim that all L2 speech productions errors are due to perception, but a basic tenet is that many production errors are perceptually motivated.

The Perceptual Assimilation Model (PAM) (Best, 1994) is another model which attempts to account for the perception and discrimination of non-native sounds. The model predicts that listeners will assimilate non-native contrasts to the closest phoneme in their native inventory. PAM predicts four types of non-native phoneme discrimination and contrast assimilation: Two-Category contrast, Single-Category contrast, Category Goodness, and Non-Assimilable (Best, 1994, p. 14). PAM has also been extended to second language learning with the PAM-L2 model (Best & Tyler, 2007). PAM-L2 uses the four types of phoneme discrimination and contrast assimilation in PAM as a base for predicting the likelihood of acquiring L2 phonemes when the learner is actively learning the L2. Unlike SLM, PAM-L2 does not make any predictions about the production of speech.

5.2 Minority Language Bilingualism

Regarding minority languages, speakers who have acquired the language from home/parents and speakers who have acquired the language from school immersion have been found with acquisitional differences, with the implication that later input may lead to difference of linguistic systems. It has been found that young children in a Welsh language home with a Welsh societal language area are more likely to acquire the consonant mutation system, have greater knowledge of vocabulary, and can assign plural suffixes in Welsh (Gathercole & Thomas, 2009; Thomas & Gathercole, 2005; Thomas, Lewis, & Apolloni, 2012), compared to speakers with an English home background and a Welsh societal language area. Home language differences have also been found in other languages, such as Simonet's (2010) study of Catalan-Spanish bilinguals in Majorca which found that speakers with different language dominance differed in their degree of velarization of laterals; while this study refers to dominance rather than home language, one of the dominance criteria was the language which participants used at home as a child combined with participants considering their home language as their native language and at the time of recording the language they use most frequently. The study by Bosch, Costa, and Sebastián-Gallés (2000) also found home language differences in Catalan-Spanish bilinguals where Spanish-dominant speakers performed more poorly than Catalan-dominant speakers in perceiving a vowel contrast /ɛ/-/e/ that only exists in Catalan, as well as Amengual and Chamorro's (2015) perception study of Galician-Spanish bilinguals that found Galician dominant speakers distinguished Galician-specific front and back mid vowels compared to Spanish dominant speakers who largely merged them.

Another study of Galician-Spanish bilinguals also found effects of speakers' dominant language in the production and perception of various acoustic measures. The study by Tomé Lourido and Evans (2018) investigated dominant language effects of the mid-vowel contrasts /ɛ/-/e/ and /ɔ/-/o/, the fricative contrast /s/-/ʃ/, and word-final vowels on Galician-Spanish bilinguals and speakers that switched their dominant language to Galician (*neofalantes*). *Neofalantes* are new speakers of Galician who switched from their dominant language (Spanish) to predominantly or exclusively speak Galician for ideological reasons (Tomé Lourido & Evans, 2018, p. 4). The results of the production experiment showed little evidence that *neofalantes* had acquired the mid-vowel contrast, however they were able to acquire the fricative contrast. Spanish-dominant speakers were also able to acquire the fricative contrast, although Spanish-dominant speakers and *neofalantes* produced these phonemes with greater overlap than the Galician-dominant speakers who had a more distinct contrast. For word-final vowels, all groups used reduced vowels and *neofalantes* behaved more like Galician-dominant speakers in production. The results for the perception experiment showed that *neofalantes* behaved more like Spanish-dominant speakers than Galician-dominant speakers in the perception of mid-vowel and fricative contrasts. Overall, Tomé Lourido and Evans (2018) concluded that "even with extensive use of the L2 and a high motivation to learn, dominant bilinguals are not able to form new native-like phonetic categorise in production or perception" (p. 36) when they switch language late in life. Therefore, new speakers of Galician are more likely to process their new dominant language through their former dominant language.

Tomé Lourido and Evans' conclusion that dominant bilinguals cannot form native-like categories in production in a non-dominant language can also be seen between different dominant Catalan-Spanish bilinguals (Simonet, 2011). Simonet (2011) looked at Catalan-dominant and Spanish-dominant bilingual speakers' productions of Spanish /o/ and Catalan /o/ and /ɔ/ (mid-

back vowels) to investigate whether non-dominant speakers' productions are native-like and the interaction between the dominant and non-dominant phonetic systems of Catalan-Spanish bilinguals. The participants were Spanish-Catalan speakers all born and raised in Majorca and were separated into groups by their dominant language. The results found that Catalan vowels /o/ and /ɔ/ are different acoustically in terms of fronting and height, and the Spanish /o/ is identical to Catalan /o/ in both height and fronting but different to Catalan /ɔ/, and thus there is no phonetic overlap between Catalan /ɔ/ and Spanish /o/ (p. 95). The Catalan-dominant speakers produced the /o/ and /ɔ/ contrast whilst the Spanish-dominant speakers did not realize a contrast but produced a lower merged mid-back vowel. Simonet (2011, p. 103) suggests that Spanish-dominant speakers have developed a 'new' phonetic category for their non-dominant language as this merged vowel was unlike the native Catalan /o/ and /ɔ/ vowels.

Despite studies that show different home and dominant language have effects on the acquisition and production of speech, a number of studies have shown that speakers with different home and societal languages have no difference in their production of speech and that these factors can be overridden by other social factors. For example, the study by Morris (2017) investigated home and societal language background effects on /l/-darkening in Welsh-English bilingual speakers. He examined the speech of speakers from two towns in Wales with different dominant societal languages: Mold (English speaking society) and Caernarfon (Welsh speaking society). Speakers from these areas were also split into whether they were from a Welsh-speaking home or English-speaking home creating four groups of speakers. The results showed no significance for home language but found an interaction between language and area; there were greater differences between Welsh and English in Caernarfon than in Mold (Morris, 2017, p. 23). When /l/ was in onset position, speakers in Caernarfon were found to differentiate between their two languages and produced lighter tokens in English than in Welsh (pp. 27-18).

These results may be attributed to peer groups influenced by linguistic background and language attitudes in Caernarfon; speakers home language correlated with the language they used in society. Participants from English-speaking homes in Caernarfon expressed negative views towards Welsh and both groups made comments on the way English is spoken with a 'funny' accent in the area. Those from Welsh-speaking homes did not overtly express negative views of English but commented on its increased use in the area.

In previous work using the same dataset, Morris (2013) found that speakers from Caernarfon in Welsh-speaking homes regularly produced the Welsh voiced alveolar trill and post-vocalic /r/ in English productions, whereas these Welsh features were absent from speakers from English-speaking homes. Moreover, all speakers from Mold (both Welsh and English home languages) did not produce any Welsh variations of /r/ in their English (Morris, 2013, p. 263). He suggests that these results might be due to a lack of Welsh influence on the speech of a largely monolingual population in Mold and those from English-speaking homes in Caernarfon orient away from markedly Welsh English (Morris, 2013, p. 263), potentially due to the speakers' attitudes towards Welsh accents when speaking English.

Other research in minority languages, such as Nance's (2020) work on Gaelic aspirated/voiceless stops and the work by Mayr, Morris, Mennen, and Williams (2017) on Welsh and English monophthongs, also show no significant difference between different home language speakers within bilingual communities. Nance (2020) looked into the acquisition of Gaelic and English stop consonants from pre-adolescent (age 7-11) Gaelic-English bilingual speakers with different home languages. Speakers were categorised whether they grew up in an English-speaking household and acquired Gaelic through immersion education (childhood consecutive bilinguals) or a Gaelic-speaking household (childhood simultaneous bilinguals). The results showed that

there were few or no differences in the phonetics and phonology of stops relating to speakers' home language (Nance, 2020, p. 22). Nance suggested these results are due the childhood consecutive Gaelic leaners having enough language input and opportunity to 'catch up' on any initial differences in language production to the childhood simultaneous learners.

Mennen, Kelly, Mayr, and Morris (2020) also found no significant effects of home language (Welsh-speaking or English-speaking home) between Welsh and Welsh English bilingual speakers and monolingual Southern Standard British English (SSBE) speakers aged 16-18 from the English-dominant area Carmarthenshire. The results showed no difference in the production of English monophthongs between the two sets of bilinguals and the monolingual SSBE speakers, and no difference in the production of Welsh monophthongs between the two sets of bilinguals. Therefore, this study found no effect of linguistic experience. These results may be explained by the long-term language contact of Welsh and English and the shift from Welsh monolingualism to Welsh-English bilingualism. However, the lack of experience-based effects can not only be described by language contact and other factors must also be responsible for the patterns observed. A potential reason for the lack of production differences is that individual linguistic experience can be overridden by highly homogeneous peer groups, similar to the conclusions from Kerswill and Williams (2000) who suggest that adolescence is an important time in linguistic development as speakers begin to peer groups instead of caregivers as their models of acquisition. Although Mayr et al. (2017) do state that more testing needs to be done to fully support this conclusion in the current study.

Mennen et al.'s (2020) study into the production lexical stress correlates using similar participant groups as Mayr et al. (2017), also attributed their findings to convergence between Welsh and English and discuss the possibility that the varieties of Welsh and Welsh English

spoken in the area are a sign of peer group identity. Participants included Welsh and Welsh English bilinguals with different home languages and a monolingual Welsh English group from Carmarthenshire aged 16-18, and monolingual SSBE speakers aged 19-21 (slightly older due to the inability of gaining permission to record within a school). Mennen et al. looked at five correlates of lexical stress: fundamental frequency and intensity ratios of stressed and unstressed vowels, duration of the post-stress consonant, and the duration of stress and unstressed vowels. The comparison between Welsh English and Welsh with SSBE revealed that SSBE differed from both Welsh English and Welsh on all measures of lexical stress (p. 12). While there were some differences between Welsh and monolingual Welsh English speakers (intensity of stressed and unstressed vowels and unstressed vowel duration), these differences were outnumber by the acoustic measures that did not significantly differ (fundamental frequency of stressed and unstressed vowels, post-stress consonant duration, and stressed vowel duration). These results suggest that some convergence between Welsh and Welsh English has occurred and Mennen et al. suggests the phonetic overlap is likely "caused by the continued co-existence of the Welsh and Welsh English in the community, resulting in cross-linguistic convergence" (p.13). The results regarding the English-dominant and Welsh-dominant Welsh-English bilinguals showed that home language did not influence the realisation of lexical stress. Both groups of speakers differentiated their language for the duration of unstressed vowels, but merged intensity values for both languages. These results may be explained by the fact that certain features in Welsh and Welsh English are converging, such as monophthongs (Mayr et al., 2017). Mennen et al. therefore state that between-group differences would only be expected for features that are distinct in the two languages, such as the difference in production of unstressed vowel duration, and where cross-language difference is less clear the bilingual

speakers will not differentiate between languages, such as the merged intensity results (Mennen et al., 2020, p. 14).

These studies that do not find any significant effect of home language within bilingual speakers highlight that a wide range of factors influence speech production and complement previous studies that do find significant effects on speech production (along with speech perception and acquisition of language specific features) between bilingual speakers with different home and dominant languages. The studies mentioned above suggest no differences were found due to homogenous peer groups and individual linguistic experience can be overridden be social factors, as well as convergence from long-term language contact.

6. Research Questions and Hypotheses

The overall aim of this research is to investigate the implementation of voicing in inter-vocalic fricatives in Welsh-English bilinguals in North Wales, and the extent of the regularity of voicing productions between Welsh and Welsh-English.

Following from the above literature, this research also aims to investigate three controlled independent variables shown to potentially affect devoicing: place of articulation, vowel height, and fricative duration.

1. Is the production of voicing in Welsh fricatives different to Welsh English fricatives?

   Hypothesis: Voicing productions are more likely to be consistently voiced in Welsh English than in Welsh

2. Does place of articulation affect voicing in Welsh and Welsh English fricatives?

   Hypothesis: Devoicing is more likely to occur in posterior articulations than anterior articulations.

3. Does preceding vowel height affect voicing in Welsh and Welsh English fricatives?

   Hypothesis: Devoicing is more likely to occur with preceding high vowels than low vowels.

4. Does fricative duration affect voicing proportions?

   Hypothesis: Devoicing is more likely to occur in relatively long fricative productions compared to short productions.

7. Methodology

7.1 Data Collection

7.1.1 Participants

Four participants took part in the study, and will be referred to hereafter as participant 1, 2, 3, 4. All the speakers were male aged between 18-28, grew up in North Wales, and identified as having native or near native Welsh and Welsh-English. The study did not purposely seek male participants, however only male speakers responded to the recruitment material. No participant reported any known or previous hearing impairments or speech disorders. The participants were recruited from posters around the University of Leeds campus and a post into the University of Leeds Welsh society Facebook page.

All of the speakers grew up in North Wales and have not resided out of North Wales for longer than one year. At the time of the recording, the speakers were all students who reside in West Yorkshire during the university academic year and return to North Wales out of term time; participant 2 and 4 have resided in West Yorkshire for 2 years, participant 1 for 3 years, and participant 4 for four months. The area participants grew up and reside outside of term time was restricted to North Wales to ensure speakers spoke the same variety of Welsh. However, due to the restrictions of recruiting Welsh bilingual speakers who can attend the recording studio at the University of Leeds, I did not restrict the speakers to be from a certain area or region within North Wales.

Participant 2, 3, and 4 acquired Welsh from their parents from birth and use it in their household and when talking to maternal and paternal grandparents. Participant 1 acquired Welsh from secondary school at the age of 12 and speaks English at home and with their grandparents. No participant learned another language besides English and Welsh from an early

age. In regards to language use, participant 1 mostly uses Welsh-English and participant 2, 3, and 4 mostly use Welsh whilst residing in Wales and all mostly use English while in Leeds.

	Parents	Maternal and paternal grandparents	Primary school (4-12 years old)	Secondary school (12-16 years old)	University
Participant 1	English	English	English-medium	Welsh-medium	English
Participant 2	Welsh, English	Welsh	Bilingual English-Welsh	Bilingual English-Welsh	English
Participant 3	Welsh	Welsh	Welsh-medium	Welsh-medium	English
Participant 4	Welsh	Welsh	Welsh-medium	Welsh-medium	English

Table 7: Participants' language background

7.1.2 Fricatives

There were three groups of target fricatives categorised by place of articulation, which were further distinguished by phonological voicing ([+voice] or [-voice]) and preceding vowels. These categorisations were chosen specifically to answer various research questions. Research question 2 (Does place of articulation affect voicing in Welsh and English fricatives?) hypothesises that fricatives with a more anterior articulation will produce more voicing than fricatives with a more posterior articulation, therefore three places of articulation that begin with an anterior articulation and progressively become more posterior were chosen to investigate how voicing is produced between different articulations. Research question 3 (Does vowel height affect voicing in Welsh and English fricatives?) hypothesises that high vowels will influence lower *voicing proportions*, therefore the fricatives were further distinguished into

fricatives after a high vowel and fricatives after a low vowel to be able to investigate the devoicing of [+voice] fricatives and the voicing of [-voice] fricatives as an effect of vowel height.

The below table provides an example of target fricatives and the categorisation method[1] (for the full list of target fricatives see Appendix D):

	English			
	High Vowel		Low Vowel	
	[+voice]	[-voice]	[+voice]	[-voice]
Labiodental	*beaver* /ˈbiːvə/	*refurb* /ˈɹiːfəːb/	*clever* /ˈklɛvə/	*graphic* /ˈgɹafɪk/
Dental	*seething* /ˈsiːðɪŋ/	*lethal* /ˈliːθəl/	*leather* /ˈlɛðə/	*method* /ˈmɛθəd/
Alveolar	*breezy* /ˈbɹiːzi/	*recent* /ˈɹiːsənt/	*dazzle* /ˈdazəl/	*asset* /ˈasɛt/

Table 8: English example target words

	Welsh			
	High Vowel		Low Vowel	
	[+voice]	[-voice]	[+voice]	[-voice]
Labiodental	*ifanc* /ˈiːvank/	*eliffant* /ɛliːˈfant/	*afal* /ˈaval/	*ceffyl* /ˈkɛfɪl/
Dental	*gwiddon* /ˈgwiːðɔn/	*chwithig* /ˈkwiːθɪg/	*addas* /ˈaðes/	*bathyn* /ˈbaθɪn/
Alveolar	n/a	n/a	n/a	*casét* /ˈkasɛt/

Table 9: Welsh example target words

[1] English transcriptions taken from OED Online (2019) and Welsh translations and transcriptions taken from University of Wales Trinity Saint David (2019) and Evans (1993).

Labiodental, dental, and alveolar fricatives were chosen to be able to investigate research question 2. However, due to the phonotactics of Welsh some categories (place of articulation/vowel height) did not have a fricative present to analyse. [+voice] alveolar fricatives were not included for Welsh as they are not present in the North Welsh sound system (Hannahs, 2013). Despite not being able to make a full comparison between Welsh and English for alveolar fricatives, I still included the [+voice] alveolar fricative for English to be able to make a comparison between [+voice] and [-voice] alveolar fricatives within English. The [-voice] alveolar fricative /s/ was also not included for the high vowel category in Welsh due to the phonological constraints of this sound appearing word medially and between two high vowels.

7.1.3 Words and Sentences

To elicit the target words from participants two sets of sentences were constructed: one in English and one in Welsh (see Appendix D). The Welsh set consisted of 18 words that were produced 3 times resulting in 54 fricative productions, and the sentences consisted of two target words per sentence equalling 27 sentences (see Appendix D). The English set consisted of 24 words that were produced 3 times resulting in 72 fricative productions, and the sentences consisted of two words per sentence equalling 36 sentences (see Appendix D). Overall, 126 fricatives were elicited per participant from the 63 sentences.

The structure of the target words also controlled for various variables. All fricatives were word medial and intervocalic; half of the fricatives were preceded by a high vowel and half by a low vowel. Fricatives were within a disyllabic word and primary stress fell on the first syllable giving the target fricative secondary stress.

