PRE-ASPIRATION IN WELSH ENGLISH:

A CASE STUDY OF ABERYSTWYTH

A THESIS

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<td>br</td>
<td>breathiness</td>
</tr>
<tr>
<td>CRaper</td>
<td>aperiodic creak</td>
</tr>
<tr>
<td>CRaperFIN</td>
<td>aperiodic creak occurring at the end of a vowel (final)</td>
</tr>
<tr>
<td>CRaperINI</td>
<td>aperiodic creak occurring at the beginning of a vowel (initial)</td>
</tr>
<tr>
<td>CRaperMED</td>
<td>aperiodic creak occurring within a vowel (medial)</td>
</tr>
<tr>
<td>CRaperWH</td>
<td>aperiodic creak occurring throughout a vowel (whole)</td>
</tr>
<tr>
<td>CRper</td>
<td>periodic creak</td>
</tr>
<tr>
<td>CRperFIN</td>
<td>periodic creak occurring at the end of a vowel</td>
</tr>
<tr>
<td>CRperINI</td>
<td>periodic creak occurring at the beginning of a vowel</td>
</tr>
<tr>
<td>CRperMED</td>
<td>periodic creak occurring within a vowel</td>
</tr>
<tr>
<td>CRperWH</td>
<td>periodic creak occurring throughout a vowel</td>
</tr>
<tr>
<td>f₀</td>
<td>fundamental frequency</td>
</tr>
<tr>
<td>GF</td>
<td>glottal friction</td>
</tr>
<tr>
<td>GS</td>
<td>glottal stop</td>
</tr>
<tr>
<td>GSini</td>
<td>glottal stop occurring at the beginning of a vowel</td>
</tr>
<tr>
<td>GSfin</td>
<td>glottal stop occurring at the end of a vowel</td>
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<tr>
<td>GSwh</td>
<td>vowel realised as a glottal stop</td>
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<td>post</td>
<td>post-aspiration</td>
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<tr>
<td>pre</td>
<td>pre-aspiration</td>
</tr>
<tr>
<td>unpost</td>
<td>unaspirated release</td>
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<td>voice</td>
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### Abbreviations of oral aspects

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<td>affrication</td>
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<tr>
<td>clo</td>
<td>voiceless closure</td>
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<td>rel</td>
<td>release</td>
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<td>sp</td>
<td>spirantisation</td>
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### Abbreviations of journals

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<tr>
<td>ICPhs</td>
<td><em>International Congress of Phonetic Sciences</em></td>
</tr>
<tr>
<td>JASA</td>
<td><em>Journal of the Acoustical Society of America</em></td>
</tr>
<tr>
<td>JIPA</td>
<td><em>Journal of the International Phonetic Association</em></td>
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Abstract

This thesis examines the phonetic, phonological, and social aspects of pre-aspiration in English spoken in Aberystwyth, mid Wales. Pre-aspiration refers to a period of voiceless (primarily) glottal friction occurring in the sequences of sonorants and phonetically voiceless obstruents (e.g. in *mat [maʰt]*) or *mass [maʰs]*)).

Chapter 1 summarises the objectives of this thesis and where the thesis is positioned with respect to our current knowledge of the phenomenon and the relevant theoretical issues. Chapter 2 introduces the data used to address these objectives.

Pre-aspiration is usually considered as consisting of a voiced glottal component, or breathiness, and a voiceless glottal component, or voiceless pre-aspiration, and these are treated as a single unit in a number of analyses (Helgason 2003; Helgason & Ringen 2008; Karlsson & Svantesson 2011; Morris 2010; Ringen & van Dommelen 2013; Stevens & Hajek 2004b, 2004c; Stevens 2010, 2011). Chapter 3 shows that this is not adequate because distinguishing the two enables us to discover patterns that would remain obscured otherwise – such as breathiness being a possible precursor to pre-aspiration. This is demonstrated through the segmental and prosodic conditioning of pre-aspiration and breathiness.

Chapter 4 shows that although pre-aspiration is not an obligatory feature of Aberystwyth English (in the sense that it would occur in 100% of time where it can), it nevertheless forms two clear categories sensitive to phonological rather than phonetic vowel height. However, phonological vowel height on its own cannot explain these two categories and interacts with a number of other conditioning factors.

Whilst Chapter 3 investigates the relationship between pre-aspiration and breathiness, Chapter 5 looks into that of pre-aspiration and glottalisation and demonstrates that the two can occur in the same environment, which enlightens the debates related to the historical connections between pre-aspiration and glottalisation in particular (e.g. Kortland 1988). It furthermore reveals that although it is not known why they are co-occurring for some speakers and mutually exclusive or allophonic for others, their relationship is conditioned prosodically and not segmentally.

Chapter 6 illustrates that pre-aspiration is an acoustic correlate of the fortis-lenis contrast in plosives in production at least equally well as breathiness, voicing, release duration, or the duration of the preceding vowel, and better than voiceless closure duration, glottalisation, or f\textsubscript{0} before or after the plosive in question in the word-medial (*cotter [kʰbʰtʰə] ~ codder [kʰbda]*) and the word-final positions (*cot ~ cod*). It is therefore at least as important as the other four correlates.

Chapter 7 finds that pre-aspiration also exhibits social conditioning. Females pre-aspirate more frequently than males, which is often found in pre-aspiration studies, but this difference disappears as the age decreases. Furthermore, the frequency of breathiness, and the duration of pre-aspiration and breathiness are not conditioned by gender. However, all four variables are affected by age. Pre-aspiration thus seems to be undergoing an advancing sound change according to Labov’s Principle II (2001: 292) and breathiness seems to be its precursor.

Chapter 8 summarises the results and outlines questions for further research.
Lay Abstract

This thesis examines pre-aspiration in English spoken in Aberystwyth, mid Wales. Pre-aspiration is a sound very similar to h (as in honey), and it can be found mainly in the sequences of vowels (a, e, i, o, u, etc.) and certain consonants (p, t, k, f, th, s, sh). In English, pre-aspiration would be manifested as a h sound inserted in the following words as indicated: pe\textipa{\textipa{h}}t, pe\textipa{\textipa{h}}t, pt\textipa{\textipa{h}}t, po\textipa{\textipa{h}}t, pu\textipa{\textipa{h}}t, ma\textipa{\textipa{h}}p, ma\textipa{\textipa{h}}tt, ma\textipa{\textipa{h}}ck, o\textipa{\textipa{h}}ff, mo\textipa{\textipa{h}}th, ma\textipa{\textipa{h}}ss, ma\textipa{\textipa{h}}sh. Because the sound is understudied in English, the work focuses on what other sounds condition the presence of the phenomenon and its duration, if it is sensitive to social factors such as age or gender as well, and it suggests some implications for sound changes including pre-aspiration.

Chapter 1 summarises the questions addressed in this thesis and outlines where this work is positioned with respect to our current knowledge of the phenomenon and the relevant theoretical issues. Chapter 2 describes the data used to answer these questions.