The fricatives were between two vowels with either a high vowel or low vowel prior to the fricative (e.g. ‘breezy’ /ˈbɹiːzi/, ‘hazard’ /ˈhazəd/). The reason for the distinction of having the fricatives after a high vowel or low vowels is to be able to investigate the effects of high vowels on de/voicing, as research has suggested that vowel height has an effect on the devoicing of stops (Yavas, 1997; Ohala, 1976). The low vowels prior to the fricative ranged between /a/, /ɛ/, /ʌ/, and for the high vowels they all had /i/ before the fricative. All words in Welsh and English (besides ‘diddorol’ /diːˈðɔrɔl/ (*interesting*)) were consistent in regard to stress position within the word. Due to the regularity of stress in Welsh, where primary stress falls on the penultimate syllable of a word (Hannahs, 2013), disyllabic words were chosen to ensure consistency in the placement of stress (e.g. ‘beaver’ /ˈbiːvə/, ‘afal’ /ˈaval/). This ensured the words had first syllable primary stress and second syllable secondary stress (besides ‘diddorol’). As the fricatives were word medial, they were placed as the first sound within the second syllable giving them secondary stress. ‘ellifant’ and ‘diddorol’ were not consistent with the disyllabic words due to the phonological environment constraints of /f/ and /θ/. Therefore, to obtain /f/ and /θ/ within the requirements of being word medial, between vowels, and after a high vowel I opted for trisyllabic words instead of removing them from the study. Despite ‘ellifant’ being a trisyllabic word, the fricative is the first sound within the final syllable giving it secondary stress similar to the disyllabic words. However, the fricative in ‘diddorol’ is placed on the penultimate syllable giving it primary stress, which is a factor that will need to be considered in the results.

The sentence structure did not follow a set pattern and were structured around the words as they varied in type (noun, adjective, verb, and adverb). Despite the lack of a set sentence structure, there were several variables controlled for within the sentence: sentence medial target words, syllables before the first target word, syllables after the last target word, and tense.

Sentence example:

English – ‘The freezing weather will give you breathing problems’

Welsh – ‘Mae'r eliffant a'r bathor yn ffrindiau’

[*The elephant and dormouse are friends*]

The reasons for having a minimum number of syllables before and after the target words was to ensure the words were sentence medial. The minimum number of syllables before the first target word in the sentence was one and the maximum was six. In the English words, syllables ranged from one to six, with a median of 1 before the first target word. In the Welsh words, syllables ranged from one to three, with a median of 1 before the first target word. The minimum number of syllables after the second target word in the sentence was two and the maximum was 4. In the English words, syllables ranged from two to four, with a median of 3 after the second target word. In the Welsh words, syllables ranged from two to four, with a median of 3 after the second target word. The tense of the sentences was controlled for each language to ensure consistency between the sentences. The Welsh sentences were in present tense, and the English sentences refer to future time by using the auxiliary verb ‘will’.

7.1.4 Procedure

The recordings took place in the University of Leeds Linguistics and Phonetics departmental recording studio using a cardioid condenser microphone (Audio-Technica AT2020), a USB audio interface (M-Audio Fast Track Pro) and the recording software Audacity (Audacity Team, 2019) running on a windows PC.

Before the recording participants were asked to fill out a language background questionnaire (see Appendix C). The questionnaire was used to gather general demographic data, participants' language use, and participants language experience. General demographic data included age, place of birth and where participants grew up, if they lived outside of Wales for a period longer than 1 year, and if they had any speech disorders or hearing impairments. This data was collected to ensure participants were a homogeneous group that all resided in North Wales, and that they fit the specification for participating in the study. The questions on language experience were aimed at establishing the acquisition of Welsh and English, including who they learnt the language from and at what age, and language use involved understanding where they used each language and with whom.

The participants throughout the data collection were spoken to in English. The recruitment, explanation of the procedure, and language background questionnaire were carried out in English. To collect the data the constructed sentences appeared on a monitor in front of the participants for 8 seconds, and then changed to a blank screen where the participants were instructed to repeat the sentence just seen (Dilley & Pitt, 2010). This elicitation procedure was chosen over read word/sentence lists to try to elicit speech as close to spontaneous speech as possible but in a controlled environment. Participants were told that they could stop and take a break from the recording at any time, and a break was given to the participants between each language so they did not tire and lose concentration during the task. Following Dilley and Pitt (2010), instructions emphasized accurately repeating the sentence verbatim and not on the clarity of speech, which deters the participants from altering their speech for the purposes of the study and reduces any potential uncharacteristic articulations in their productions.

7.2 Analysis

7.2.1 Acoustic and Categorical Analysis

Data was analysed in Praat (Boersma & Weenink, 2019). Praat textgrids were created to firstly segment target words and then the target fricatives. As the fricatives were between vowels, they were firstly segmented from the preceding vowel's offset of the second formant to determine the left edge of the friction and the onset of the second vowel formant from the following vowel to determine the right edge of the friction.

Once all the fricatives were segmented, a Praat script using 'fraction of locally unvoiced frames' was used to extract the voicing proportion ('proportion of voicing' in Davidson (2016, 2018); (Eager, 2015)). Voicing proportion refers to the voicing duration within the overall fricative duration, e.g. 90% (90% of the frames within the fricative show periodicity). Voicing proportion was used for categorical analysis, along with investigating the distribution of voicing proportions. Following the categorical coding used by Davidson (2016, 2018), tokens were classed as "voiced" if they had 90% and greater voicing, "partial" if they had between 11%-89% voicing, and "voiceless" if they had 10% and less voicing. These measurements were chosen to include a "partial" voicing category so as not to categorise fricatives as either fully voiced (100%) or completely devoid of voicing (0%) and to be able to investigate voicing patterns in fricatives that do not fit into a [+voice] or [-voice] category.

The Praat script also extracted the fricative duration. Following Davidson's (2016) methodology, fricative duration was also used to investigate what Davidson calls 'voicing shape': *voicing shape* is a measurement that will show whether the voicing present increases/decreases/remains steady over the production of the fricative. The *voicing proportion* measurement does not inform where in the fricative duration voicing is being produced, therefore for this analysis the

Praat script segmented the fricative duration into smaller sub-sections (three thirds) to measure the *voicing proportion* throughout different sections of the fricative (onset, middle, offset) to determine the *voicing shape.* The "partial" tokens went through this further analysis to investigate how voicing behaves in fricatives that were not categorised as "voiced" or "voiceless". Four categories were used to investigate the presence and patterns of voicing (taken from Davidson (2016)): "bleed" – the proportion of voicing decreased from the first interval to the third interval, "negative VOT" – the proportion of voicing increased from the first interval to the third interval, "trough" – the proportion of voicing decreased from the first interval to the second and then increased from the second interval to the third, and "hump" – the proportion of voicing increased from the first interval to the second and then decreased from the second interval to the third. Despite following Davidson's (2016) method there was no specific measurements regarding numeric boundaries determining what an increase or decrease would be. Therefore, a specific numerical boundary was not used and any increase or decrease between the thirds of the fricative was used to determine the *voicing shape*.

The below figures demonstrate each voicing shape:

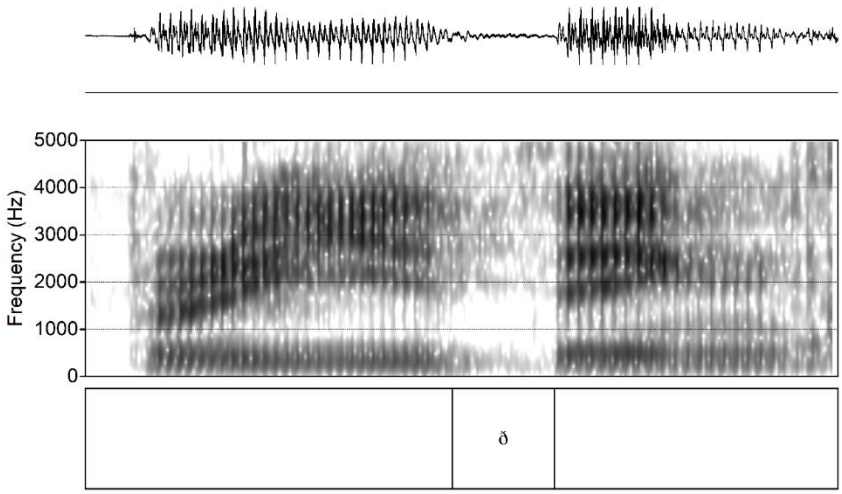

Figure 1: Spectrogram showing *voicing shape* "bleed"

This fricative was categorised as “bleed” as the *voicing proportion* decreased continuously throughout the length of the fricative. As shown in the spectrogram the voicing bar has stronger striations at the beginning of the fricative and gradually becomes weaker.

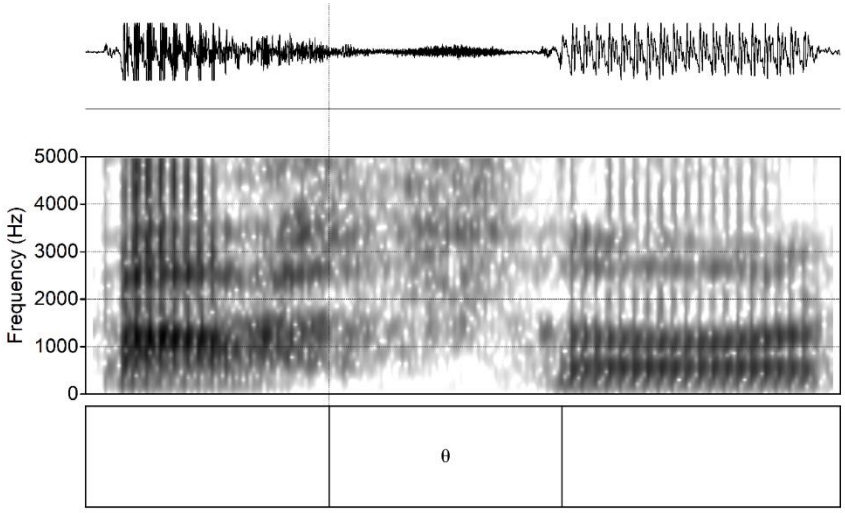

Figure 2: Spectrogram showing *voicing shape* “negative VOT”

This fricative was categorised as “negative VOT” as there is no voicing at the start and middle of the fricative and the *voicing proportion* increases at the end of the fricative. As shown in the spectrogram the voicing bar shows striations at the end of the fricative.

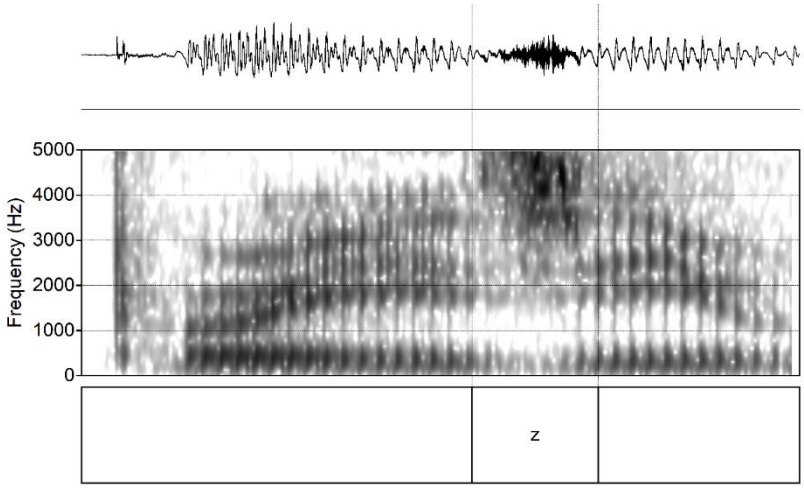

Figure 3: Spectrogram showing *voicing shape* “trough”

This fricative was categorised as “trough” as the *voicing proportion* decreases in the middle of the fricatives and then increases at the end. As shown in the spectrogram the voicing bar shows stronger striations at the beginning and end of the fricative and the middle shows weaker striations.

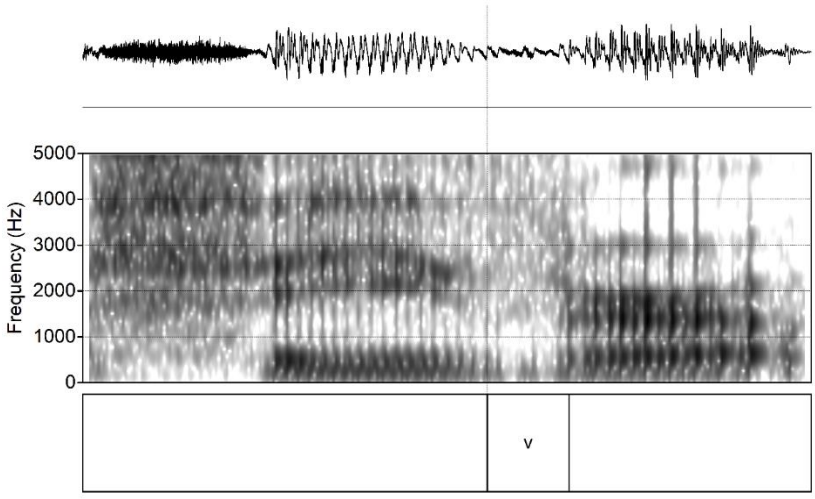

Figure 4: Spectrogram showing *voicing shape* “hump”

This fricative was categorised as “hump” as the *voicing proportion* increases in the middle of the fricatives and then decreases at the end. As shown in the spectrogram the voicing bar shows weaker striations at the beginning and end of the fricative and stronger striations in the middle.

7.2.2 Data Normalisation

Fricative duration was normalised for articulation rate to account for any effect of articulation rate on *voicing proportion*. As articulation rate affects the speed in which participants produce speech this will affect the fricative duration measurements; a high articulation rate would produce a fricative with a shorter duration and a low articulation rate would produce a fricative with a longer duration. Therefore articulation rate may potentially affect the results of research

question 4; it was hypothesised that fricatives with shorter durations are more prone to producing higher *voicing proportions*.

To calculate the articulation rate, the number of syllables in the sentence containing the target word was divided by the sentence duration. The articulation rate for each sentence was divided by the mean articulation rate for all sentences to calculate whether this sentence was faster or slower than the participants' average articulation rate; above 1 was considered faster and below 1 was considered slower. The fricative duration was then divided by this measurement (which indicates whether the sentence was faster or slower than the mean) to produce the normalised fricative duration. This calculation was done separately for Welsh and English for each participant.

7.2.3 Qualitative Analysis

All qualitative analysis was carried out in R (R Core Team, 2019), using the *lme4* package (Bates, Mächler, Bolker, & Walker, 2015) to perform linear mixed effects models on the relationship between voicing proportion and language, vowel height, place of articulation, and fricative duration. Participant was used as a random effect.

7.2.4 Removed Tokens

504 fricatives were recorded for analysis, however 23 tokens had to be removed leaving 481 fricatives that were included in the analysis. Participant 1 had one token removed ('Lethal'), Participant 2 had two tokens removed ('Lethal', 'Diddorol'), Participant 3 had 18 tokens removed (2 Welsh tokens, 16 English tokens), and Participant 4 had one token removed ('Lethal'). Participant 3 had the majority of removed tokens, which included eight English high

vowel tokens, eight English low vowel tokens, one Welsh high vowel token, and one Welsh low vowel token. For the removed tokens, participants continued the friction into the following vowel and therefore, there was no distinguishable boundary between the fricative and vowel for there to be a tier boundary separating them.

7.2.5 List of Variables

The below table is the list of dependant variables and terminology that will be used to discuss the results within this thesis.

Variable	**Level (categorical variables)**
Phonological Voicing	[+voice]
	[-voice]
Voicing Proportion	n/a
Categorical Voicing	"Voiced"
	"Partial"
	"Voiceless"
Voicing Shape	"Bleed"
	"Hump"
	"Trough"
	"Negative VOT"

Table 10: List of variables and levels used throughout this thesis

8. Results

The results of this study will be presented in two sections: [+voice] fricatives and [-voice] fricatives. Within these sections they will look at (i) the distribution of voicing proportions produced by the participants, along with the categorical coding distribution and voicing shape of "partial" tokens, (ii) research question 1 "Is the production of voicing in Welsh fricatives different to Welsh English fricatives?", (ii) research question 2 'Does place of articulation affect voicing in Welsh and English fricatives?', research question 3 'Does vowel height affect voicing in Welsh and English fricatives?', research question 4 'Does fricative duration influence voicing proportions?', and the final section will investigate individual differences between participants.

8.1 [+voice] Fricatives

The results will firstly address the [+voice] fricatives as the main focus of this study is to investigate the difference in voicing productions between Welsh and English

8.1.1 Distribution of Voicing:

This section will present the results of the distribution of voicing productions and will look into the distribution of *voicing shape* to further investigate the pattern of voicing throughout the fricative productions.

Figures 5 and 6 show the distribution of *voicing proportions* for the English and Welsh [+voice] fricatives.