Pre-aspiration has been usually seen as consisting of two sounds: a voiced h and a voiceless h, i.e. a h sound during which the vocal folds either vibrate or not. The voiced pronunciation of h is known as breathiness. The two h's are usually treated as a single unit. Chapter 3 shows that this is not adequate because distinguishing the two enables us to discover patterns that would remain obscure otherwise.

Chapter 4 suggests that pre-aspiration is conditioned by a mixture of phonetic effects, i.e. effects that should be explainable articulatorily or aerodynamically, and phonological effects, i.e. effects that are of a cognitive character and cannot be explained by articulatory and aerodynamic factors.

Whilst Chapter 3 investigates the relationship between pre-aspiration and breathiness, Chapter 5 looks into that of pre-aspiration and glottalisation. Glottalisation is frequently found in today’s English in words such as water, in which the t sound is missing and replaced by a glottal catch. At first blush, pre-aspiration and glottalisation would seem incompatible as the former involves spreading of the vocal folds and the latter their closing. This chapter nonetheless demonstrates that pre-aspiration and glottalisation can co-occur in the same sound. This finding enlightens the debates related to the historical connections between pre-aspiration and glottalisation in particular (e.g. Kortland 1988).

Chapter 6 illustrates that pre-aspiration helps to distinguish /p/ from /b/ (lap vs lab), /t/ from /d/ (pat vs pad), and /k/ from /g/ (lack vs lag) as it only occurs in /p/, /t/, and /k/. It is therefore at least as helpful in this regard as other such correlates of the /p/, /t/, /k/ vs /b/, /d/, /g/ distinction that are traditionally thought of as the most important.

Chapter 7 finds that women pre-aspirate more frequently than men, which is in accordance with many pre-aspiration studies, but this difference decreases as the age decreases and results in no gender difference in the youngest speakers. Breathiness is not affected by gender. The frequency and the duration of pre-aspiration and breathiness are nevertheless conditioned by age: on the whole, pre-aspiration and breathiness are becoming more frequent and longer in duration. This chapter also supports the suggestion that breathiness is a precursor to pre-aspiration.

Chapter 8 summarises the results and outlines questions for further research.
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“When I first started out I had little more than a collection of enthusiasms to work with.”


This thesis is dedicated to Aberystwythians.
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This piece of work has taken me on one of the most adventurous journeys of my life. But it would be a lie to say that the enjoyment from the adventure came without climbing a number of steep mountains, slaying a number of beasts (and leaving some behind partially wounded so that I could keep on going), getting lost in mists and fogs, and feeling exhausted and discouraged at many points on the way. And, as is the case in many stories and fairy-tales, the central character would never have reached the final destination without the help of many.

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Chapter 1 - Introduction

The present thesis examines the phonetic, phonological, and social aspects of pre-aspiration in English spoken in Aberystwyth, mid Wales. Pre-aspiration is a period of (primarily) glottal friction found in words such as mass [maðs] or matt [maðt]. More specifically, this work aims to answer the following questions:

1. Is the usual definition of pre-aspiration adequate? (mainly Chapter 3, but also Chapters 4-7)

2. Is pre-aspiration a phonetic or also a phonological linguistic feature of English spoken in Aberystwyth? (Chapters 4 and 6)

3. Are pre-aspiration and glottalisation mutually exclusive in the same environment? (Chapter 5)

4. Is pre-aspiration conditioned socially in English spoken in Aberystwyth? (Chapter 7)

The first question addresses the general assumption that pre-aspiration has two components: a voiced and a voiceless interval of (primarily) glottal friction. Although these two intervals tend to be treated as if they were subject to the same linguistic and social conditioning, the fact is that we do not know if they really are. Chapter 3 and also the other chapters suggest that the two components should be distinguished in phonetic, phonological, and sociolinguistic research.

The second question originates from the claim that pre-aspiration is a very rare phenomenon. However, this seems to be due to its being labelled as extremely rare phonologically because it is very rarely contrastive. This is problematic in at least two respects. Firstly, a linguistic phenomenon does not have to be contrastive in order to be of interest to linguists. Secondly, establishing the contrastiveness of a phenomenon is not a straightforward matter. Chapters 4 and 6 show that pre-aspiration is sensitive to phonological conditioning even if not found in 100% of the cases where it could have occurred and that it is at least as important as a correlate of the “voicing” contrast in plosives (/p/, /t/, /k/ vs /b/, /d/, /g/), further referred to as the
fortis-lenis contrast,\(^1\) as other acoustic correlates, such as release duration, voicing, or vowel duration word-medially (*patter*) and word-finally (*pat*).

The third question comes out of one strand of the historical debates surrounding pre-aspiration, which assume that at a historical stage A, either pre-aspiration or glottalisation is ever present in the same context, and develop into glottalisation or pre-aspiration, respectively, by a historical stage B. This presumption is problematic because it is difficult to see exactly how pre-aspiration can develop from glottalisation and vice versa. This problem disappears in the light of Chapter 5, which demonstrates that pre-aspiration and glottalisation can co-occur in the same environment. However, the chapter also shows that predicting whether the relationship is that of mutual occurrence or exclusivity (complementarity) is problematic. Their relationship is determined prosodically and not segmentally in the plosive context. In the fricative context and also in one speaker in the plosive context, pre-aspiration is nearly obligatory and glottalisation is independent from pre-aspiration, determined segmentally. Further research remains to show to what extent glottalisation is a prosodic and/or a segmental phenomenon.

The fourth question is raised because our understanding of pre-aspiration in Aberystwyth English would not be complete without considering social constraints on the phenomenon. Chapter 7 shows that pre-aspiration is undergoing an advancing sound change, increasing in its frequency with the decreasing of age especially in the male population. Furthermore, it is only the frequency of pre-aspiration which is subject to gender/sex differences, and these disappear in the youngest speakers. No gender differences are found in the duration of pre-aspiration and the same is the case for the duration and the frequency of breathiness. Because of a tendency reported by a number of pre-aspiration studies, namely, that women/females pre-aspirate more frequently and/or with longer durations than men/males, it has been put forward that this pattern is motivated by physiological differences in the two sexes. If pre-aspiration is indeed at least initially conditioned by physiological sex rather than social gender, the physiological differences can be overridden by social pressures, as illustrated by Aberystwyth English. Both aspects of pre-aspiration and

\(^1\) The choice of the terms fortis and lenis is explained at the beginning of Chapter 6, which deals with the acoustic correlates to the fortis-lenis contrast in plosives.
breathiness are sensitive to age, and breathiness is ahead of pre-aspiration, which supports the suggestion that breathiness is a precursor to pre-aspiration.

The four questions are approached here through acoustic analyses of production data, and the following conclusions are reached. Firstly, the generally adopted definition of pre-aspiration is not always appropriate methodologically. Secondly, it is not the case that pre-aspiration and glottalisation are always mutually exclusive in the same environment. Thirdly, pre-aspiration is at least as relevant for the phonetic and phonological description of the plosives in English spoken in Aberystwyth as other linguistic aspects that are usually thought as the most important (such as release duration). Finally, although women/females may oftentimes pre-aspirate more frequently and with longer durations than men/males for physiological reasons, this physiological effect is not strong enough to escape the effects of social pressures, and unless more data from a range of unrelated pre-aspirating languages spoken by populations from different cultures are looked into, it remains a hypothesis that pre-aspiration is conditioned by physiological sex.

Three goals are pursued in what follows in this chapter. Firstly, pre-aspiration is compared to other laryngeal phenomena regarding its cross-linguistic occurrence and the frequency of its being studied (1.1.). Secondly, the four questions this thesis asks are set in the context of the previous research (1.2.-1.5.). Finally, this chapter is concluded with the reasons behind the choice of Welsh English, i.e. English spoken in Wales, and more specifically English spoken in Aberystwyth, for the purposes of this thesis (1.6.).

1.1. Pre-aspiration as an understudied laryngeal phenomenon

In comparison to other laryngeal phenomena, pre-aspiration remains understudied. This section primarily compares the amount of work that has been devoted to pre-aspiration to that focusing on other laryngeal phenomena.

Languages use a whole array of laryngeal phenomena to convey a number of functions. The richness of such phenomena and the abundance of ways these can be used to carry linguistic and social information undoubtedly come from the
complexities of the larynx and its components. Pre-aspiration is one of the most rarely occurring laryngeal phenomena.

A distinction useful for the typology of laryngeal phenomena is based on the domain in which they apply. Laryngeal phenomena can be grouped into two broad types: global and local. The main difference between global and local laryngeal phenomena is that, when they are local, their presence is segmentally contrastive (e.g. post-aspiration in bat [p] vs pat [pʰ]; glottalisation in bat [paʔ] vs bad [pad]), whereas if a speaker has a tendency to signal the end of a conversational turn for example with glottalisation (e.g. Ogden 2004), the function of this glottalisation is not segmentally contrastive and is used to signal a function beyond the level of a segment or subsegment. The distinction can be useful because it reflects that laryngeal phenomena are used for different linguistic functions and that these functions can affect the same phenomenon in the same variety; however, the dimension is scalar rather than binary.

Laryngeal phenomena which can be global involve phonation types (modal phonation, creaky phonation/glottalisation, harsh phonation, breathiness, falsetto, whisper), and intonation (global changes in \( f_0 \)). Pre-aspiration belongs primarily to the realm of local laryngeal phenomena, which include voicing, post-aspiration, pre-aspiration, and tone (local changes in \( f_0 \)). Segmental local laryngeal phenomena also include ejectives and implosives. In addition, as shown by Moisik and others (2013, and references therein), the epilarynx, which forms an important component of the larynx, is not responsible just for harsh phonation but for many pharyngeal phenomena as well, and pharyngeals should be added to the wide range of laryngeal phenomena.

Within the local laryngeal phenomena, fundamental frequency (\( f_0 \)) is a very frequently studied phenomenon in phonetic and phonological research. It is in fact in the centre of attention of an entire subfield of tone and intonation. Our understanding of \( f_0 \) is based on incomparably more, and more systematic studies than our understanding of pre-aspiration (for phonological analyses, e.g. Gussenhoven 2004; Kingston 1984 &1986; Ladd 1996; for phonetic and sociolinguistic analyses, Cho, Jun & Ladefoged 2002; Dmitrieva, Llanos, Shultz & Francis 2015; Gilbert &
Weismer 1974; Gruenenfelder & Pisoni 1980; Haggard, Ambler & Callow 1970; Lee, Politzer-Ahles & Longman 2013; Ohde 1984; Pépiot 2014; Shultz, Francis & Llanos 2012; Umeda 1981; to name but a very few). Tonal languages belonging to various families exist, but these languages tend to occur in the same areas (Gussenhoven 2004: 42), which are not limited to Asia and Africa (e.g. Kim, to appear; Kingston 1984). Natural languages use intonation, including sign languages (Dachkovsky, Healy & Sander 2013).

Apart from \( f_0 \), the most-widely discussed local laryngeal phenomena are those of voicing and post-aspiration, fairly widespread cross-linguistically, and the number of pre-aspiration studies is scarce in comparison with these as well. Voicing and post-aspiration appear mainly in the debates related to phonetic cues to and correlates of the fortis-lenis contrast, mainly in Germanic languages (for voicing, e.g. Beckman, Jassen & Ringen 2013; Beckman, Helgason, McMurray & Ringen 2011; Benkí 2005; Docherty 1992; Helgason & Ringen 2008; Iverson & Salmons 2006; Stevens & Hajek 2004c; for post-aspiration, e.g., Beckman, Jassen & Ringen 2013; Beckman, Helgason, McMurray & Ringen 2011; Kehrein & Golston 2004; Cho, Jun & Ladefoged 2002; Jacques 2011; Helgason & Ringen 2008; Nance & Stuart-Smith 2013; Ringen & van Dommelen 2013; Stevens & Hajek 2010; to name but a few). Voicing and post-aspiration have also been subject to sociolinguistic analyses to some extent (voicing: Jacewicz, Fox & Lyle 2009; Smith 2012; post-aspiration: e.g. Dubois & Horvath 2000; Kang 2014; Oh 2011; Michnowicz & Carpenter 2013; Nance & Stuart-Smith 2013; Ringen & van Dommelen 2013).

Across areally diverse languages (Ladefoged & Maddieson 1996: 53), glottalisation (defined here as constriction in the laryngeal structures resulting in a series of irregular glottal pulses and/or relative lowering in \( f_0 \)) has similarly received considerable attention in phonetic, phonological, and sociolinguistic studies when compared to pre-aspiration (for phonetic studies of global and local glottalisation, e.g. Batliner, Bruger, Johne & Kießling 1993; Bird, Caldecott, Campbell, Gick & Shaw 2008; Bissiri, Lecumberri, Cooke & Volín 2011; Blankenship 2002; Dilley, Shattuck-Hufnagel & Ostendorf 1996; Huffman 2005; Keating & Garellek 2015; Skarnitzl 2004; Slifka 2006; Wolk, Abdelli-Beruh & Slavin 2012; for phonological studies of glottalisation, e.g. Batliner, Bruger, Johne & Kießling 1993; Bird, Caldecott, Campbell, Gick & Shaw 2008; Bissiri, Lecumberri, Cooke & Volín 2011; Blankenship 2002; Dilley, Shattuck-Hufnagel & Ostendorf 1996; Huffman 2005; Keating & Garellek 2015; Skarnitzl 2004; Slifka 2006; Wolk, Abdelli-Beruh & Slavin 2012; for phonological"

\(^{2}\) This term is defined in more detail in Chapter 5.
studies of local glottalisation, e.g. Blevins 2003; Kehrein & Golston 2004; Macaulay & Salmons 1995; Silverman 1997; for sociolinguistic studies of global and local glottalisation, e.g. Docherty 2007; Docherty & Foulkes 1999; Docherty, Foulkes, Milroy, Milroy & Walshaw 1997; Foulkes, Docherty & Watt 2001; Mees & Collins 1999; Schleef 2013; Watt & Milroy 1999; Yuasa 2010, to name but a few).