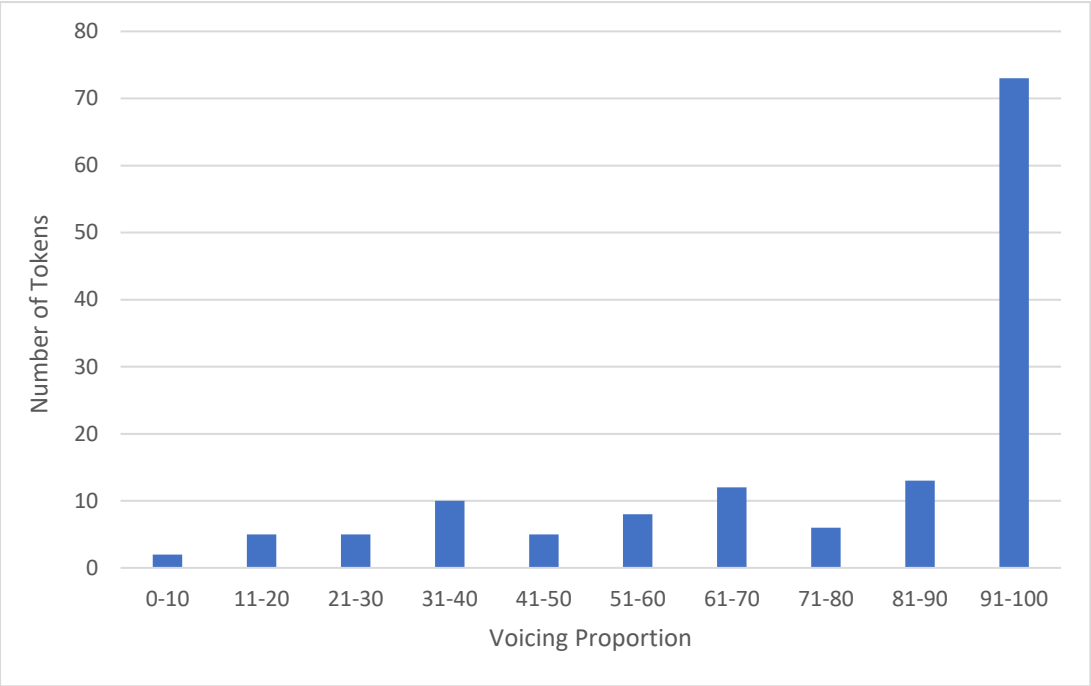

Figure 5: Distribution of *voicing proportion* in [+voice] English fricatives

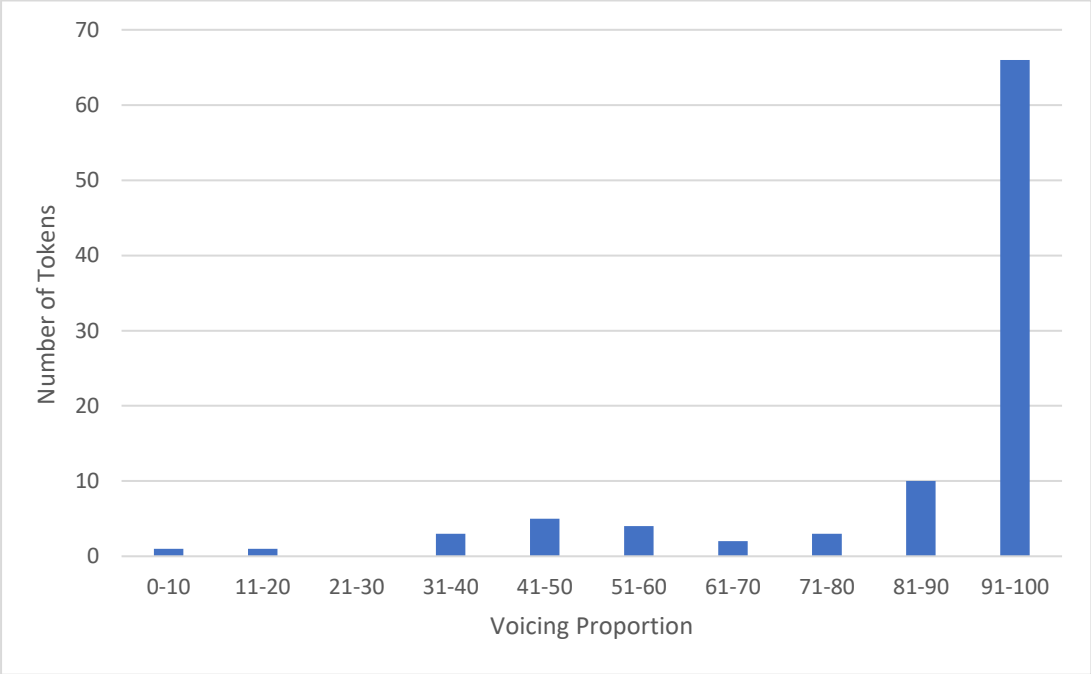

Figure 6: Distribution of *voicing proportion* in [+voice] Welsh

For English [+voice] fricatives, *voicing proportion* values are mostly above 90; 73 fricatives (53% of tokens) fall between 91-100. The remaining v*oicing proportion* bins then concentrate around 10 tokens and below. The next *voicing proportion* bins with the highest number of tokens after

91-100 are 81-90 with 13 tokens (9% of tokens), 61-70 with 12 tokens (8% of tokens), and 31-40 with 10 tokens (7% of tokens). The rest of the *voicing proportion* bins that contain tokens have between 8 and 2 tokens. English tokens are divided between fricatives produced at 91-100 and tokens produced below this *voicing proportion* (a 53%/47% divide). The mean *voicing proportion* for English [+voice] fricatives is 78 (SD = 0.28).

For Welsh [+voice] fricatives, *voicing proportion* values are also mostly above 90; 66 fricatives (69.5% of tokens) fall between 91-100. The remaining v*oicing proportion* bins then concentrate around 10 tokens and below. 81-90 voicing has 10 tokens (10.5% of tokens) and is the next *voicing proportion* with the highest number of tokens after 91-100. The rest of the *voicing proportion* bins, that contain tokens, have between 5 and 1 tokens. The only *voicing proportion* without any tokens producing voicing of this proportion is 21-30. The mean *voicing proportion* for Welsh [+voice] fricatives is 88 (SD = 0.21).

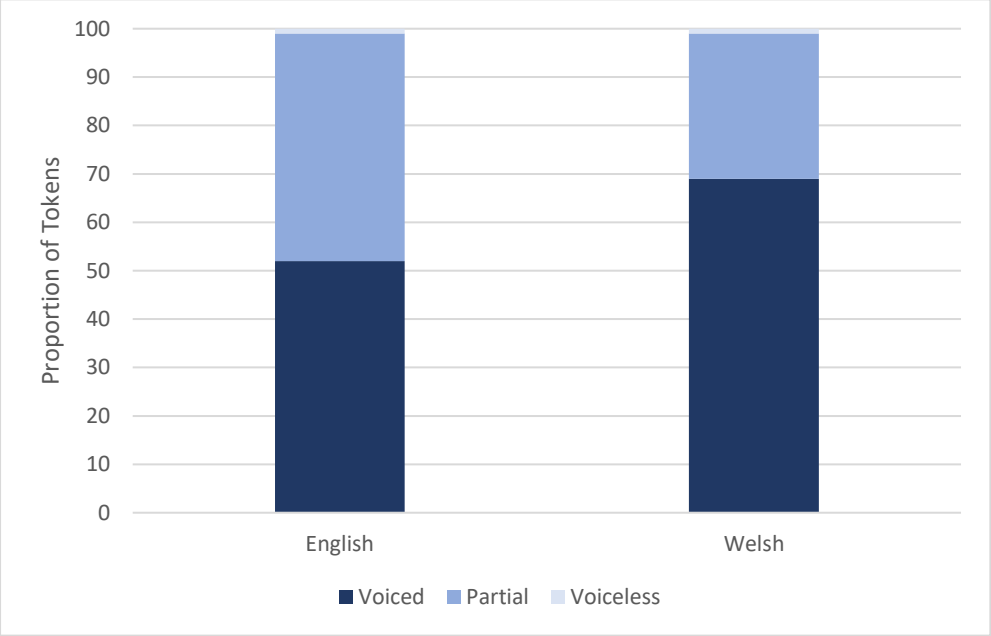

Figure 7: Bar chart of [+voice] Welsh and English voicing categories

Looking at the distribution of fricatives with *categorical coding*, the difference between Welsh (N = 94) and English (N = 139) voicing productions can be seen more clearly in Figure 7. As Figure 7 presents the proportion of tokens in each category this shows a clearer comparison of the [+voice] tokens as Welsh has a lower number of overall tokens compared to English. Welsh and English both have the same low proportion of "voiceless" fricatives, which show that complete devoicing is rare for Welsh and English. However, for "voiced" and "partial" fricatives they differ. Welsh has a higher proportion of "voiced" tokens than English, which can be seen above through; Welsh has 16.9% more fricatives produced between 91-100. English, therefore, has a higher proportion of "partial" tokens than Welsh. This indicates that the participants are less consistent in producing fully voiced fricatives in English compared to Welsh. However, full voicing cannot be claimed as the norm for Welsh either with just over two thirds of the fricatives being fully voiced.

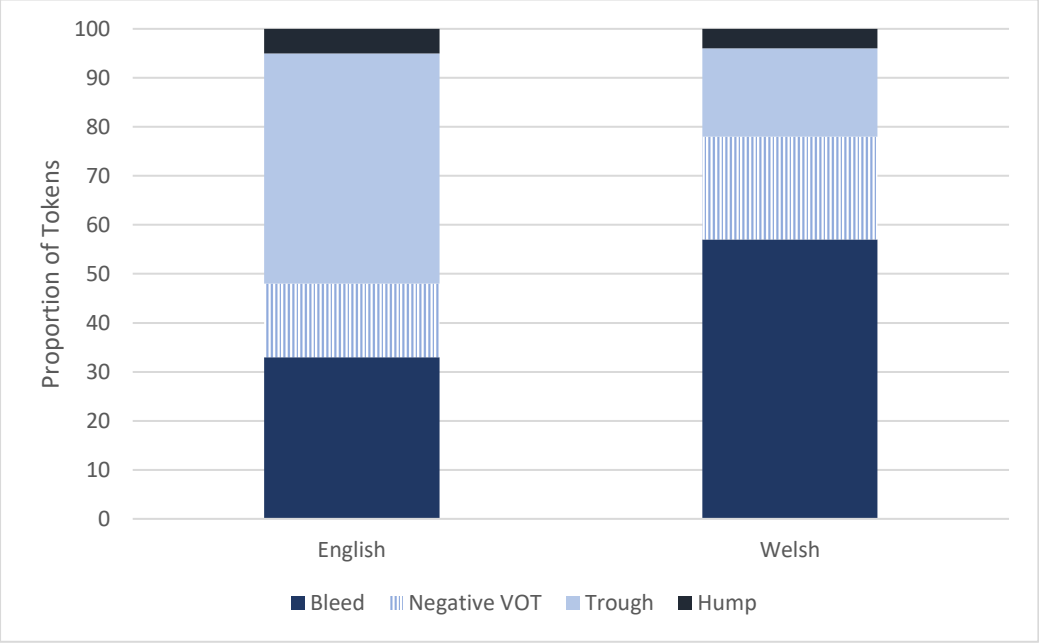

Figure 8: Bar chart of [+voice] Welsh and English voicing shape proportions

Figure 8 shows the distribution of *voicing shape* from the "partial" [+voice] fricatives in English (N = 65) and Welsh (N = 28). The most common *voicing shapes* are "bleed" and "trough" followed by "negative VOT" and "hump". For [+voice] English fricatives, "trough" is the shape produced the most at 47%, followed by "bleed" at 33%, "negative VOT" at 15%, and "hump" with the lowest proportion at 5%. For [+voice] Welsh fricatives, "bleed" is the shape produced the most at 57%, followed by "negative VOT" at 21%, "trough" at 18%, and "hump" with the lowest proportion at 4%. Devoicing of [+voice] fricatives is observed to occur as a result of voicing not being maintained throughout the duration of the entire fricative. In English, voicing mostly continues from the preceding vowel, dies out, and then increases again before the onset of the following vowel ("trough"), and for Welsh voicing mostly continues from the preceding vowel and then dies out before the end of the fricative ("bleed").

8.1.2 Research Questions

This section will address each research question starting with RQ1 and the differences between Welsh and English. The model used was run on both the raw and normalised date and the same analysis was ran twice using each set of data. The raw data was normalised to account for potential effects speaking rate had on the production of the target fricatives. However, as the raw and normalised data yielded the same results, the results of the raw data will be presented below.

A linear mixed effects model was used to analyse the relationship between *voicing proportion* and language (Welsh and English), place of articulation (labiodental, dental, and alveolar), vowel height (high and low), and duration as a continuous factor. The reference level for language is

Welsh/English, labiodental for place of articulation, and high for vowel height. The results of the model run on [+voice] fricative data is presented below:

	Estimate	STD. Error	Df	t value	Pr(>|t|)
Intercept	1.248	0.061	38.064	20.283	<2e-16 ***
Language -Welsh	0.034	0.028	223.962	1.204	0.230
Vowel - Low	0.037	0.025	223.721	1.476	0.141
Place of Articulation - Dental	0.004	0.028	224.928	0.160	0.873
Place of Articulation - Alveolar	-0.186	0.041	226.986	-4.539	9.17e-06 ***
Duration	-7.277	0.942	185.028	-7.718	7.12e-13 ***

Table 11: [+voice] Model including Welsh and English
*** indicates significance

The data was then separated by language and the models were run on the data for Welsh and English individually. This was done to be able to analyse the data and patterns of Welsh and English separately and then to provide a comparative analysis between both languages. The below tables display the results of the models run on Welsh [+voice] fricatives and English [+voice] fricatives:

	Estimate	Std Error	df	t value	Pr(>|t|)
Intercept	1.259	0.058	31.556	21.556	< 2e-16 ***
Vowel - Low	0.027	0.034	88.095	0.784	0.435
Place of Articulation - Dental	0.044	0.035	88.246	1.251	0.214
Duration	-7.14	0.952	52.149	-7.496	7.9e-10 ***

Table 12: Welsh [+voice] fricatives model
*** indicates significance

The intercept refers to labiodental fricatives preceded by a high vowel. The results show that fricatives preceded by low vowels did not produce *voicing proportions* significantly different to

high vowels, a dental place of articulation did not produce *voicing proportions* significantly different to labiodental fricatives, and duration has a significant effect on *voicing proportion*.

	Estimate	Std Error	Df	t value	Pr(>|t|)
Intercept	1.411	0.116	45.655	12.143	6.74e-16 ***
Vowel - Low	0.028	0.036	133.431	0.77	0.442
Place of Articulation - Dental	-0.032	0.042	131.101	-0.767	0.444
Place of Articulation - Alveolar	-0.163	0.052	124.66	-3.083	0.00253 **
Duration	-9.881	1.916	66.731	-5.157	2.43e-06 ***

Table 13: English [+voice] fricatives
*** indicates significance
** indicates significance

The intercept refers to labiodental fricatives preceded by a high vowel. The results show that fricatives preceded by low vowels did not produce *voicing proportions* significantly different to high vowels, a dental place of articulation did not produce *voicing proportions* significantly different to labiodental fricatives, but an alveolar place of articulation did produce *voicing proportions* significantly different to labiodental fricatives, and duration has a significant effect on *voicing proportion*.

8.1.2.1 Research Question 1 – The difference between Welsh and English

This section will look at the results of research question one: 'Is the production of voicing in Welsh fricatives different to Welsh-English fricatives?' and address the hypothesis that voicing productions are more likely to be consistently voiced in English than in Welsh.

Looking at the overall model (Figure 9) including both Welsh and English, there is no significant difference in the production of *voicing proportions* across Welsh and English. Looking at the graph below all participants consistently produce full voicing in both Welsh and English. However, all participants devoice fricatives with some frequency in English, but in Welsh only P1

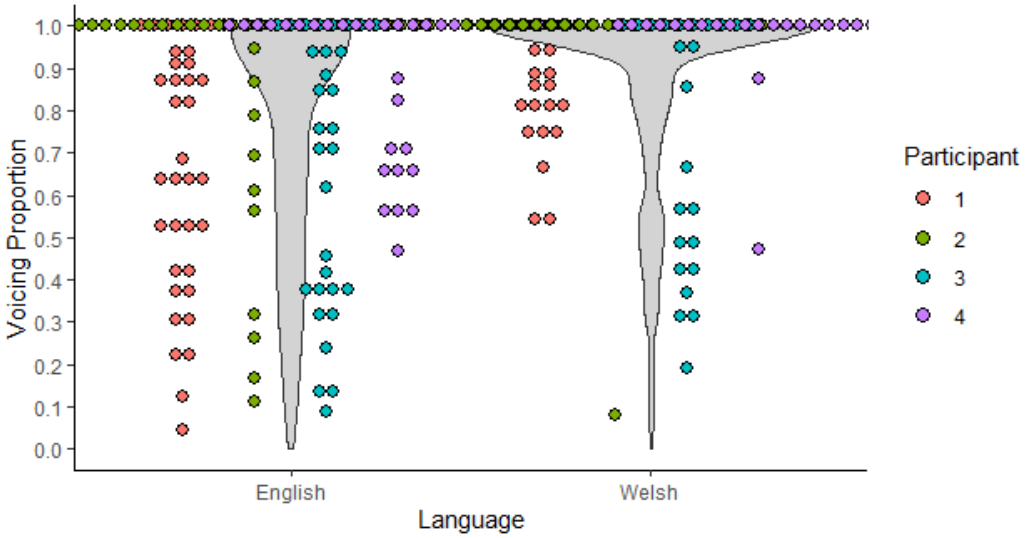

Figure 9: Violin plot showing the distribution of [+voice] fricatives between Welsh and English

and P3 devoice fricatives with some frequency. Despite some descriptive differences, there are statistically no differences in *voicing proportions* across Welsh and English.

8.1.2.2 Research Question Two - Place of Articulation

This section will look at the results of research question two: 'Does place of articulation affect voicing in Welsh and English fricatives?' for [+voice] fricatives, and address the hypothesis that devoicing is more likely to occur in posterior articulations than anterior articulations.

Looking at the overall model (Table 11) containing both Welsh and English, *voicing proportions* from dental fricatives are not significantly different to labiodental fricatives. Alveolar fricatives, on the other hand, do produce *voicing proportions* significantly different to labiodental

fricatives. These overall results were expected due to the influence of a reduced size of the oral cavity for alveolar fricatives and confirm the hypothesis that alveolar fricatives will produce the least voicing. The individual English model (Table 13) follows this pattern of alveolar fricatives having significantly lower *voicing proportions* to labiodental fricatives, while dental fricatives do not. The individual Welsh model (Table 12) follows the overall model in regards to labiodental and dental fricatives, but not alveolar as they were not included for Welsh.