On the other hand, breathiness has been subject to fewer studies. It has attracted attention of phonetic, phonological, and sociolinguistic analyses as well (for phonetic studies of relatively global and local breathiness, e.g. Blankenship 2002; Hillenbrand, Cleveland & Erickson 1994; Södersten & Lindestad 1990; Wayland & Jongman 2003; for phonological studies of local breathiness, e.g. Silverman 1997; for sociolinguistic studies of relatively global and local breathiness, e.g. Borsel & Janssens 2009; Di Paolo & Faber 1990; Henton & Bladon 1085). The number of studies focusing on breathiness seems comparable to those interested in pre-aspiration. Contrastive breathiness appears to be even rarer than pre-aspiration based on the descriptions of each. Maddieson mentions only one language contrasting modal and breathy vowels – Tamang (1984: 132), but contrastive breathiness is found in languages from a number of families, including Dravidian, Indo-European (Indo-Aryan languages), Mezatecan, or Tibeto-Burman (Ladefoged & Maddieson 1996: 57-8, 317). Many of such languages are found in the same area.

In the last few decades, harsh voice has been shown to be of interest to phonological as well as sociolinguistic questions (Moisik 2013 and the references therein). Just like epilaryngeal phenomena and breathiness, pre-aspiration has been somewhat understudied in comparison to the other laryngeal phenomena. This is most likely due to the claim that pre-aspiration is a very rare phenomenon: even ejectives and implosives seem to be more frequent in the world’s languages. Ladefoged & Maddieson state that “[e]jectives are not at all unusual sounds, occurring in about 18 percent of the languages of the world (Maddieson 1984a), in languages as diverse as Mayan, Chadic and Caucasian” (1996: 78). They also note that “[a]bout 10 percent of the world’s languages contain implosives [based on Maddieson 1984a]” (1996: 82). Clayton presents an overview of pre-aspirating languages – his overview

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3 See Chapter 5 for more details.
4 “Relatively global and local” is used because the studies focus on the degree of breathiness in a vowel, i.e. a segment.
includes 20 languages, belonging to 8 language families (2010: 67-8). In some ways it expands as well as decreases Silverman’s overview (2003) due to differences in what is considered pre-aspiration. Clayton excludes pre-aspiration originating in the process of debuccalisation of /s/ (pasta [pasta] → [pahta]), as reported e.g. for a number of Spanish dialects (e.g. Ruch & Harrington 2014: 13).

Ejectives and implosives have received less attention in comparison to other laryngeal phenomena, but despite this they have been subject to phonetic, phonological, and some sociolinguistic studies (for phonetic studies of ejectives: Kingston 1984; Stevens & Hajek 2008; Hosted & Rose 2011; for phonetic studies of implosives: Cun 2004; Demolin, Ngonga-Ke-Mbembe & Soquet 2002; McLaughlin 2005; Wright & Shryock 1993; for phonological studies of ejectives: Fallon 2002; Gallagher 2010; Gallagher 2011; Kingston 1984; for sociolinguistic studies of ejectives: Gordeeva & Scobbie 2011, McCarthy & Stuart-Smith 2013). According to Maddieson (1984), Ejectives are found in the Caucasus, Africa, the Americas, and they have also been reported in Australia (Hajek & Bowden 2002).

In contrast to ejectives, implosives are an areal phenomenon, found mainly in West African languages (Ladefoged & Maddieson 1986: 82). Pre-aspiration resembles implosives in being generally considered an areal phenomenon (Helgason 2002: iii; Morris 2010; McKenna 2013), found mainly in Northern Europe in Scandinavian and Celtic languages. Yet, Silverman’s and Clayton’s overviews do not support that pre-aspiration is areal in the same way as implosives seem to be.

Studies of pre-aspiration in specific languages that have occurred in the last 15 years can be divided into several groups. First, there are studies which report pre-aspiration incidentally, i.e. the works look into other related or unrelated phenomena (Clayards & Knowles 2015; Hickey 2015; Iosad, in press; Kettig 2015; Watson 2007). Another group of pre-aspiration studies are primarily exploratory studies which map

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5 These are Algonquian (Cree, Fox, Menominee, and Ojibwa), Arawakan (Goiyiro), Finno-Ugric (Forest Nenets and Sami), Indo-European (English, Faroese, Icelandic, Irish, Italian, Norwegian, Scottish Gaelic, and Swedish), Mongolic (Halh), Tarascan, Uto-Aztecan (Hopí and Tohono O’odham), and Witotoan (Bora).
6 Families and languages included in Silverman (2003) which are not part of Clayton (2010)’s overview are Algic (Eastern Ojibwa), Chamicuro and other Maiupuran (Arawakan) languages, and Oto-Maguean (Huautla Mazateco). Unlike Clayton, Silverman includes clusters of /h/C in pre-aspiration phenomena. As Silverman (2003) states himself, “[t]his distinction–real or imagined–has no bearing on the issues of present concern.”
7 I am thankful to Thomas Kettig for drawing my attention to this paper.
whether pre-aspiration occurs in a variety and how frequently, what its phonetic realisations are, and less frequently whether it is subject to any segmental or prosodic factors (Bosch 2007; Helgason 2003; Jones & Llamas 2003; Knooihuizen 2013; McRobbie-Utasi 1991, 2003; Morris 2010; Roos 2003; Stevens & Hajek 2004b; Stevens & Hajek 2007; Stevens 2010). This group of studies also subsume exploratory studies of sonorant devoicing (Stevens & Hajek 2004a).

There is a considerable number of works looking into the fortis-lenis and/or singleton-geminate contrast, in which pre-aspiration is either under the spotlight or one of the potential cues and correlates examined (DiCanio 2012a; Gordeeva & Scobbie 2010; Gordeeva & Scobbie 2013; Helgason & Ringen 2008; Karlsson & Svanesson 2011; Ringen & van Dommelen 2013; Stevens & Hajek 2004c; Svanesson & Karlsson 2012; Tronnier 2002). One of such studies also provides sociolinguistic analyses (Nance & Stuart-Smith 2013).

No major systematic studies of the phonetic correlates of the fortis-lenis contrast in British English seem to have been carried out since Docherty’s study, in which speakers of Southern British English were used (1992: 181), who were not reported as pre-aspirators. It will be shown that pre-aspiration is fairly widespread in English accents (at least in Europe); however, despite the increasing reports of pre-aspiration occurring in English spoken in the UK and the Republic of Ireland, it is unknown what role it plays in the fortis-lenis contrast in accents of English other than Scottish Standard English (Gordeeva & Scobbie 2010, 2011, 2013). A systematic study of the acoustic correlates to the fortis-lenis contrast is therefore in place.

Nance & Stuart-Smith (2013) and Helgason, Stölten & Engstrand (2003) present recent works focusing primarily on the sociolinguistic aspects of pre-aspiration.

Finally, there are studies of pre-aspiration with very specific questions, which will be discussed in more detail in various parts of this thesis (Árnason & Schäfer 2012; van Dommelen, Holm & Koreman 2011; Gordeeva 2007; Stevens 2011; McKenna 2013; Stevens & Reubold 2014).

The most important recent studies of pre-aspiration have already been mentioned. Clayton (2010) provides a study on the history of pre-aspiration in a typological
perspective and Helgason (2002) combines synchronic studies of pre-aspiration in the Nordic languages to shed light on the history of pre-aspiration in these languages.

Some suggestions for why pre-aspiration is a rare phenomenon are given in sections 1.4-1.5. Before a further discussion of this, however, the definition of pre-aspiration is discussed in more detail as are the implications for our understanding of its patterning based on how pre-aspiration is defined (1.2.-1.3.).

1.2. How should we define pre-aspiration?

Pre-aspiration can be defined as a period of (primarily) glottal friction occurring in the sequences of sonorants and voiceless obstruents. In cases where the sonorant is a vowel, pre-aspiration is commonly found following the modal portion of that vowel (\textit{mat} [ma³tʰ] or \textit{mass} [ma³sʰ]), or at the juncture of the vowel and the consonant (Helgason 2002: iii). The phenomenon is often treated as consisting of two components: a voiced period of glottal frication (breathiness) and a voiceless period of glottal friction (pre-aspiration, or voiceless pre-aspiration). Breathiness is therefore often considered part of pre-aspiration in a broader sense (Helgason 2003; Helgason & Ringen 2008; Karlsson & Svantesson 2011; Morris 2010; Ringen & van Dommelen 2013; Stevens & Hajek 2004b, 2004c; Stevens 2010, 2011) and pre-aspiration can thus refer to two things: a period of breathiness combined with voiceless pre-aspiration, or just the voiceless pre-aspiration. In this thesis, the term pre-aspiration is used specifically for the voiceless interval.

Through a number of phonetic, phonological, and social analyses, this thesis shows that although pre-aspiration and breathiness exhibit a number of consistent similarities, they also show a number of differences, and pre-aspiration and breathiness should thus be treated as two laryngeal phenomena.

For example, pre-aspiration and breathiness agree in that they are affected in the same way by vowel height, vowel backness/roundness, and the type of utterance the token in question appears in (isolation vs carrier sentence: \textit{pat} vs \textit{Say pat once}.). Furthermore, they are both affected by phonological rather than phonetic vowel height.
However, pre-aspiration and breathiness differ in a number of other aspects as well. The major difference lies in their conditioning by the manner of articulation of the consonant they are associated with (plosive vs fricative – 'CVP(V) vs 'CVF: matt vs mass), by whether they are in stressed or unstressed syllables ('CVP(V), 'CVF vs 'CVCVC: matt, matter, mass, vs gullet, Wallace), and also by the place of articulation of the fricative in 'CVF words (/f/ vs /θ/ vs /s/ vs /ʃ/: if, myth, miss, fish). Pre-aspiration occurs more frequently in stressed than unstressed syllables and it is less frequent with fricatives than plosives in unstressed syllables ('CVCVF vs 'CVCVP: Wallace vs gullet). In contrast, breathiness is found more frequently with fricatives irrespective of whether it appears in stressed or unstressed syllables. Next, although both pre-aspiration and breathiness are acoustic correlates to the fortis-lenis contrast in plosives (/p/, /t/, /k/ vs /b/, /d/, /ɡ/), pre-aspiration is presumably more reliable because it never occurs in the lenis series, whilst breathiness does. Finally, the two are subject to the same conditioning by social age; however, only pre-aspiration occurrence is sensitive to gender.

The differences in the conditioning of pre-aspiration and breathiness would not necessarily imply that the two are not two components of a single laryngeal phenomenon if these differences were complementary. For example, there can be a trade-off in which the higher the vowel, the shorter the pre-aspiration, but the longer the breathiness. Nonetheless, on the whole pre-aspiration and breathiness do not reveal complementarity and it is concluded that pre-aspiration and breathiness are not merely two components of the same laryngeal phenomenon.

Furthermore, breathiness is likely to be a precursor of pre-aspiration because it occurs obligatorily with fricatives and plosives in unstressed syllables ('CVCVP: gullet; 'CVCVF: Wallace) and because in stressed syllables it is obligatory with fricatives ('CVF: mass), whereas pre-aspiration is not obligatory with fricatives and plosives in unstressed syllables and with fricatives in stressed syllables. Breathiness thus co-occurs with pre-aspiration with plosives most frequently ('CVP, 'CVPV: matt, matter). Hence, pre-aspiration only reaches obligatory application if breathiness does, but obligatory breathiness does not imply obligatory pre-aspiration.

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8 P = plosives; F = fricative; C = consonant; V = vowel.
A relatively old research question that potentially benefits from pre-aspiration and breathiness being distinguished is that of the segmental affiliation of pre-aspiration: is pre-aspiration affiliated with the vowel (C|V|^h:C: [m|a|h|s]), the consonant (C|V|^h:C: [m|a|s]), both (C|V|^h:C: [m|a|h|s]), or neither (C|V|^h:C: [m|a|s])? This question goes hand in hand with our understanding of certain sound changes. These are further discussed in what follows.

1.3. Segmental affiliation of pre-aspiration

The affiliation debates associated with pre-aspiration present an unresolved issue. Authors differ in whether the phenomenon is considered a subsegmental part of the consonant, of the vowel, a segment of its own, or an autosegment/prosody (see Árnason 1986 for the most important references, also Lodge 2007). Pre-aspiration thus poses challenges concerning its segmental affiliation, and this may be because pre-aspiration and breathiness are usually not distinguished in discussion of the segmental affiliation of pre-aspiration (e.g. Stevens & Reubold 2014: 472; Thráinsson 1979).

In particular, it has been argued that pre-aspiration is part of the nucleus rather than the coda based on the fact that when the word in question is uttered contrastively, it is pre-aspiration that lengthens and not the consonant (Árnason 1986: 11-12). This interpretation proposes the solution that pre-aspiration has both segmental and suprasegmental characteristics by assigning to it the status of “a prosody with nucleus being its domain” (1986: 18). This applies to both pre-aspiration and sonorant devoicing. Clayton, similarly to Árnason, mentions that when pre-aspiration is shorter with a phonologically long vowel than when with a phonologically short one, this can be interpreted as pre-aspiration being part of the coda, whereas if pre-aspiration lengthens as the vowel lengthens, it is part of the vowel nucleus (2010: 14). Lodge suggests that distinguishing the individual components of pre-aspiration in the broader sense may shed light on the affiliation debates (2007: 93), but unfortunately the suggestion is not too specific.

However, it is not clear if it is the breathy portion or the voiceless portion that lengthens and, in consequence, we do not know if the consonant really does not
lengthen if we do not know whether pre-aspiration is part of the consonant. It seems plausible that only the breathy or only the voiceless portion could lengthen, and this is indeed confirmed by Kingston (1990: 420), who reports breathiness being much less variable in duration across speaking rates (10-50ms) than pre-aspiration (10-100ms). Indeed, Kingston claims that pre-aspiration and breathiness are co-ordinated with the vowel and the consonant differently (1990: 420) and his report is supported by the phonetic and phonological analyses of the conditioning of pre-aspiration and breathiness carried out in this thesis. Our results point to the possibility that pre-aspiration and breathiness are both associated with both the vowel and the consonant, but these associations vary in their strength. Hence, pre-aspiration and breathiness imply that the two could go in the same direction regarding their affiliation, but they could equally well go in the opposite directions.