The *voicing proportion* for English alveolar fricatives has a considerably lower average than labiodental and dental fricatives, as would be expected from the findings of previous studies which find that alveolar devoices more fricatives than labiodental and dental fricatives.

		Mean *Voicing Proportion* - overall
English	Labiodental	90
	Dental	86
	Alveolar	58
Welsh	Labiodental	89
	Dental	87

Table 14: Mean *voicing proportion* for [+voice] fricatives

Looking at the results descriptively Figure 10 and 11 are violin plots which shows the production of [+voice] fricatives plotted for place of articulation (labiodental, dental, alveolar) and *voicing proportion*. For Welsh (Figure 10) both labiodental and dental have a similar distribution of *voicing proportions*. Some dental fricatives have lower voicing proportions (below *voicing proportion* 25) than labiodental fricatives, but there is no significant difference between the two distributions. Labiodental fricatives have a voicing proportion between 31 and 100 and dental fricatives have a voicing proportion between 3 and 100.

For English (Figure 11) both labiodental and dental have similar patterns of distribution, whereas alveolar does not. Comparing labiodental and dental, dental does have lower *voicing proportion* productions than labiodental with two fricatives that go below 37, but similar to Welsh this does not create a significant difference between labiodental and dental productions which is confirmed by the results of the model. Alveolar fricatives compared to labiodental fricatives have a larger and more even distribution of *voicing proportions*, which also have frequent productions at lower *voicing proportions*. This shows that alveolar fricatives have a higher frequency of devoiced tokens than labiodental and dental fricatives, as confirmed by the model.

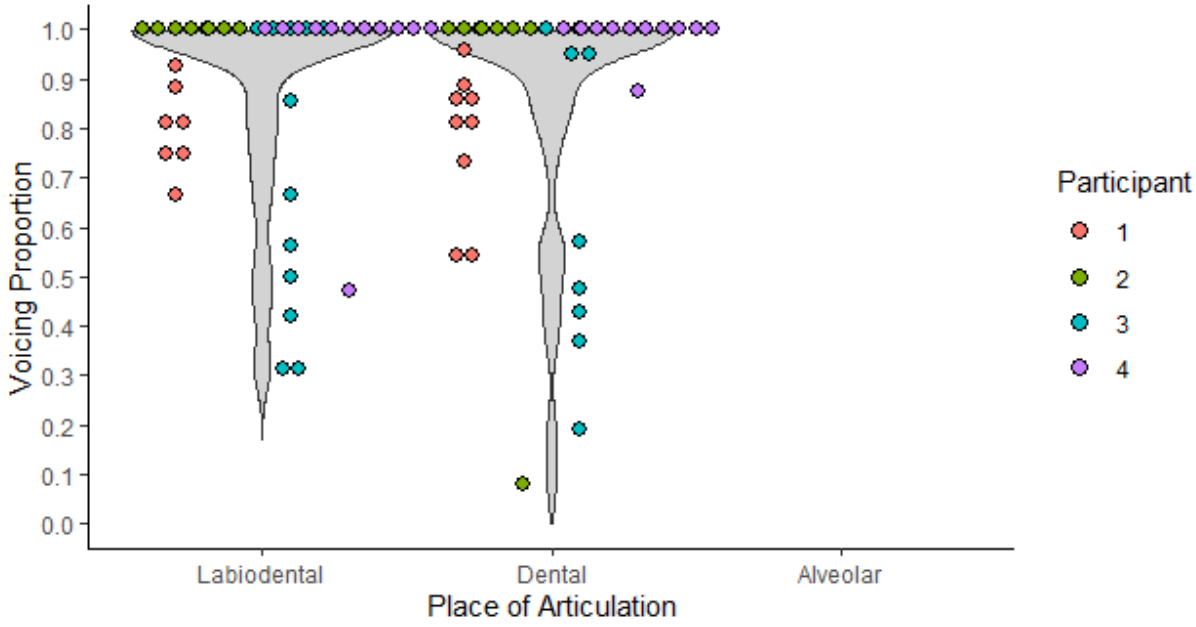

Figure 10: Welsh [+voice] fricatives – place of articulation

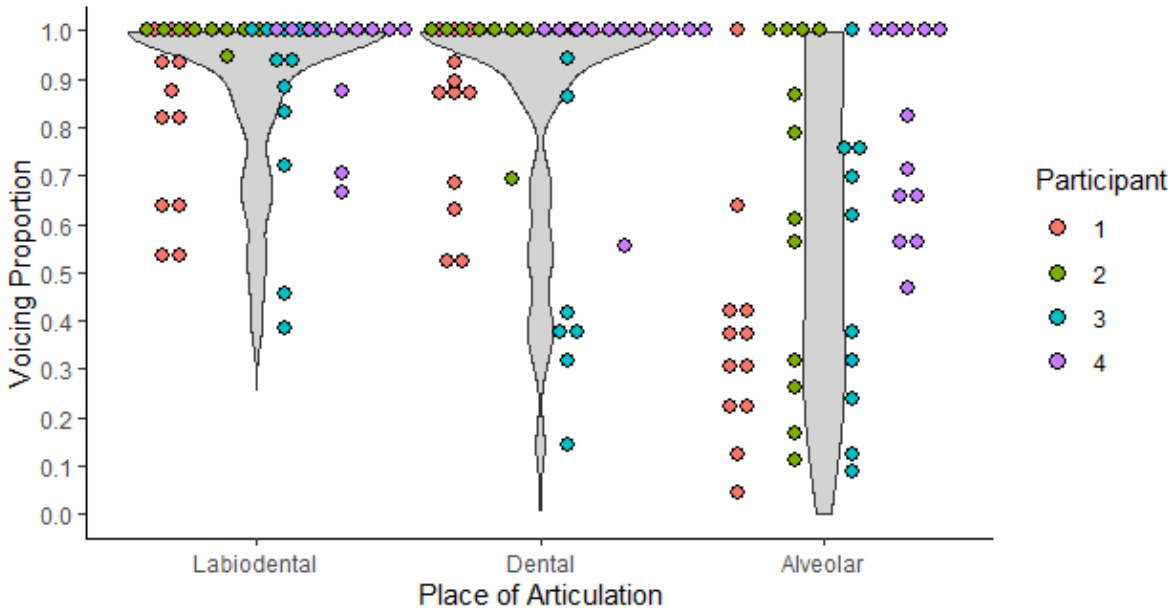

Figure 11: English [+voice] fricatives – place of articulation

8.1.2.3 Research Question 3 - Vowel Height

This section will look at the results of research question three: 'Does vowel height effect voicing in Welsh and English fricatives?' for [+voice] fricatives, and address the hypothesis that devoicing is more likely to occur with high vowels than low vowels.

Looking at the model overall (Table 10) containing both Welsh and English, low vowels are not significantly different to high vowels in the production of *voicing proportions*. Both the individual language models (Table 11 and 12) also follow this pattern and do not significantly differ in the production of *voicing proportions* between high and low vowels. These results are unexpected and go against the hypothesis which anticipated that high vowels would produce less voicing (lower *voicing proportions*) than low vowels.

Looking at the results descriptively Figure 12 and 13 are violin plots which shows the production of fricatives plotted for vowel height (high and low) and *voicing proportion*. For Welsh [+voice]

fricatives, high and low vowels have a similar distribution of *voicing proportions*. Both high and low vowels are produced within a similar range; 19-100 for high vowels and 8-100 for low vowels. However, the productions are not consistently produced throughout each range and cluster at various *voicing proportions*. For English [+voice] fricatives, high and low vowels have a similar distribution of voicing proportions; 9-100 for high vowels and 4-100 for low vowels. However, unlike Welsh the *voicing proportions* are evenly distributed throughout each range.

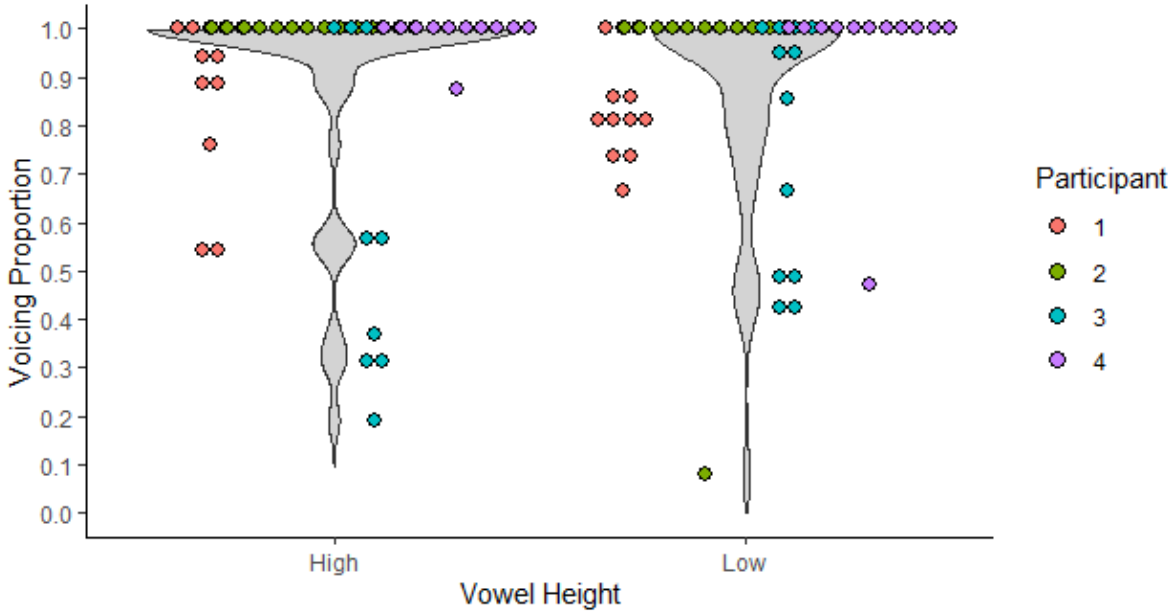

Figure 12: Welsh [+voice] fricatives – vowel height

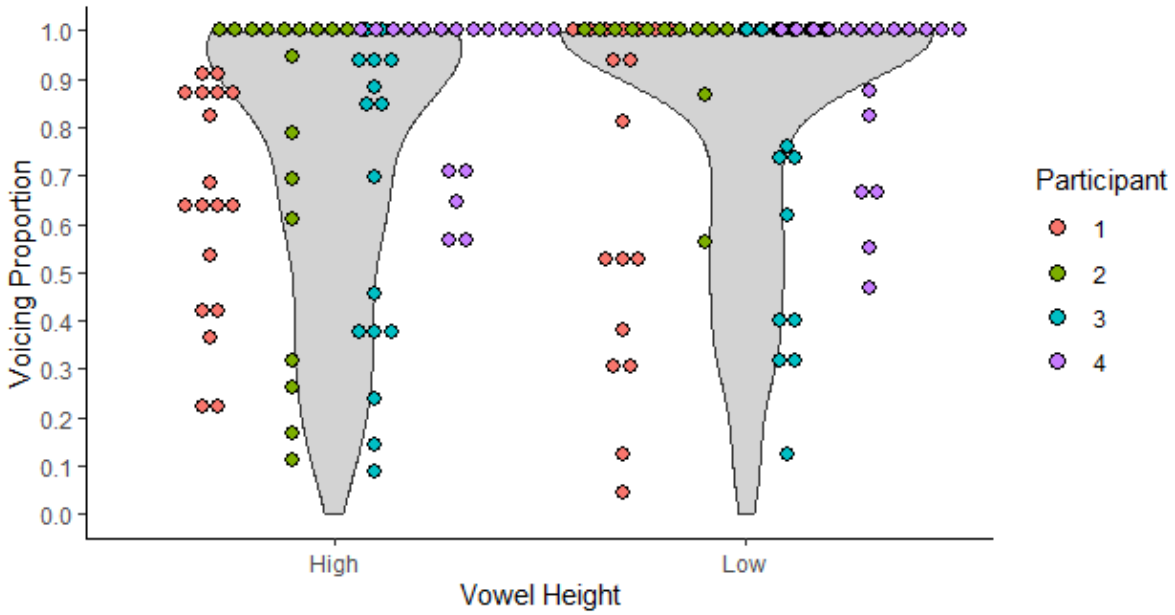

Figure 13: English [+voice] fricatives – vowel height

8.1.2.4 Research Question Four - Duration

This section will look at the results of research question 4: 'Does fricative duration influence voicing proportion?' for [+voice] fricatives, and address the hypothesis that devoicing is more likely to occur in relatively long fricative productions compared to short productions.

Looking at the overall model (Table 10) containing both Welsh and English, duration has a significant effect on *voicing proportion* for [+voice] fricatives. Both the individual language models (Table 11 and 12) also show that duration has a significant effect on *voicing proportion*.

Looking at the results descriptively Figure 14 and 15 are scatter charts which show the duration (ms) and *voicing proportion* of fricatives. For Welsh [+voice] fricatives the durations ranged between 31 and 179 milliseconds and the *voicing proportions* ranged between 19 and 100. The 179 ms fricative is an outlier in the data and the nearest highest duration is 100 milliseconds. The outlier is a production of the target word "addo" by participant 2. The pattern of *voicing*

proportions is that fricatives with shorter durations are produced with higher *voicing proportions* than fricatives with longer durations. For English [+voice] fricatives the durations ranged between 31 and 87 milliseconds and the *voicing proportions* ranged between 4 and 100. Similar to Welsh fricatives, the pattern of *voicing proportions* is that fricatives with shorter durations are produced with higher *voicing proportions* than fricatives with longer durations. The pattern for both languages confirms the hypothesis with the shorter durations producing full voicing and fricatives with longer durations producing more partial voicing.

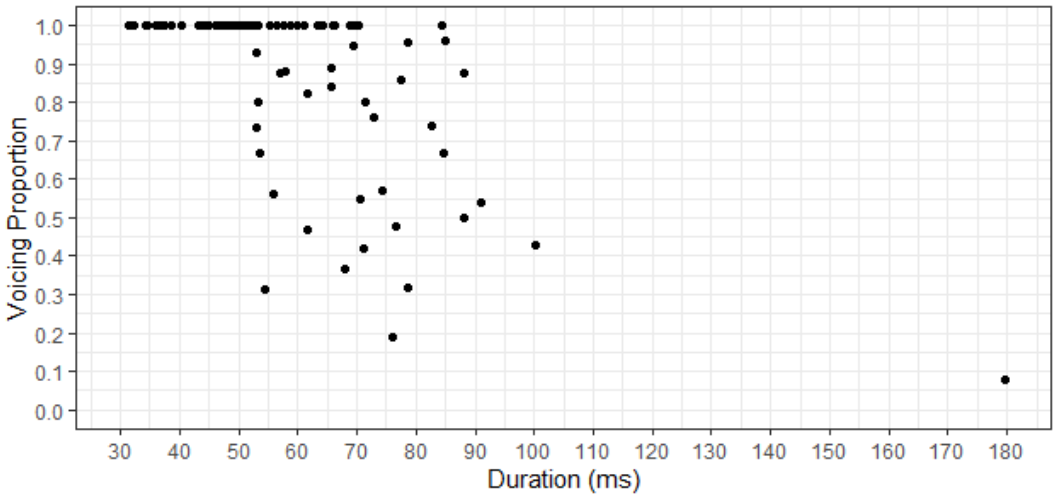

Figure 14: Welsh [+voice] fricatives - duration

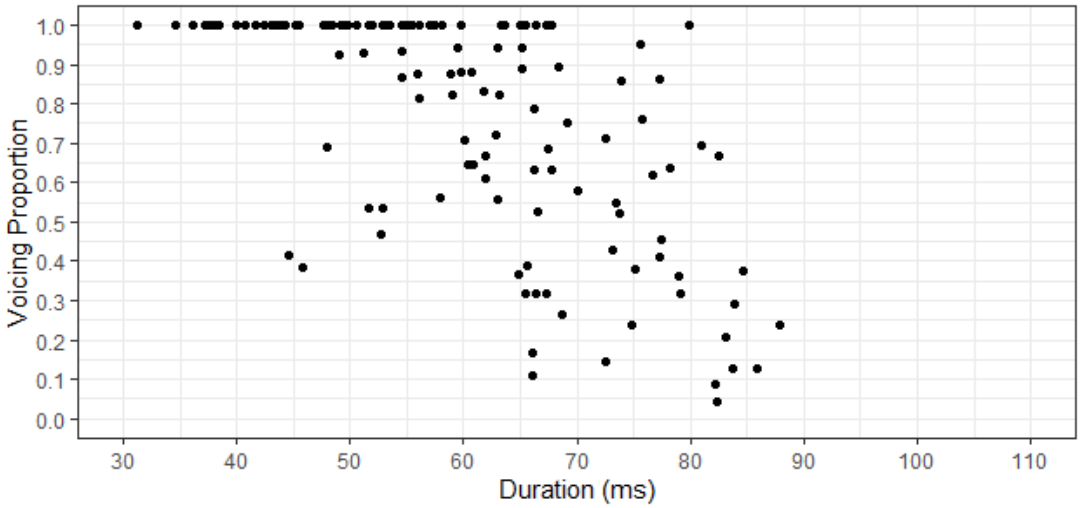

Figure 15: English [+voice] fricatives - duration

8.1.2.5 Individual Differences

This section will present the results of the individual participants' distribution of voicing productions looking at the differences between each speaker and across each language. The below figures are violin plots of each participants' fricative productions in English and Welsh.