These suggestions are in line with Lodge (2007: in particular 92; 2009: 57), who critically reviews Gussmann (2002)’s analyses of Icelandic pre-aspiration as a segment. In the definition of pre-aspiration provided above, pre-aspiration is therefore purposely not defined here as being found between a sonorant and an obstruent for reasons discussed in Lodge (2007: 82): defining pre-aspiration as an interval occurring between two segments assigns it a special status that makes it a priori neither part of the sonorant nor that of the obstruent but a segment of its own or possibly some sort of suprasegment/prosody.

Overall, these suggestions and findings corroborate those of Stevens & Reubold (2014), who hypothesise that pre-aspiration may lead to degemination in Italian because it is perceptually associated with the preceding vowel rather than the consonant. They find that in perception the respondents parse pre-aspiration independently, i.e. neither with the vowel nor with the consonant (2014: 471). In production, the same subjects differ in whether pre-aspiration is independent, part of the consonant, or part of the vowel (2014: 482-3). But it is not known to what extent this could be due to individual differences in the production of breathiness.

Another example which points to an unambiguous change in the affiliation of pre-aspiration is that of Mongolian dissimilation. For the historical development of Mongolic languages, it has been proposed that pre-aspiration affiliated to the post-tonic plosive has shifted its affiliation to become post-aspiration of the pre-tonic
plosive, which had originally been unaspirated: $TV^h_T > T^bVT$ (Svantesson & Karlsson 2012: 462). Such dissimilations could happen in two ways. Firstly, the change is non-local and the pre-aspiration suddenly shifts its affiliation; or, secondly, this change is local and happens via an increasing breathiness of the vowel associated with a decreasing pre-aspiration. The authors however also report Mongolic languages where this phonological dissimilation did not happen and in which we find phonetic dissimilation instead: $T^bV^h_T$ words can have shorter post-aspiration of the prevocalic $T$ when the postvocalic consonant is pre-aspirated than words in which the postvocalic consonant is a sonorant ($T^bV_{sonorant}$). It remains to be shown what role breathiness has in these processes and whether these processes are non-local or local.

Similarly, distinguishing pre-aspiration and breathiness can shed more light on our understanding of certain synchronic alternations. Silverman (2003) mentions alternations in $V:P$ with $V^h:P$ in Tarascan and also in Cree, Gaelic, Goajiro, Hopi, Maipuran, Ojibwa, and West Norwegian.9 Where these alternations are synchronic and not contrastive (as seems to be the case at least in Tarascan), it may be the case that the distinction is in fact a continuum of a fully modal vowel, partially breathy vowel, and a partially breathy vowel and pre-aspiration, rather than that of a fully modal long vowel and a vowel followed by pre-aspiration.

Hence, distinguishing breathiness from pre-aspiration can be useful because, if vowels and consonants are thought of as two ends of the same scale, the fact that breathiness is articulatorily and acoustically closer to the vocalic end and pre-aspiration to the consonantal end explains why in some languages/varieties pre-aspiration (in the broad sense, i.e. including breathiness) is part of the consonant in some languages but part of the vowel in others (Clayton 2010: 182) and why its affiliation can be subject to sound change (Árnason 1986: 21).

This thesis does not address the affiliation issue directly, but it puts forward the hypothesis that distinguishing breathiness from voiceless pre-aspiration may in fact lead to more conclusive and more productive results regarding the debates concerned with the affiliation of pre-aspiration in the broader sense.

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9 Not all of these reports seem to be based on acoustic analyses however and should be considered with caution.
The second question this work addresses is whether pre-aspiration is a phonological phenomenon in English spoken in Aberystwyth. This question is of interest for research into pre-aspiration in general, because the phenomenon is often seen as rare and rarely phonological, as further discussed in section 1.4.

1.4. Pre-aspiration as rare and rarely phonological

The most well-known study of pre-aspiration is that “On the rarity of pre-aspirated stops” by Silverman (2003). Silverman’s paper suggests that pre-aspirated plosives are a rare feature; however, more recent studies call this into question. Since his publication, the phenomenon has been reported, in most cases for the first time, in several accents of British and Irish English (Leeds English – Wilhelm, in prep; Liverpool English – Watson 2007: 171, 183, 201; also Lodge 2007: 76 and the references therein; Manchester English – Hejná & Scanlon 2015; Bramley, Maher & Paterson 2015; Middlesbrough English – Jones & Llamas 2003; Scottish Standard English – Gordeeva & Scobbie 2010; SSBE – Kettig 2015: 24-6, who also drew my attention to pre-aspiration present in the Queen’s speech in the 1957 Christmas Broadcast, personal communication; English spoken in Northern Wales – Morris 2010; Bramley, Maher & Paterson 2015), recently also North American English (Clayards & Knowles 2015); Welsh (Morris 2010; Morris & Hejná 2014; Iosad, in press), Italian (e.g. Stevens 2010), San Martín Itunyoso Trique (DiCanio 2012a), and various Mongolic languages, including Halh, Chahar, Baarin, Horcin, and Shiliin Gol (Svantesson, Tsendina, Karlsson & Franzén 2005: 12-8, 204-6; Karlsson & Svanesson 2011; Svanesson & Karlsson 2012; Ramstedt 1902, quoted in Svantesson, Tsendina, Karlsson & Franzén 2005: 12).

Although Clayton acknowledges Tyneside English pre-aspiration in his overview of pre-aspirating languages, he also notes that it is considerably constrained and not likely to be phonologised as a contrastive feature (2010: 82). This is because it has been found primarily in utterance-final /p/, /t/, /k/ followed by a pause.

At least the following languages did not “make it” to Silverman’s and Clayton’s works: Chechen and Inguish (Catford 1977: 114), Western Yugur (Roos 1998), Ket,
Tuvinian, and Ude(ge) (Liberman 1982: 126, 300), and Welsh (Ball 1984: 18), and there is also a report of pre-aspiration in Hull English (Williams & Kerswill 1999: 147). Dwyer also discusses pre-aspiration in “Tuva, Tofalar/Karagas, Sarïgh Yoghur, Salar, and the Kälpin vernacular of Uyghur” (2000: 423). In the case of Chechen and Inguish, the lack of mention can be easily explained since Catford only notes it in a passing comment in a general textbook of phonetics. In the case of Welsh, pre-aspiration is only mentioned in a passing comment as well and this is the case also for Hull English. Pre-aspiration merits further exploration especially in these languages and their varieties.

Three factors may be responsible for the rarity of pre-aspirated consonants reported in the past and for the sudden increase of reports of pre-aspiration. Firstly, very good quality recordings are necessary to identify pre-aspiration reliably in the first place, especially if it is short, and so pre-aspiration may be more frequent than believed because it has been unnoticed in a number of languages. Although it is possible that more languages have recently innovated pre-aspiration, in his thesis Clayton (2009) concludes that the phenomenon is rare because it is difficult to innovate. Pre-aspiration is therefore either not recent in the studies reporting it in more languages, or it cannot be that difficult to innovate after all. Secondly, it may also be that pre-aspiration was noticed by linguists in the past, but was not seen as important and therefore not mentioned. Finally, it is possible that pre-aspiration has been reported in other languages, but the report was written in a language other than English (e.g. Ramstedt 1902 for Mongolian). Helgason expresses concerns along similar lines, namely the fact that pre-aspiration is a very subtle phonetic phenomenon that may go unnoticed unless it is specifically looked for (2002: 32).

The claim that pre-aspiration is rare may also be better understood in the context of pre-aspiration seen as an extremely rare phonological phenomenon (Clayton 2010: iii) or as not “a feature [necessarily] required for distinguishing underlying forms [in any language]” (Ladefoged & Maddieson 1996: 73). This impression most likely resulted from two causes. The first is related to our understanding of phonological contrast, the latter to a dichotomy between normative and non-normative pre-

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10 I am grateful to Yang Li for pointing Dwyer’s study out to me.
11 Catford’s passing comment is quoted in another classic in phonetic textbooks in the sections referenced as discussing pre-aspiration (Laver 1994: 358).
aspiration (Helgason 2002: in particular 21-3), which is often adopted in the pre-aspiration literature.

First, it is not clear how contrastiveness is established, why pre-aspiration should be seen as phonological only if contrastive, and why pre-aspiration should be of interest to linguists only if phonological. Although it is true that pre-aspiration is reported as contrastive at the surface level only in Icelandic, Faroese, Scottish Gaelic, and Lule Sami by Ladefoged & Maddieson (1996: 70), Silverman (2003) describes more languages as possessing contrastive pre-aspiration, including (at least) Chamicuro, Icelandic, Lule Sámi, Oraibi Hopi, Scottish Gaelic, and Tarascan; and Clayton discusses phonological functions of pre-aspiration in a typological perspective throughout his thesis (2010).

Some studies tend to view pre-aspiration as non-phonological because they adopt a dichotomy of normative and non-normative pre-aspiration (Helgason 1999b; Morris 2010: section 6.1.; Wretling, Strangert & Shaeffler 2002). A phenomenon is defined as normative if all the speakers of an accent/dialect use that feature in the same way (Helgason 2002: 21). It is important to emphasise that the obligatory and optional application should be equal to normativeness and non-normativeness only in the context of intra-group, or inter-speaker, variability, not in the context of intra-speaker variability. Based on Helgason’s definition, if all the speakers in a community pre-aspirated 10% of their tokens, this should be considered normative because this is what is, as far as can be assessed objectively based on acoustic analyses, a “non-deviant” trait in the community.12

Crucially, normativeness as defined above should not be put on par with being relevant for the phonology since evidence of inter- or intra-speaker variability does not necessarily entail that the phenomenon is not phonologically relevant (Coetzee & Pater 2011; Sebregts 2014: Chapter 6, also page 13). It seems slightly surprising then that based on analyses of one speaker of the Gräsö dialect of Swedish Helgason himself concludes that “[…] judging from the sheer duration of the preaspirations produced by this informant, as well as their phonological distribution, it seems most likely that they are normative in the informant’s dialect.” (Helgason 1999b: 1851)

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12 See Helgason (2002: 21, 23) for a discussion emphasising that non-normative pre-aspiration is not the same as pre-aspiration undergoing free variation.
Normativeness as defined in Helgason (2002) is equalled to being phonologically relevant in Helgason (1999). Indeed, normative pre-aspiration is defined differently in Helgason (1999) as phonologically conditioned and obligatory (1999b: 1854). Furthermore, Helgason (2002) equals normativeness to obligatoriness (2002: 8), which is the meaning adopted by Wretling, Strangert & Shaeffler (2002), and the dichotomy can thus be confusing if two definitions are given to it in the same work (Helgason 2002). Furthermore, Ringen & van Dommelen have recently shown that a sample of speakers may include one individual with durations much longer than those of the other speakers (2013: 485), which makes the speaker deviant in Helgason’s terms. Because the term can have multiple definitions based on 1) inter-speaker consistency vs 2) phonological conditioning and obligatory application, this thesis does not adopt the framework of normative vs non-normative pre-aspiration. The dichotomy is nevertheless useful in the first sense.

Normativeness as defined by Helgason (1999; 2002: 8) is further problematic because it is not clear what rate of occurrence pre-aspiration should exhibit to count as normative. This has been previously pointed out by Morris (2010). In addition, it would seem that it is not the case that for a speaker A, who pre-aspirates, pronunciations of speaker B, who does not pre-aspirate, would necessarily be perceived as deviant.

The truth is that not much is known about the phonological aspects of pre-aspiration in languages other than Icelandic or Sámi (e.g. Árnason 1986, McRobbie-Utasi 2003). The second question this thesis poses therefore is whether pre-aspiration is a phonetic or also a phonological linguistic feature of English spoken in Aberystwyth.

Firstly, it is demonstrated that pre-aspiration and breathiness are relevant for its phonological description even if not obligatory in the traditional sense (i.e. occurring 100% of the time) because the distributions of the duration of pre-aspiration form two non-overlapping categories. Furthermore, although it is not approaching obligatory application in some speakers, pre-aspiration and breathiness are nevertheless conditioned by phonological vowel height. Hence, pre-aspiration can be seen as phonologically relevant if subject to phonetic analyses and if we accept the fact that a phenomenon can be phonologically relevant even if it is not obligatory. Finally, if we look into what role pre-aspiration has as an acoustic correlate of the
fortis-lenis contrast in plosives, we conclude that pre-aspiration occurrence plays at least as important a role as four other correlates of the contrast (presence of voicing, vowel duration, presence of breathiness, and release duration) at least word-medially and word-finally. Amongst presence of pre-aspiration, presence of breathiness, presence of voicing, pre-aspiration duration, breathiness duration, voicing duration, voiceless closure duration, release duration, preceding and following vowel duration, $f_0$ at the onset of the following and at the offset of the preceding vowel, and vowel-initial breathiness duration, several strong correlations are found in the majority of the speakers. There is a positive correlation between aspects of one group – pre-aspiration duration, breathiness duration, and release duration. There is also a strong positive correlation between another group of aspects – vowel duration and voicing duration. The same applies to the frequency of occurrence of these correlates (not relevant for vowel duration).

These two groups, or bundles, of acoustic correlates are strongly correlated in an inverse way. This means that it is extremely difficult, if not impossible, at least based on the acoustic evidence, to decide which of these should be the most important correlate of the contrast and if there is one constantly most important correlate in the first place. Rather, all these correlates contribute to distinguishing the contrast as an amalgam. This observation is in line with those of Lisker & Abramson (1967: 3, 20-4), who find that voicing lead serves to enhance the fortis-lenis contrast variably in various conditions, and variably so for different speakers (of American English), as well as a number of other studies reporting on enhancing aspects that distinguish the contrast or trade-offs (e.g., Kingston, Diehl, Kirk & Castleman 2008; Liberman, Delattre & Cooper 1958; Scobie 2002) or on covert contrast acquisition (Kirby 2010 & 2011).