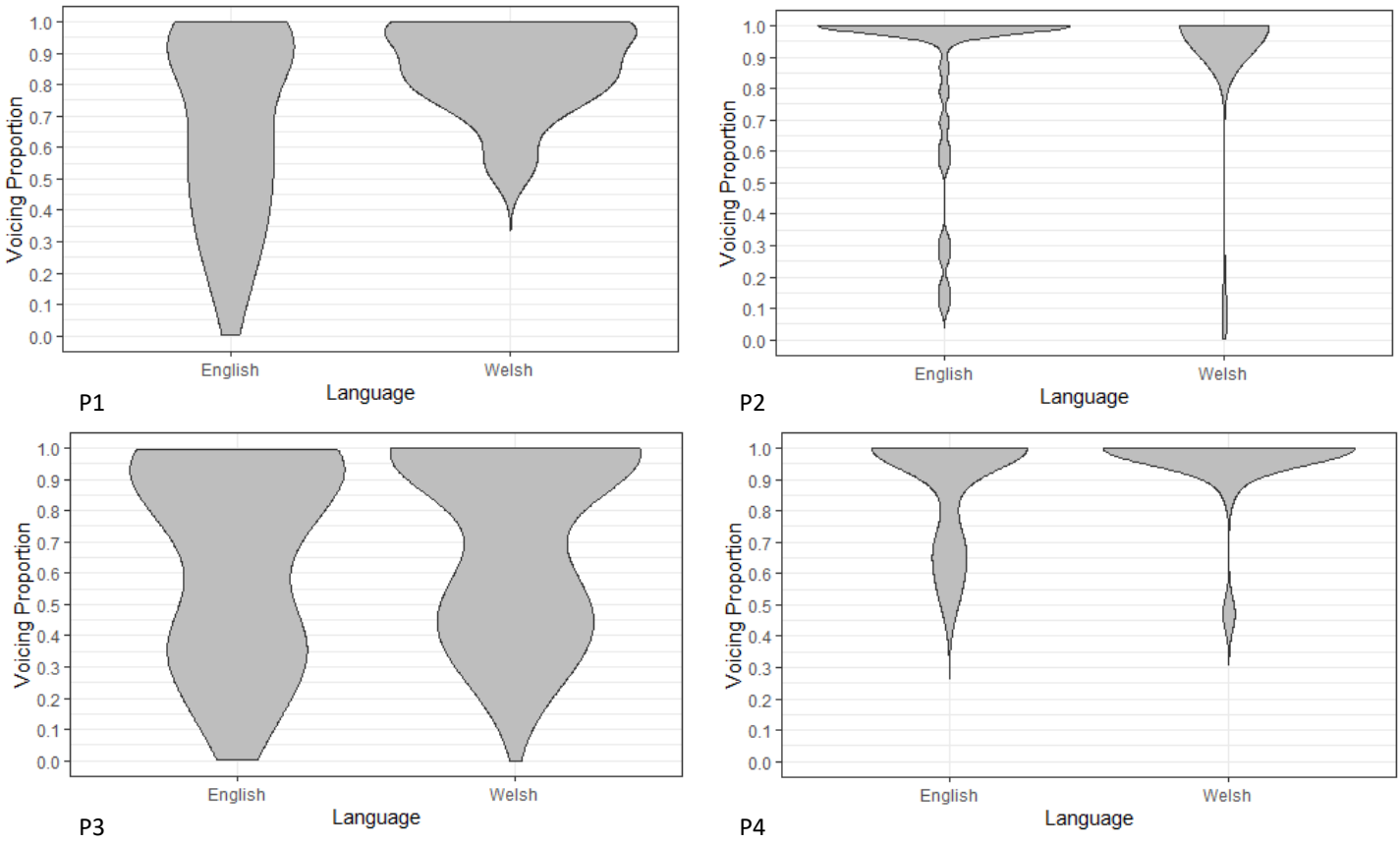

Figure 16: Graphs showing the distribution of voicing in [+voice] Welsh and English fricatives by participants

Overall, P2, P3, and P4 have similar distributions of *voicing proportions* for English [+voice] fricatives and Welsh [+voice] fricatives, while P1 has different distributions for English and Welsh. P1 produced higher *voicing proportions* and had a smaller distribution for Welsh [+voice] fricatives; the minimum *voicing proportion* for English is 4 and 54 for Welsh (excluding the outlier at 5) and the first quartile for English is 42.5 and 79 for Welsh. It is important to note that

P1 has a different language background to the other participants, which might have influenced the difference in distributions, however more research into the differences in voicing productions from speakers of different languages backgrounds is needed to confirm this hypothesis.

8.2 [-voice] Fricatives

8.2.1 Distribution of Voicing:

This section will present the results of the distribution of voicing productions and will look into the distribution of *voicing shape* to further investigate the pattern of voicing throughout the fricative productions.

Figures 17 and 18 show the distribution of *voicing proportions* for the English and Welsh [-voice] fricatives.

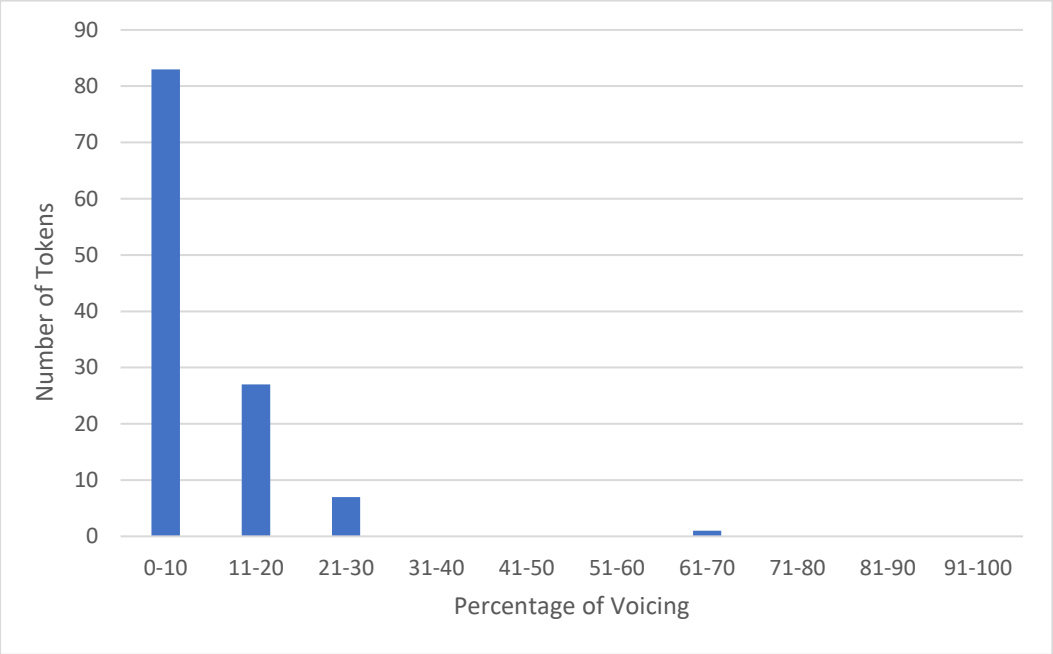

Figure 17: Distribution of *voicing proportion* in [-voice] English fricatives

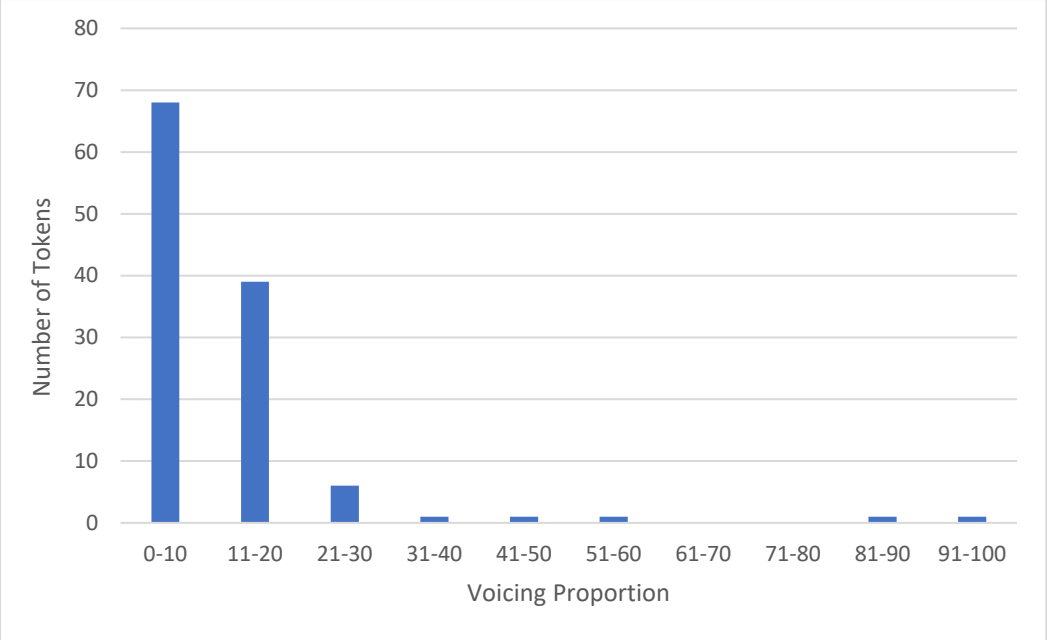

Figure 18: Distribution of *voicing proportion* in [-voice] Welsh fricatives

For English [-voice] fricatives, *voicing proportion* values are mostly below 10; 83 fricatives (69% of tokens) fall between 0-10. Voicing is then mostly produced between 11-20 with 28 tokens (24% of tokens) and between 21-30 with 7 tokens (6% of tokens). There is 1 token produced at 61-70 *voicing proportion* and the rest of the *voicing proportion* bins do not contain any tokens. The mean *voicing proportion* for English [-voice] fricatives is 9 (SD = 0.07).

For Welsh [-voice] fricatives, *voicing proportion* values are mostly below 10; 68 fricatives (58% of tokens) fall between 91-100. Voicing is then mostly produced between 11-20 with 39 tokens (33% of tokens) and 21-30 with 6 tokens (5% of tokens). The rest of the *voicing proportion* bins, that contain tokens, have 1 token (each containing 0.8% of tokens). The *voicing proportions* that do not contain any tokens are 61-70 and 71-80. The mean *voicing proportion* for Welsh [-voice] fricatives is 11 (SD = 0.13).

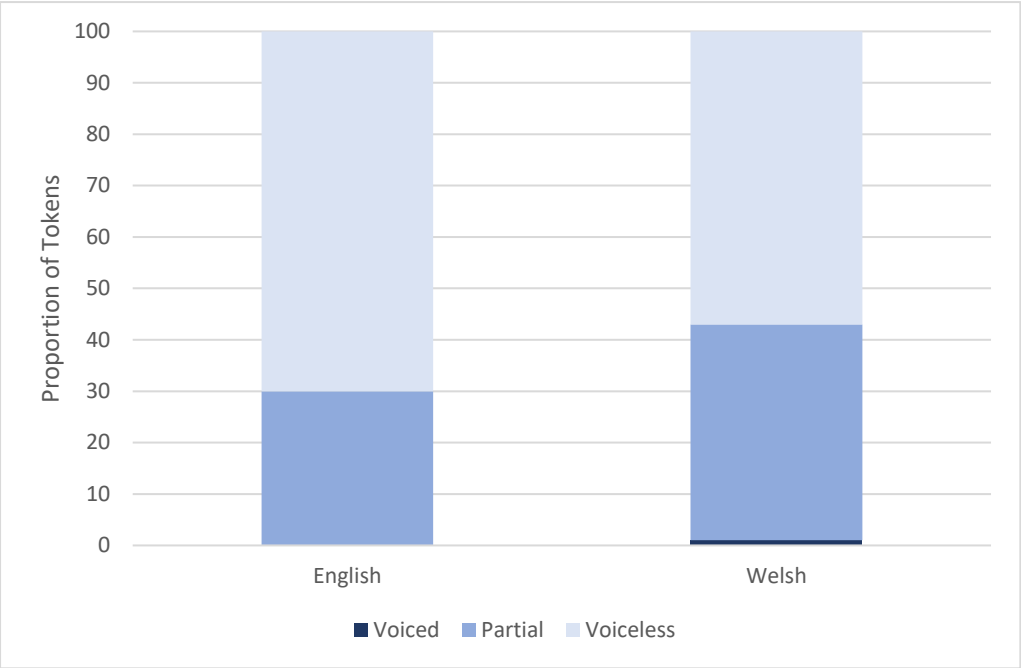

Figure 19: Bar chart of [-voice] Welsh and English voicing categories

Looking at the distribution of fricatives with *categorical coding*, the difference between Welsh (N = 118) and English (N = 118) voicing productions can be seen more clearly (see Figure ?). English has no "voiced" fricatives, whereas Welsh has 1 "voiced" fricative, which show that full voicing is rare for Welsh and English [-voice] fricatives. However, for "voiceless" and "partial" fricatives they differ. English has a higher proportion of "voiceless" tokens than Welsh, which can be seen above through Figures 18 and 19; English has 11% more fricatives produced between 0-10. Welsh, therefore, has a higher proportion of "partial" tokens than English.

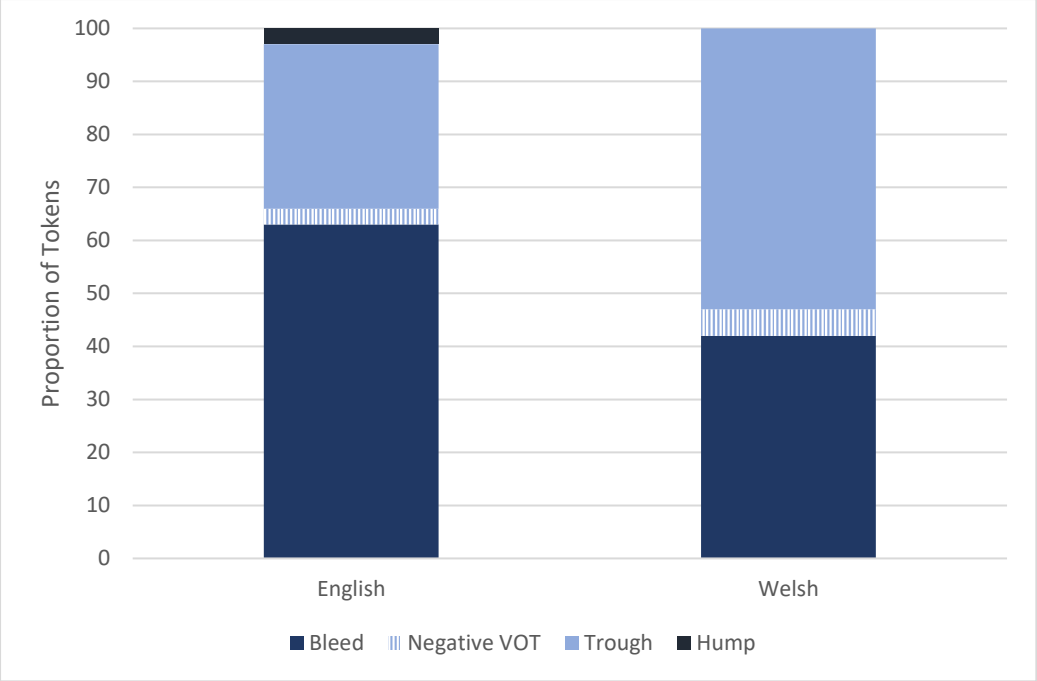

Figure 20: Bar chart of [-voice] Welsh and English voicing shape proportions

Figure 20 shows the distribution of *voicing shape* from the "partial" [-voice] fricatives in English (N = 35) and Welsh (N = 49). The most common *voicing shapes* are "bleed" and "trough" followed by "negative VOT" and "hump". For [-voice] English fricatives, "bleed" is the shape produced the most at 63%, followed by "trough" at 31%, and then "negative VOT" and "hump" with the lowest proportion at 3% each. For [-voice] Welsh fricatives, "trough" is the shape produced the most at 53%, followed by "bleed" at 42%, and "negative VOT" with the lowest proportion at 5%. Voicing of [-voice] fricatives is mainly caused by edge vibrations; voicing carries over into the fricative from the preceding vowel and voicing begins at the end of the fricative in anticipation for the voicing in the post vowel.

8.2.2 Research Questions

This section will address each research question starting with research question 1 and the differences between Welsh and English. The same model configuration as the [+voice] fricatives was run for the [-voice] fricatives. The results of the model are presented below:

	Estimate	STD. Error	df	t value	Pr(>|t|)
Intercept	2.898e-01	4.171e-02	3.324e+01	6.948	5.87e-08 ***
Welsh	2.138e-02	1.351e-02	2.273e+02	1.582	0.115
Vowel Low	8.261e-04	1.356e-02	2.271e+02	0.061	0.951
Dental	1.585e-02	1.612e-02	2.294e+02	0.983	0.327
Alveolar	-9.474e-03	1.736e-02	2.300e+02	-0.546	0.586
Duration	-1.579e+00	2.993e-01	8.541e+01	-5.276	9.86e-07 ***

Table 15: Model including Welsh and English [-voice] data
*** indicates significance

The below tables display the results of the models run on Welsh [-voice] fricatives and English [-voice] fricatives:

	Estimate	Std Error	df	t value	Pr(>|t|)
Intercept	0.372	0.061	25.811	6.046	2.25e-06 ***
Low Vowel	0.037	0.025	110.757	1.501	0.136
Dental	0.049	0.025	111.089	1.971	0.051
Alveolar	-0.026	0.033	110.083	-0.799	0.426
Duration	-2.305	0.446	73.146	-5.161	2.04e-06 ***

Table 16: Welsh [-voice] fricatives model
*** indicates significance

The intercept refers to labiodental fricatives preceded by a high vowel. The results show that fricatives preceded by low vowels did not produce *voicing proportions* significantly different to

high vowels, a dental and an alveolar place of articulation did not produce *voicing proportions* significantly different to labiodental fricatives, and duration has a significant effect on *voicing proportion*.

	Estimate	Std Error	df	t value	Pr(>|t|)
Intercept	0.159330	0.050525	25.702893	3.153	0.00408 **
Low Vowel	-0.002767	0.013518	111.185922	-0.205	0.83819
Dental	-0.031464	0.017461	112.062477	-1.802	0.07424
Alveolar	-0.031789	0.016416	112.851261	-1.936	0.05531
Duration	-0.408320	0.370602	50.703756	-1.102	0.27576

Table 17: English [-voice] fricatives model
** indicates significance

The intercept refers to labiodental fricatives preceded by a high vowel. The results show that fricatives preceded by low vowels did not produce *voicing proportions* significantly different to high vowels, a dental place of articulation did not produce *voicing proportions* significantly different to labiodental fricatives, and duration does not have a significant effect on *voicing proportion*.

8.2.2.1 Research Question 1 – The difference between Welsh and English

This section will look at the results of research question one: 'Is the production of voicing in Welsh fricatives different to Welsh-English fricatives?' and address the hypothesis that voicing productions are more likely to be consistently voiced in English than in Welsh.

Looking at the overall model (Table 15) including both Welsh and English, there is no significant difference in the production of *voicing proportions* across Welsh and English. Looking at the graph (Figure 21) below all participants consistently produce voiceless fricatives in both Welsh and English and predominantly produce fricatives under 3 *voicing proportion*.

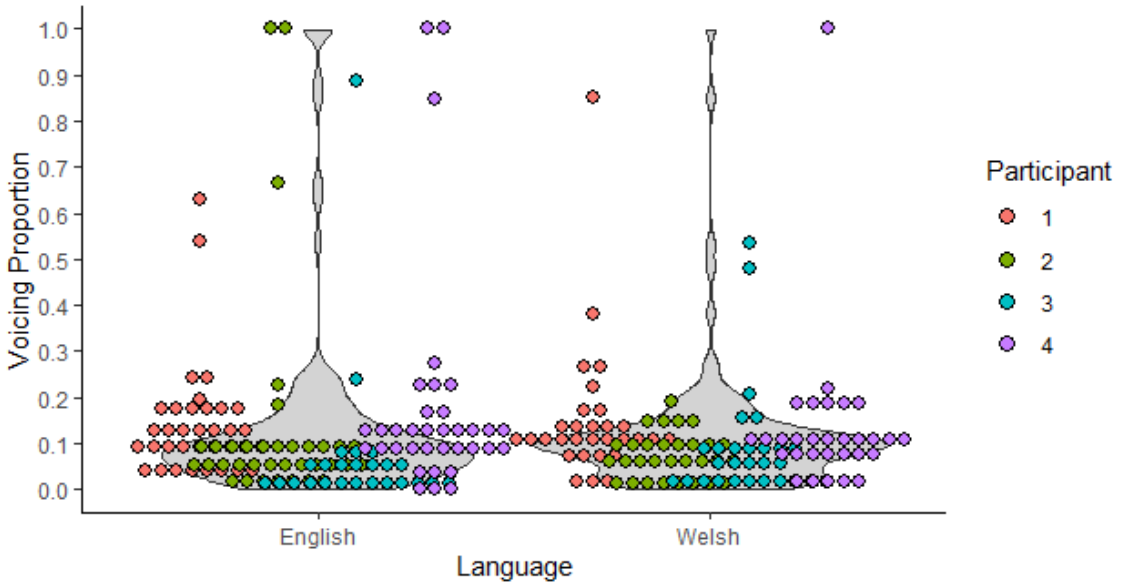

Figure 21: Violin plot showing the distribution of [-voice] fricatives between Welsh and English

8.2.2.2 Research Question Two – Place of Articulation

This section will look at the results of research question two: 'Does place of articulation affect voicing in Welsh and English fricatives?' for [-voice] fricatives, and address the hypothesis that voicing is more likely to occur anterior articulations than interior articulations.

Looking at the overall model (Table 15) containing both Welsh and English, *voicing proportions* for both dental and alveolar fricatives are not significantly different to labiodental fricatives. The individual language models for Welsh (Table 16) and English (Table 17) both follow the overall model's pattern; both dental and alveolar fricatives do not have significantly different *voicing proportions* to labiodental fricatives. These results do not confirm or go against the hypothesis that alveolar fricatives will produce the least voicing.

Looking at the results descriptively Figure 22 and 23 are violin plots which shows the production of fricatives plotted for place of articulation (labiodental, dental, alveolar) and *voicing proportion*. For Welsh (Figure 22) labiodental and alveolar have a similar distribution of *voicing* proportions although labiodental does produce fricatives with higher *voicing proportions* than alveolar, but this does not create a significant difference between labiodental and alveolar. Labiodental produces fricatives between 0 and 38 *voicing proportion* and alveolar produces fricatives between 0 and 18 *voicing proportion*. The distribution of *voicing proportions* for dental fricatives does have some similarities with labiodental and alveolar fricatives; a large proportion of productions are produced below *voicing proportion* 25, however dental fricatives have a larger range of *voicing proportions* between 0 and 100.

For English (Figure 23) both dental and alveolar fricatives have a similar pattern of distribution to labiodental; they produce all (alveolar) or the majority (labiodental and dental) of fricatives under *voicing proportion* 25. Labiodental produces fricatives between 0 and 63 *voicing proportion* with two fricatives produced above *voicing proportion* 25, dental produces fricatives between 0 and 27 *voicing proportion* with one fricative produced at 63 *voicing proportion*.

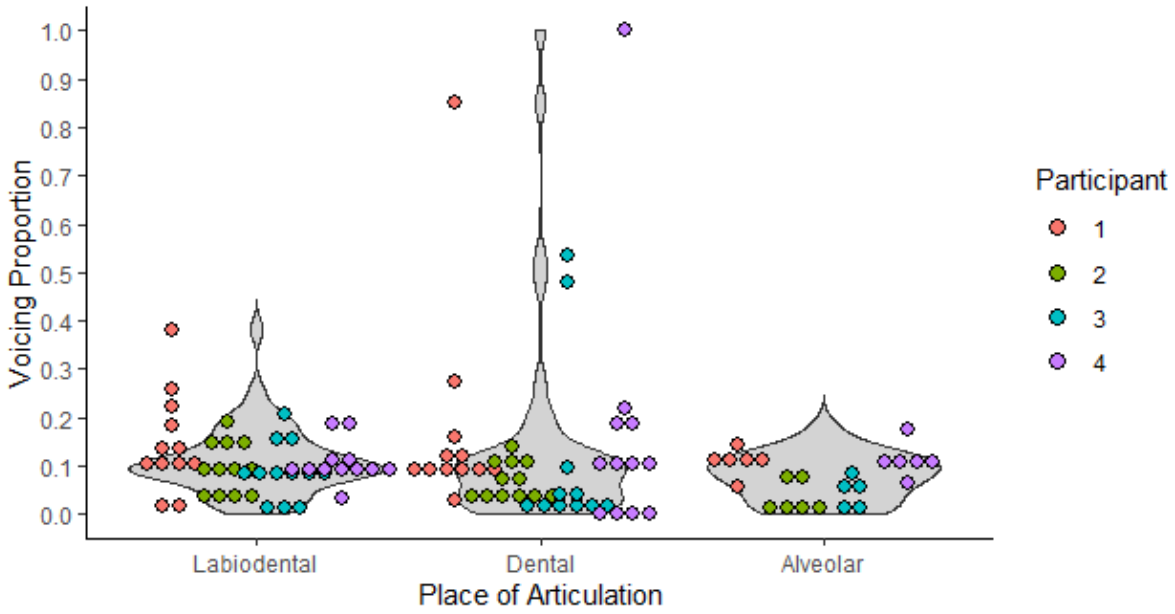

Figure 22: Welsh [-voice] fricatives – place of articulation

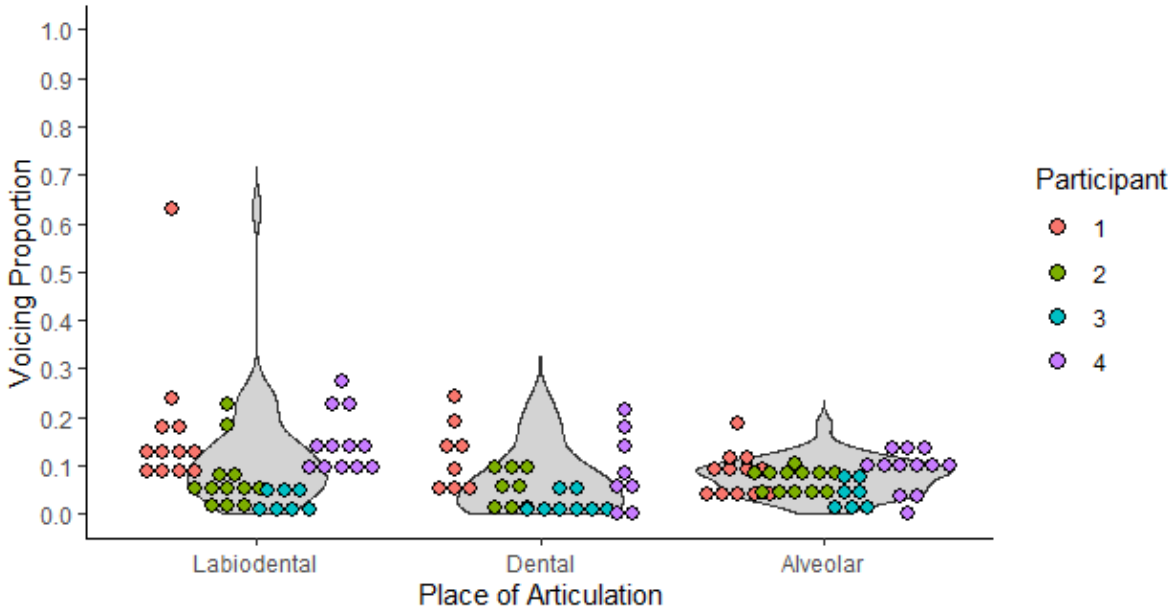

Figure 23: English [-voice] fricatives – place of articulation

8.2.2.3 Research Question 3 - Vowel Height

This section will look at the results of the analysis to address research question three: 'Does vowel height affect voicing in Welsh and English fricatives?' for [-voice] fricatives, and address the hypothesis that lower *voicing proportions* are more likely to occur with high vowels than low vowels.

Looking at the model overall (Table 14) containing both Welsh and English, low vowels are not significantly different to high vowels in the production of voicing. The individual language models for Welsh (Table 15) and English (Table 16) also follow this pattern. The results from both languages do not confirm the hypothesis that high vowels will have lower *voicing proportions* compared to low vowels.

Looking at the results descriptively Figure 24 and 25 are violin plots which shows the production of fricatives plotted for vowel height (high and low) and *voicing proportion*. For Welsh [-voice] fricatives high and low vowels have different distributions of *voicing proportions*; high vowels range between 2 and 26 *voicing proportion* and low vowels range between 0 and 100 *voicing proportion*. Despite low vowels having a large distribution the majority of productions are under *voicing proportion* 25, which is similar to the distribution of high vowels, and there are six fricatives that have a *voicing proportion* above 25. Although low vowels have some fricatives with high *voicing proportions*, there is no significant difference between high and low vowels. For English [-voice] fricatives high and low vowels have similar distributions of *voicing proportions*; high vowels range between 0 and 24 *voicing proportion* and low vowels range between 0 and 63 *voicing proportion*. Low vowels have the majority of fricatives produced under 27 *voicing proportion*, similar to high vowels, with one fricative production above this at 63.

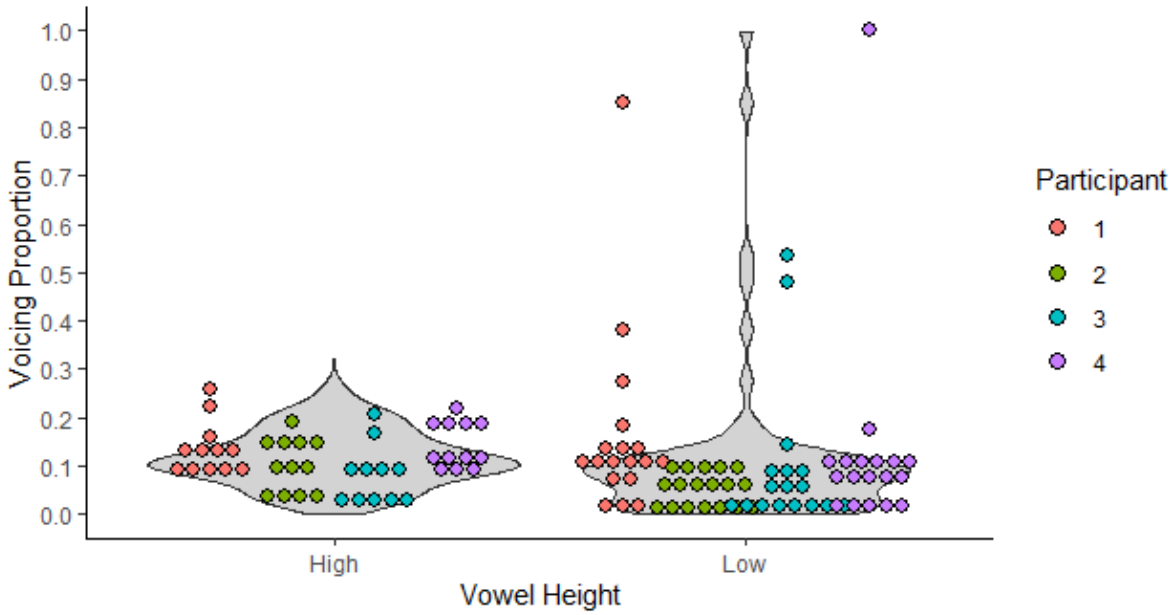

Figure 24: Welsh [-voice] fricatives – vowel height

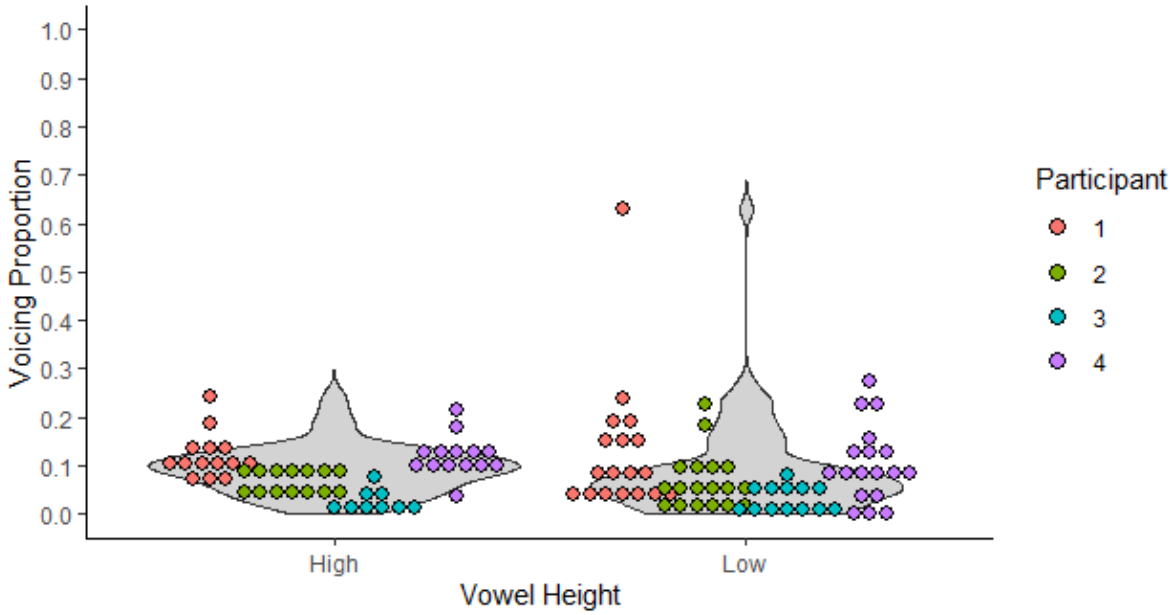

Figure 25: English [-voice] fricatives – vowel height

8.2.2.4 Research Question Four - Duration

This section will look at the results of research question 4: 'Does fricative duration influence voicing proportion?' for [-voice] fricatives, and address the hypothesis that voicing is more likely to occur in relatively short fricative productions compared to long productions.

Looking at the overall model (Table 14) containing both Welsh and English, duration is a significant variable in voicing [-voice] fricatives. The individual language model for Welsh (Table 15) follows the overall model's pattern and finds that duration is a significant variable in voicing. The English language model does not follow this pattern; duration is not significant variable in voicing.

Look at the results descriptively Figure 26 and 27 are scatter charts which shows the production of fricatives plotted for duration (ms) and *voicing proportion*. For Welsh [-voice] fricatives the durations ranged between 6 and 248 milliseconds and the *voicing proportions* ranged between 0 and 100. The pattern of *voicing proportions* is that fricatives with shorter durations are produced with higher *voicing proportions* than fricatives with longer durations. For English [-voice] fricatives the durations ranged between 63 and 214 milliseconds and the *voicing proportions* ranged between 0 and 63. There is no discernible pattern between *voicing proportion* and duration with all but one fricative produced under *voicing proportion* 30.

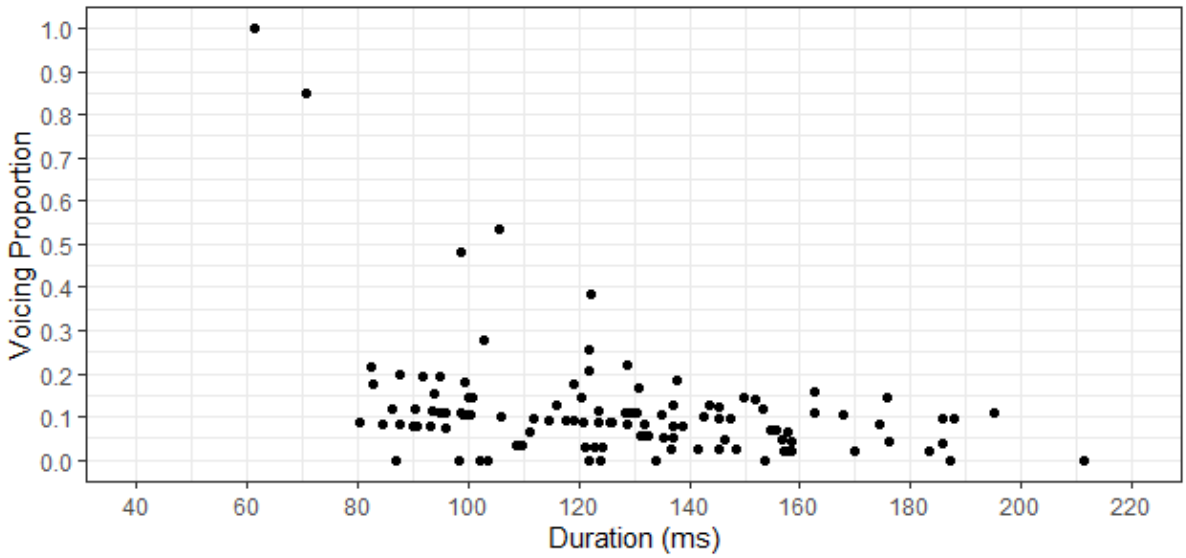

Figure 26: Welsh [-voice] fricatives - duration

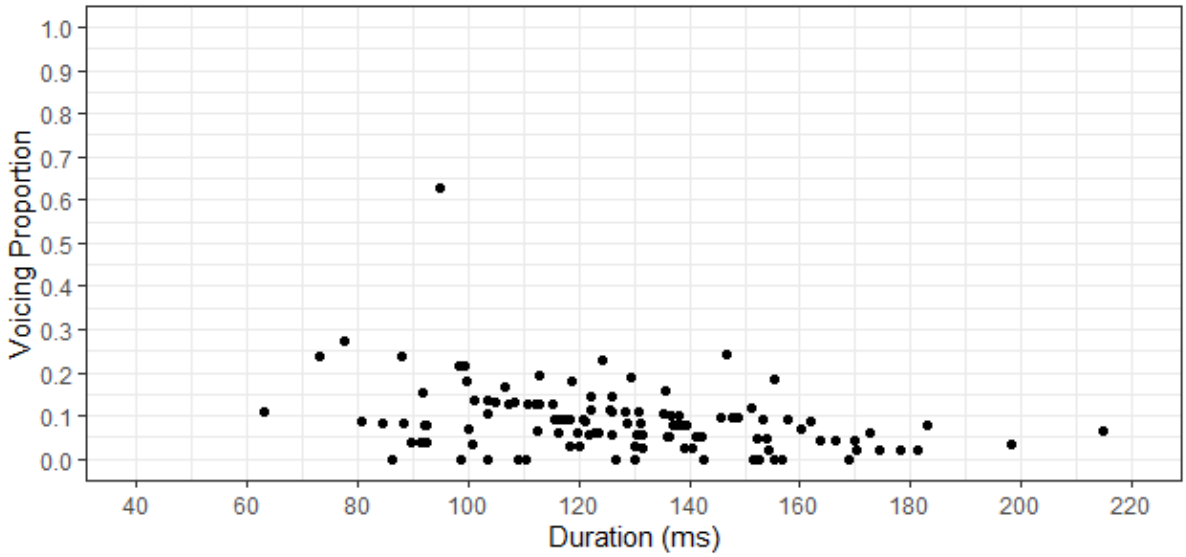

Figure 27: English [-voice] fricatives – duration

8.2.2.5 Individual Differences

This section will present the results of the individual participants' distribution of voicing productions looking at the differences between each speaker and across each language. The below figures are violin plots of each participants' fricative productions in English and Welsh.

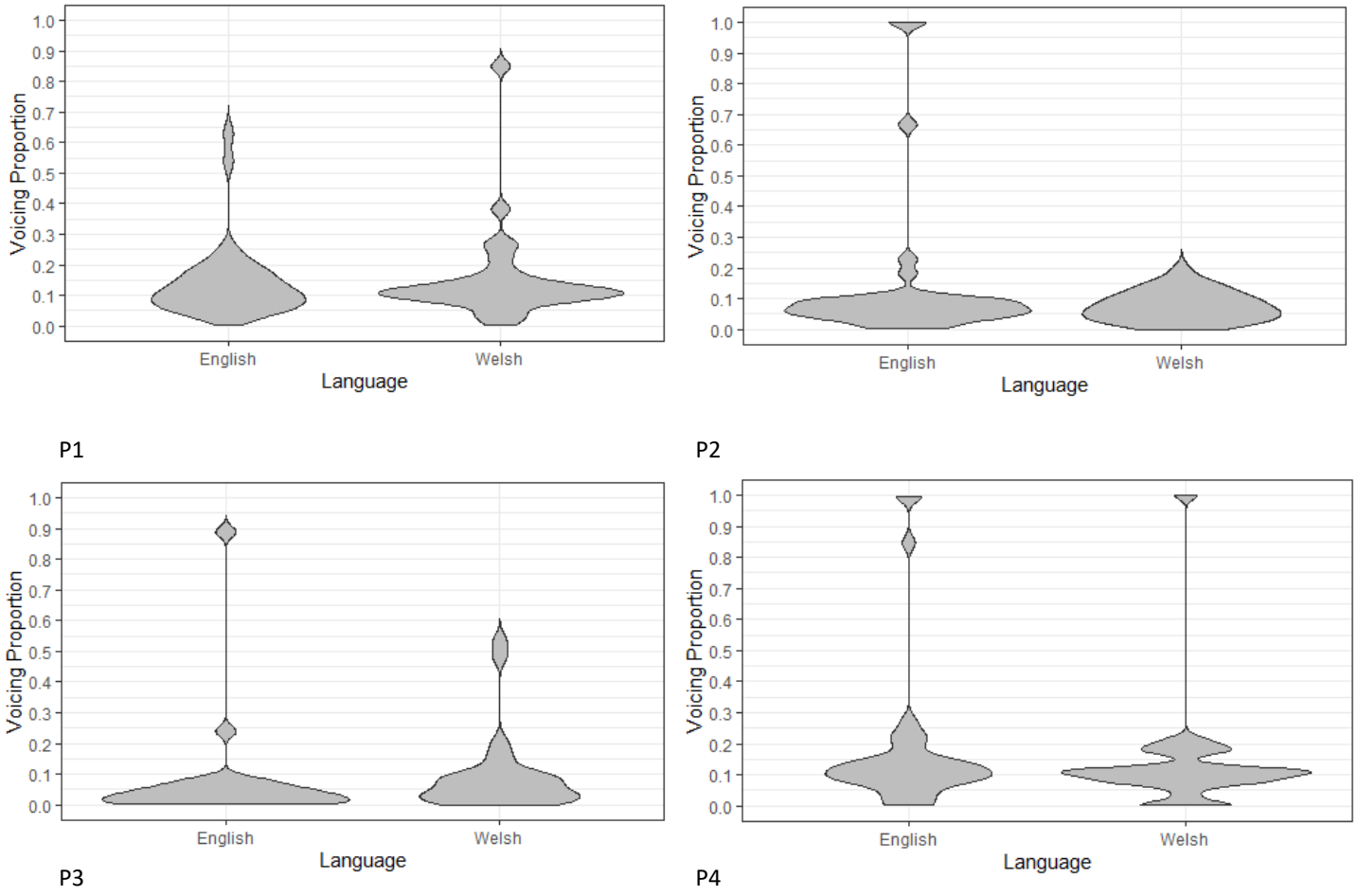

Figure 28: Graphs showing the distribution of voicing in [-voice] Welsh and English fricatives by participants

The distribution of *voicing proportions* in English and Welsh [-voice] fricatives do not show large differences between participants. Participants produce similar ranges of *voicing proportions*

across English and Welsh which demonstrates that participants are consistent in their productions across languages for [-voice] fricatives. Looking at the patterns between the participants, P1 and P4 have similar distributions for Welsh and English, and P2 and P3 also have similar distributions.

9. Discussion

The overall aim of this study was to investigate the implementation of voicing in inter-vocalic fricatives in Welsh-English bilinguals and three independent variables that potentially affect devoicing: place of articulation, vowel height, and fricative duration. First the results of the [+voice] fricatives will be discussed followed by the results of the [-voice] fricatives with some comparison with the [+voice] results.

9.1 [+voice] Fricatives

9.1.1 Research Question 1: Voiced intervocalic fricatives in Welsh and English

The first finding of this study is that there is no statistically significant difference in the production of voicing between Welsh and English [+voice] fricatives. These findings disprove the hypothesis that a difference would be found and that Welsh fricatives would have more inconsistent voicing productions than English. This hypothesis stemmed from studies that had different results on whether phonetic voicing in Welsh was a conclusive factor in distinguishing between [+voice] and [-voice] obstruents. The results showed that the *voicing proportions* of [+voice] fricatives are similar in Welsh and English and that both languages are inconsistent at producing fully voiced fricatives. Although both languages are inconsistent, Welsh does have a

higher proportion of fricatives that are produced with full voicing which demonstrate that participants are more consistent at producing voicing in Welsh than English.

In the descriptive analysis Welsh and English showed differences in the distribution and realisation of voicing. The fricatives were coded into “voiced”, “partial”, and “voiceless” categories based on the proportion of voicing produced within the fricative. The descriptive analysis and numerical analysis display a difference in patterns; the numerical analysis found no statistically difference between Welsh and English but the descriptive analysis did show some differences. The difference in patterns may stem from how the fricatives were coded categorically, and further research is needed to explore this difference in patterns found.

Looking at the descriptive results Welsh, unexpectedly, had more fully voiced tokens than English demonstrating that participants produced voicing more consistently in Welsh than English; 69% of fricatives in Welsh were produced with full voicing and 30% of fricatives with partial voicing, whereas fricatives in English had a 52%/47% split of fully voiced fricatives and partially voiced fricatives. Both Welsh and English had few instances of “voiceless” fricatives at 1% for Welsh and English.

The high proportion of fully voiced Welsh fricatives are unexpected due to (i) previous studies that find voicing in Welsh is not obligatory in what may be considered a [+voice] fricative (Ball & Müller, 1992) and (ii) voicing in Welsh is generally found to be inconclusive at distinguishing between [+voice] and [-voice] sounds due to significant overlaps in voicing productions (Baran, 2020a) which indicates that Welsh [+voice] fricatives do not produce full voicing consistently. For the English fricatives, the results pattern with previous studies such as Davidson (2016) who also finds that English word medial fricatives are produced with full voicing for about half the tokens and 45% with partial voicing. These results are unexpected because the surrounding

environment should facilitate voicing due to the edge vibrations from the post and preceding vowels. Looking into the *voicing shape*, as discussed below, English fricatives do capitalise on the intervocalic environment but do not sustain voicing in the middle of the fricative duration and therefore there is a high number of "partial" fricatives.

Devoicing in both Welsh and English [+voice] fricatives was observed to occur as a result of voicing not being maintained throughout the duration of the entire fricative. However, how the voicing was produced and the *voicing shape* differed between Welsh and English, which suggests a difference at the suprasegmental level. The *voicing shape* of "partial" fricatives in Welsh was predominantly "bleed" which occurred for 57% of the "partial" fricatives, meaning that the fricative started with a higher *voicing proportion* and gradually lowered throughout the duration of the fricative. The *voicing shape* of "partial" fricatives in English was predominantly "trough" which occurred for 44% of the "partial" fricatives, meaning the fricative started with a high *voicing proportion*, lowered or stopped in the middle of the fricative, and then increased again towards the end of the fricative. The predominant *voicing shapes* in English and Welsh are not surprising because they both take advantage of the phonation from the surrounding vowels. For both Welsh and English "hump" is the least produced *voicing shape* which is similarly not surprising since this pattern would not be taking advantage of the intervocalic environment and the surrounding voiced vowels.

The results of the English fricatives match the findings of Davidson's (2016, 2018) studies which looked at voicing in American English fricatives. In Davidson's (2016) study the *voicing shape* of word medial fricatives was predominantly "trough" with approximately 65% of "partial" fricatives displaying this shape and in her 2018 study word medial fricatives were again predominantly produced with the "trough" shape which occurred for 54% of fricatives. One

main difference to note is that the *voicing shape* "negative VOT" is rarely present in both Davidson's studies but is produced with some frequency by participants in this study. In both Welsh and English, "negative VOT" is the third most common *voicing shape* produced for 15% of English fricatives and 21% of Welsh fricatives. The higher proportion of the "negative VOT" shape may stem from the small number of "partial" tokens analysed and further analysis with a larger dataset would be needed to investigate whether the higher proportions are in fact due to the size of the dataset. Another possible reason for higher instances of "negative VOT" compared to Davidson's results may stem from influence from Welsh onto English; this hypothesis can be further investigated if the proportion of tokens produced stay the same or increase when the size of the dataset is increased.

However, as previously mentioned, there are not enough tokens for the difference between Welsh and Welsh English to be conclusive and the results should be treated with caution. Further study into *voicing shape* would be needed to confirm whether there would be a significant difference between Welsh and English. From the results above, I hypothesis that devoicing overall will stem from voicing not being maintained, but for the *voicing shape* itself it cannot be hypothesised which category Welsh and English would fall into due both languages producing all shapes at various percentages and the small amount of data analysed.

From these results, it cannot be claimed for either Welsh or English that devoicing is the norm and for Welsh it also cannot be claimed that full voicing is the norm due to a third of the fricatives being partially voiced. These results can also be explained by the intervocalic phonological context of the fricatives, which has been found to be the least devoiced context for fricatives and stops after word medial and word final. While the data overall point to the conclusion that there are no significant differences in Welsh and English voicing productions, it

is interesting to see subtle differences in the descriptive data which warrant further investigation.

9.1.2 Research Question 2: The role of place of articulation

The second finding of this study is that there was a significant difference in *voicing proportions* between labiodental and alveolar [+voice] fricatives in English, but no significant difference in *voicing proportions* between labiodental and dental [-voice] fricatives in Welsh. The [+voice] English alveolar fricatives were devoiced the most, followed by dental fricatives, and lastly labiodental fricatives with the least amount of fricatives devoiced. These results reinforce the findings of previous studies of British and American English that find fricatives with a more posterior articulation are devoiced at a higher rate than anterior fricatives (Haggard, 1978; Verhoeven et al., 2011; Westbury, 1983; Westbury & Keating, 1986). The results are also consistent with the physiological accounts of devoicing, "in which devoicing is assumed to be related to the size of the oral cavity" (Verhoeven et al., 2011). Alveolar fricatives have an overall small oral cavity size between the glottis and place of constriction than the cavity size of labiodental and dental productions; the effect of the smaller vocal tract in alveolar fricatives causes the air pressure between the subglottal and supraglottal to equalize faster which in turn causes the vocal folds to stop vibrating earlier compared to fricatives with a bigger oral cavity size.

Along with the alveolar fricatives having an overall lower mean *voicing proportion* than labiodental and dental fricatives, alveolar fricatives were evenly distributed throughout its range. Although, only P1, P2, and P3 produced *voicing proportions* through the entire range (100 – 0 *voicing proportion*) as the lowest *voicing proportion* P4 produces is 47. While this may

present a potential argument that alveolar fricatives are not always prone to a high amount of devoicing, out of the 10 fricatives that P4 devoices 8 of them where at an alveolar place of articulation. This demonstrates that overall and for each individual participant, taking into account participant's individual range and distribution, that the alveolar fricatives were devoiced at the highest frequency.

In both Welsh and English, labiodental fricatives and dental fricatives have a similar ~~a~~ distribution and range. The production of voicing in labiodental and dental fricatives was also similar, with little difference in participants' productions, across Welsh and English. These results demonstrate that fricative productions in Welsh and English at the most anterior articulations accommodated the production of voicing better than posterior articulations. For English, it also implies that alveolar is possibly the first place of articulation where devoicing becomes frequent and thus a significant factor in devoicing.

Previous research on fricatives has not identified consistent acoustic properties that could be used to distinguish between labiodental and dental fricatives; spectral, temporal, and amplitude properties of fricative noise have not been found to consistently distinguish /f/ from /θ/ and /v/ from /ð/ and therefore dental fricatives have been regarded as 'perceptually weak' (Jongman, Wang, & Kim, 2003). The results of *voicing proportion* pattern with these findings as there was no statistically significant difference of voicing productions between [+voice] labiodental and dental fricatives which demonstrates that voicing is potentially another feature which does not reliably distinguish /v/ from /ð/, however further investigation into voicing productions and perception of dental fricatives in Welsh English and Welsh would be needed.

Another reason which may explain the similarities between labiodental and dental voicing productions is the participants potentially substituting /θ, ð/ with /f, v/, known as th-fronting.

Various varieties and dialects of English, such as Southern Eastern English, Irish English, and West Midlands English, substitute /θ, ð/ with /f, v/ because labiodental and dental fricatives are acoustically similar in perception and the misperception between the sounds caused a sound change (Levon & Fox, 2014). This th-fronting may also be present in Welsh English and Welsh and therefore the *voicing proportions* do not differ as participants are potentially realising the dental fricatives as labiodental, however further investigation into the production and perception of Welsh English and Welsh fricatives would be needed to confirm this hypothesis.

9.1.3 Research Question 3: The role of preceding vowel height

The third finding of this study is that preceding vowel height does not have a significant effect in the production of voicing of [+voice] Welsh and English fricatives. These findings disprove the hypothesis that a difference would be found and that high vowels would influence more devoicing than low vowels. Also, it should be highlighted that the vowel height of the following vowel was not controlled for and the potential effects on devoicing were not looked at specifically in this study.

In Welsh, fricatives were predominantly produced with full voicing and had multiple fricatives (mainly by P1 and P3) that were produced with lower *voicing proportions*; this distribution of fricatives was the same for both high and low vowels. In English, there was a high amount of fricatives produced with full voicing but also had frequent productions at lower *voicing proportions* which are evenly distributed throughout the range. However, there was a small difference in the amount of devoiced tokens participants produced for high and low vowels; P1, P3, and P4 had an even distribution of devoiced fricatives for both Welsh and English, but P2 only frequently devoiced fricatives for high vowels.

The results illustrate that participants overall did not change their productions according to vowel height, disputing previous studies such as Yavas (1997), who investigated of preceding vowel height and devoicing of final stops in English monosyllabic words, and Jaeger (1978), who investigated 24 languages for the effects of vowel height on obstruents, find that high vowels devoice more due to the associated high oral air pressure.

Yavas found that the effect of place of articulation, in that more posterior articulations will devoice more than anterior articulations, was only observed when the preceding vowel was high; the high vowels had an accelerating effect on stops that are predisposed to devoicing (alveolar and velar stops), but low vowels did not affect the amount of voicing produced. Alveolar fricatives in this study were devoiced the most with a significant difference to the voicing of labiodental fricatives but high vowels did not influence a higher amount of devoicing compared to low vowels.

9.1.4 Research Question 4: The role of fricative noise duration

The last finding of this study is that duration has a statistically significant effect on the production of voicing in Welsh and English [+voice] fricatives; fricatives with shorter durations were produced with higher *voicing proportions* than fricatives with relatively longer durations. These findings demonstrate that voicing is better accommodated in shorter productions due to the articulatory effort of maintaining vocal fold vibration for a sustained period.

9.2 [-voice] Fricatives

9.2.1 Research Question 1: Voiced intervocalic fricatives in Welsh and English

The first finding of this study is that there is no statistically significant difference in the production of voicing between Welsh and English [-voice] fricatives. The results showed that the *voicing proportions* of [-voice] fricatives are similar in Welsh and English and that both languages are consistent at producing voiceless fricatives. Although both languages are consistent and do not differ statistically, the descriptive results show that English has a higher proportion of fricatives that are produced with no voicing.

In the descriptive analysis Welsh and English showed differences in the distribution and realisation of voicing. The difference in patterns between the numerical and descriptive results may arise from the method of categorical coding. Looking at the descriptive results Welsh had more "partial" tokens than English demonstrating that participants produced more fricatives containing voicing in Welsh than English; Welsh produced 42% of fricatives with partial voicing and 57% of fricatives as "voiceless", whereas English produced 30% of fricatives with partial voicing and 70% of fricatives as "voiceless". Comparing [+voice] and [-voice] fricatives, Welsh and English seemingly follow the same pattern with Welsh producing more tokens with partial voicing.

Voicing in both Welsh and English [-voice] fricatives is observed to occur as a result of edge vibrations due to the intervocalic environment. Similar to the [+voice] fricatives, the *voicing shape* was different between Welsh and English, which again suggests a difference at the suprasegmental level. The *voicing shape* of "partial" fricatives in Welsh was predominantly "trough" and in English it was predominantly "bleed", demonstrating the presence of voicing is caused by the continuation and anticipation of the vowel.

From these results, it cannot be claimed for either Welsh or English that partial voicing is the norm as the proportion of "partial" fricatives is not significant. The mean *voicing proportion* for Welsh is 11% and for English is 9%, which shows that when voicing is produced overall it is still relatively low. As previously mentioned, there are not enough "partial" tokens for the differences between Welsh and English for the descriptive results to be conclusive.

It also should be noted that the manual placement of boundaries could be a limitation to both the numerical and descriptive results of [+voice] and [-voice] fricatives. As some fricatives may have been included or excluded based on individual decisions of boundary placement for the onset and offset of friction and consequently any replications of this study may produce slightly different results.

9.2.2 Research Question 2: The role of place of articulation

The second finding of this study is that place of articulation has no significant effect on the voicing of [-voice] Welsh and English fricatives. All three places of articulation have similar distributions and ranges across Welsh and English. This not only shows that pace of articulation does not influence [-voice] fricatives to produce higher *voicing proportions* for fricatives at anterior articulations, but also there is no difference in voicing productions between Welsh and English.

In both Welsh and English labiodental fricatives, dental fricatives, and alveolar fricatives have a similar distribution and range. The production of voicing across the three places of articulation was also similar with little difference in participants' productions across Welsh and English. One difference to note is P2's productions of Welsh is consistently produced under 20 for *voicing*

proportion and does not have any outliers above this unlike P1, P3, and P4 who all have outliers in their productions of Welsh.

9.2.3 Research Question 3: The role of preceding vowel height

The third finding of this study is that preceding vowel height does not have a significant effect in the production of voicing of [-voice] Welsh and English fricatives. These findings disprove the hypothesis that a difference would be found and that low vowels would facilitate more partial voicing in [-voice] fricatives. In Welsh, fricatives produced after high vowels were predominantly produced fully voiceless along with frequent productions of partially voiced fricatives up to *voicing proportion* 26. For high vowels in Welsh, fricative productions follow a similar pattern to high vowels, but have 6 productions that are produced at higher *voicing proportions*. In English, fricatives were predominantly produced voiceless along with frequent productions of partially voiced fricatives up to *voicing proportion* 27; this distribution of fricatives was the same for both high and low vowels with one difference being a fricative produced with *voicing proportion* 100 for low vowels. Similar to [+voice] fricatives, these results illustrate that participants overall did not change their voicing productions according to preceding vowel height.

9.2.4 Research Question 4

The last finding of this study is that duration overall has a statistically significant effect on the production of voicing in [-voice] fricatives. However, when looking at the languages individually, duration was a significant factor for Welsh but not a significant factor for English. In English, fricatives maintain the same range of *voicing proportions* throughout the different durations. In Welsh, fricatives also seemingly follow the same overall pattern as English, however six

fricatives with shorter durations had *voicing proportions* higher than *voicing proportion* 25, while all other fricatives were produced under *voicing proportion* 25 regardless of duration.

10. Conclusion

This study adds to previous research which investigates devoicing and further adds to the limited research on the voicing of fricatives in Welsh. It has examined the voicing productions of Welsh-English bilingual speakers from North Wales in order to investigate the differences in the production of voicing between Welsh and Welsh English.

The results showed no statistically significant difference in the production of voicing between Welsh and English [+/-voice] fricatives, which disproved the hypothesis that Welsh fricatives would have more inconsistent voicing productions than English. Descriptive results did however show differences in the *voicing shape* and *categorical coding* of fricatives, which showed that participants were more consistent at producing voicing in Welsh than in English.

From the subtle differences present in the descriptive data, there is an abundance to be done in investigating the differences in the production of voicing of fricatives in Welsh-English bilinguals.

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Appendix A: Participant Information Sheet

Information Sheet

You are being invited to take part in a research project. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. Ask if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Project Title:

Voicing of Intervocalic Fricatives in Welsh and Welsh English.

What is the purpose of the project?

The aim of the project is to understand sound classification in Welsh/English bilingual speech production.

Why have I been chosen?

This project looks at Welsh-English bilinguals and you have been chosen as you have identified to fit the participant criteria. Which is as follows: 1. Aged between 18-29, 2. Have native or near native English, 3. Have native or near native Welsh 4. Grew up in Wales.

Do I have to take part?

Participation in this study is voluntary. If you do decide to take part, you will be given this information sheet to keep (and be asked to sign a consent form). You can withdraw at any time and you do not have to give a reason for withdrawing from the study.

What do I have to do?

You will be asked to attend the recording studio in the Michael Sadler building at The University of Leeds. During this session, your speech will be recorded while reading a number of sentences in both Welsh and English.

What are the possible benefits of taking part?

Whilst there are no immediate benefits for those participating in the study, it is hoped that this work will contribute to the knowledge and exposure of the Welsh language in academia.

Use and storage of research data:

Your original recordings will be saved using an assigned pseudonym (e.g. P1, P2) in an encrypted file, and only accessed by the researcher and supervisors of the project. The data which holds sensitive information, including your name, age, area where you grew up, will be scanned and stored in an encrypted file and the hard copies destroyed. The results of the recordings will be presented in the researcher's thesis. This will be accessed and read by the supervisors Leendert Plug and Gisela Tomé Lourido, a university linguistics staff member for internal examination, and an external examiner. If the researcher decides to publish the results in a public journal or entity, the results of the original data will be made openly available in the University of Leeds repository. Please note your voice recordings will not be made publicly available.

What will happen to my personal information?

Identifiable personal information that will be included in the written results are your age and the county where you grew up (if relevant to the results). For example, you will be identified in the results as – Participant 1, 27, Flintshire. Your name and town/city where you grew up will not be written or published anywhere. The forms that hold this information will be electronically stored in an encrypted file and the hard copy destroyed.

What will happen to the results of the research project?

All the information/data that we collect about you during the course of the research will be kept strictly confidential and will stored separately from the research data in an encrypted file. We will take steps wherever possible to anonymise the research data so that you will not be identified in any reports or publications.

Data collected for the purpose of this study may be re-used for additional or subsequent research and the results may be deposited in the University repository.

Contact for further information:

For any additional questions or information please contact Eskarina Yeates at mley@leeds.ac.uk.

If you wish to contact the supervisors of this student project, please see details below:

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Participant signature …….. Date……..

Researcher signature …….. Date…….

Appendix B: Participant Consent Form

Consent to take part in the research: Devoicing of voiced/lenis Fricatives in Welsh and Welsh English Bilinguals

	Add your initials next to the statement if you agree
I confirm that I have read and understood the information sheet explaining the above research project and I have had the opportunity to ask questions about the project.	
I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason and without there being any negative consequences. If you withdraw from the study your original recordings will be permanently deleted and results removed from the study. Results can be removed up until February 2020, due to thesis submission. However, after submission (October 2020) your raw data can be permanently deleted.	
I give permission for members of the research team to have access to my anonymised recordings. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the reports that results from the research. I understand that my original recordings will be kept strictly confidential.	
I agree for the data* collected to be stored and used in relevant future research in an anonymised form.	
I understand that data* may be made openly accessible (stored in a repository) when submitting work to an academic journal, if the journal requests open access to the data.	
I understand that other genuine researchers will have access to this data only if they agree to preserve the confidentiality of the information as requested in this form.	
I understand that relevant sections of the data collected during the study may be looked at by auditors from the University of Leeds where it is relevant to my taking part in this research. I give permission for these individuals to have access to my records.	
I agree to take part in the above research project and will inform the lead researcher should my contact details change during the project and, if necessary, afterwards	

Name of participant	
Participants signature	
Date	
Name of lead researcher	
Signature	
Date	

Appendix C: Participant Language Background Questionnaire

Language Background Questionnaire

General information

1. Name:

2. Sex:

Female ☐

Male ☐

3. Age:

4. Place of birth:

5. Mother's place of birth:

i. Where did your mother grow up? Please also list any places where she lived for longer than 1 year.

6. Father's place of birth:

i. Where did your father grow up? Please also list any places where she lived for longer than 1 year.

7. Place of residence during the academic year (city/town):

8. Place of residence during the rest of the year (city/town):

9. Have you lived somewhere else?

Yes ☐

No ☐ (go to question 11)

10. Write down the place and dates

Place	To	From

11. Use this space if you would like to make a comment

Language Experience

12. How old were you when you learnt Welsh? How did you learn it?

13. How old were you when you learnt English? How did you learn it?

14. Select the option that best describes your linguistic background

a. The language I use most is Welsh ☐

b. The language I use most is English ☐

c. I use both languages equally ☐

15. If you ticked c:

i. Have you always spoken both languages equally?

Yes, I have ☐

No, I use to speak Welsh more ☐

No, I use to speak English more ☐

16. Use this space if you'd like to make a comment

17. Language in education

	English	More English than Welsh	Both	More Welsh than English	Welsh
Primary School					
Secondary School					
University					

18. Which language do(es) _____ speak the most?

	English	More English than Welsh	Both	More Welsh than English	Welsh
Your mother					
Your father					
Your sibling(s)					

19. Which language do(es) _____ speak to you?

	English	More English than Welsh	Both	More Welsh than English	Welsh
Your mother					
Your father					
Your sibling(s)					

20. Do you speak other languages?

Yes ☐

No (go to question 22) ☐

21. Indicate which languages you speak, the age you started learning them, and your competence level

Language	Age of acquisition	Competence

22. Do you have any hearing impairment?

Yes ☐ Which one?

No ☐

23. Do you have any speech or language disorder?

Yes ☐ Which one?

No ☐

Language Use

24. Which language do you speak…

	English	More English than Welsh	Both	More Welsh than English	Welsh	N/A
To your mother?						
To your father?						
To your siblings?						
To your partner?						
To your maternal grandparents?						
To your paternal grandparents?						
To your closest friends?						
To your classmates?						
To your lecturers?						
To your doctors?						
To strangers?						
When shopping?						
When flirting?						
At work?						

25. In which language…

	English	More English than Welsh	Both	More Welsh than English	Welsh	N/A
Do you dream?						
Do you think?						
Do you count?						
Do you swear?						
Do you tell jokes?						
Do you take notes?						
Do you use in social networks (Facebook, Twitter etc)?						
Do you write formal letters (bureaucracy)						

26. Use this space if you would like to make a comment

<u>Self-Identity and Attitude</u>

27.

How well do you speak English? 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐

How well do you speak Welsh? 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐

28.

How well do you understand English? 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐

How well do you understand Welsh? 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐

29.

How well do you read English? 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐

How well do you read Welsh? 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐

30.

How well do you write in English? 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐

How well do you write in Welsh? 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐

31.

I feel like myself when I speak English 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐

I feel like myself when I speak Welsh 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐

32.

I identify with an English-speaking culture 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐

I identify with a Welsh-speaking culture 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐

33.

It is important to me to use (or eventually use) English like a native speaker

0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐

It is important to me to use (or eventually use) Welsh like a native speaker

0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐

<u>Other</u>

Please use this space to write about any language use you think is relevant but has not been covered through this questionnaire.

Appendix D: Sentence List

Set 1

1. The cassette is classic to my mum
   Mae'r caset yn glasurol i'm mam
   /maɪə ˈkaˌsɛt ən glaˈsəɹɔl
2. The effect of the mites is bad
   Mae effaith yn gwiddon yn ddrwg
3. The young boys are civil in court
   Mae'r bechgyn ifanc yn sivil yn y llys
4. The elephant and dormouse are friends
   Mae'r eliffant a'r bathor yn ffrindiau
5. I promise to be embarrassing tomorrow
   Rwy'n addo bod yn chwithig yfory
6. The apple is suitable to eat and drink
   Mae'r afal yn addas i'w fwyta a yfed
7. The beaver likes the coin in his house
   Mae'r afanc yn hoffi'r bathyn yn ei ty
8. The elephant is interesting and happy
   Mae'r eliffant yn diddorol ac yn hapus
9. The horse is embarrassing and sad
   Mae'r ceffyl yn chwithig ac yn drist

Set 2

1. The elephant is embarrassing and sad
   Mae'r eliffant yn chwithig ac yn drist
2. The beaver promises to eat and drink
   Mae'r afanc yn addo bwyta a yfed
3. The apple is a classic fruit to eat
   Mae'r afal yn ffrwyth clasurol i'w fwyta
4. The effect of sunburn is embarrassing and painful
   Mae effaith llosg haul yn chwithig ac yn boenus
5. The elephant is civil and kind
   Mae'r eliffant yn sivil a charedig
6. The cassette is interesting and old
   Mae'r caset yn diddorol ac yn hen
7. The mites are on the horse at night
   Mae'r gwiddon ar y ceffyl gyda'r nos
8. The coin is suitable to spend
   Mae'r bathyn yn addas i'w gwario
9. The dormouse is young and small
   Mae'r bathor yn ifanc a bach

Set 3

1. The young boy is embarrassing and funny
   Mae'r bachgen ifanc yn chwithig ac yn ddoniol
2. I promise to make you a cassette
   Dwi'n addo gwneud caset i chi
3. The elephant is sivil to people
   Mae'r eliffant yn sivil i bobl
4. The beaver is embarrassing and small
   Mae'r afanc yn chwithig ac yn fach
5. The coin and apple are small
   Mae'r bathyn a'r afal yn fach
6. The classic shirt is suitable to wear
   Mae'r crys clasurol yn addas i'w wisgo
7. The effect of lasers is interesting and cool
   Mae effaith laserau yn diddorol ac yn cwl
8. The elephant has mites and flies
   Mae gan yr eliffant widdon a phryfed
9. The horse and dormouse are small
   Mae'r ceffyl a'r bathor yn fach

Set 1

1. The lethal injection will be a hazard for children
2. The leather boots will never get dirty
3. The floor will be seething with feathers tomorrow
4. The method will need ethic approval
5. The russet sink will be decent condition
6. The recent asset will make profit
7. The council will refurb the traffic lights tonight
8. The baby beaver will be teething very soon
9. The freezing weather will give you breathing problems
10. The breezy weather will give you a fever tomorrow
11. The graphic design will dazzle the audience
12. The clever man will get a refund at the shop

Set 2

1. Tom's asset will be seething with money
2. The russet dress will dazzle the guests
3. The teething will make breathing harder
4. The student will need decent ethic documents

5. The freezing chamber will be a hazard to people
6. The leather bag will never sell hundreds
7. The clever traffic system will help
8. The beaver will get a fever Saturday
9. The builder will refurb the breezy bedroom
10. The student will get a refund for the feather jacket
11. The recent method will be approved
12. The graphic artist will design a leather handbag

Set 3

1. The doctor will never get a fever at work
2. The beaver will like the breezy weather
3. The recent update will have teething problems
4. The feather will cause breathing problems
5. The leather jacket will be russet in colour
6. The refund will have ethic complications
7. The refurb will dazzle the tenants
8. The traffic collision will be a hazard to cars
9. The new method will be clever and inventive
10. The freezing weather will be lethal to babies
11. The new asset will be decent in profit
12. The event will be seething with graphic designers