Regardless of the phonological theory, pre-aspiration is at least as relevant for the phonological description as some other laryngeal and oral correlates of the contrast, contrary to the claim that it is primarily release duration that distinguishes the phonological contrast in English (e.g. Iverson & Salmons 1995). It is difficult to assess to what extent this may be based on studies of plosives preceded by a pause and in a foot-initial position in American English – some such studies in fact do not focus on aspiration as the crucial distinctive feature and discuss more aspects
relevant for the fortis-lenis distinctions, although still for initial position (in isolation and embedded in a sentence: Lisker & Abramson 1964; isolation only: Allen, Miller & DeSteno 2003; Cho & Ladefoged 1999: 214; Flege 1982).

Despite the increasing reports of pre-aspiration and despite taking into account languages where it is not obligatory, the phenomenon is still much less frequent than many other laryngeal and supralaryngeal phenomena. Clayton suggests that this is because it is difficult to innovate, which is the subject of section 1.5. below.

1.5. Pre-aspiration as difficult to innovate

The seeming rarity of pre-aspiration is most directly connected with the question of how and why pre-aspiration innovates and transmits in a language in the first place, especially considering the claim that pre-aspiration is an “‘audio-phonetic dinosaur’ which ‘suffers from an accumulation of auditory handicaps’ (Bladon 1986: 7) and is doomed to rapid extinction whenever innovated, unless it succeeds in making itself more perceptually prominent” (Clayton 2010: 19), a phenomenon which “could hardly be less suited for communicative purposes” (Helgason 2002: 35-6, paraphrasing Bladon 1986). However, Clayton’s perceptual tests suggest that pre-aspiration is not perceptually inferior to post-aspiration, and based on that Clayton concludes that whilst pre-aspiration should not be difficult to transmit, it may be difficult to innovate (Clayton 2009). Clayton summarises four pathways of innovation of pre-aspiration: degemination of voiceless plosives, sequences of a voiceless nasal and a plosive changing into the sequences of /h/ and a voiceless plosive, borrowing/contact, and “spontaneous appearance in singleton voiceless stops” (Clayton 2010: mainly Chapter 3).

The most important and the most recent contributions to the degemination pathway are those of Ní Chasaide (1985: mainly Chapter 4), Ó Murchú (1985), and Stevens & Reubold (2014). These studies propose that pre-aspiration becomes enhanced in one environment after the weakening of phonetic voicing in a contrasting environment to support the phonological contrast or that pre-aspiration becomes enhanced and this
leads to the weakening of the phonetic voicing. Chapter 6 shows that this is not the case in the Aberystwyth data, where the individuals with more frequent pre-aspiration in /p/, /t/, /k/ also have more frequent voicing in /b/, /d/, /g/. Stevens & Reubold also propose that the closure duration shortens as a second step in the degemination scenario, which does not seem to be the case in the Aberystwyth data, as discussed in Chapter 6.

For the borrowing/contact pathway, see primarily Helgason (2002), McKenna (2013), and Ní Chasaide (1985). This source is considered in the case of Germanic and Celtic languages and also Sámi, which are all found in the north of Europe.

The spontaneous appearance could be related to local breathiness, which has been reported to occur in vowels preceding fortis obstruents in Swedish, variably in English, and Italian, although not in German and French (Ní Chasaide & Gobl 1993: 310-5).

To this can be added another precursor to pre-aspiration – the aforementioned debuccalisation of /sl/. Furthermore, at least one more precursor to pre-aspiration has been overlooked: the development from glottalisation proposed by Kortland (1988), Pentland (1977), and others referenced in Kortland (1988).

Although these six pathways have been proposed, the individual mechanisms behind each remain to be further elaborated. It is the understanding of these mechanisms that lies behind why pre-aspiration innovates. Clayton aptly draws our attention to four aspects to consider in this regard: presence of phonetic precursors, abundance of antecedent structures, competition among rephonologisation candidates, and cognitive predispositions (2010: 70).

Chapter 5 focuses on the connection between pre-aspiration and glottalisation. The debates as to whether pre-aspiration has developed from glottalisation or vice versa assume, without stating so explicitly, that pre-aspiration and glottalisation are mutually exclusive (i.e. complementary or allophonic) and do not co-occur in the same tokens. For example, the word pat could be realised as [pa^hət]\ or [pa^a^r\t], but not [pa^a^r\t]. This may be related to another assumption implicit in the phonological features of [spread glottis] and [constricted glottis]. At first blush, these require two
opposing states of the glottis. Whilst it may be true that the two are never found in the same token in a way that has to represent both spread and constricted glottis at the phonological level, this does not mean the two could never co-occur in the same token at the phonetic level.

This motivates the third question addressed by this thesis; namely, whether pre-aspiration and glottalisation are mutually exclusive in the same context. Considering the fact that pre-aspiration involves opening and laxing of the vocal folds whereas glottalisation involves constriction of the vocal folds and other laryngeal structures (e.g. ventricular folds, or even epilaryngeal structures – see Moisik 2013), it may seem surprising that such different articulatory gestures should be both associated with the same environment. The analyses of Aberystwyth English, considered in the context of those available for Manchester English, conclude that pre-aspiration and glottalisation can co-occur in the same language, variety, idiolect, and even in the same environment. However, the individuals vary in what relationships pre-aspiration and glottalisation enter, and mutual exclusivity in the same context is attested for some speakers. In the plosive context (batter, bat), some show a pattern of optional co-occurrence, some of optional exclusivity. One speaker also shows an obligatorily exclusive pattern in the plosive environment. In the fricative tokens (mass), except for one speaker the relationship is that of optional co-occurrence. Irrespective of whether a speaker exhibits the pattern of co-occurrence or exclusivity, the speakers further differ in what conditions glottalisation. This suggests a wide range of options available for phonologisation and difficulties in predicting which relationships pre-aspiration and glottalisation will enter into, but these are limited primarily by prosody and not the segmental environment.

Hence, debates focusing on the historical relationship of pre-aspiration and glottalisation need to consider the possibility of their co-occurrence and further look into the motivations behind the (dis)preferences for the various patterns.

13 Some explicit comments not related to this specific historical question are to be found: “[…] it may well be that [*[asp, glot]] is not a constraint which needs to be provided by Universal Grammar. Rather, the nature of the vocal tract (‘Universal Phonetics’) precludes this combination, as it is impossible to both spread and constrict the vocal folds at the same time (this assumes that such actions are the prime or default exponents of these features).” Honeybone (2005: 325). In Honeybone (2005), however, it seems that [constricted glottis] refers to implosives and ejectives rather than glottalisation/laryngealisation occurring in the sequences of sonorants + voiceless obstruents (“in ‘glottalised’ segments, such as ejectives and implosives” (2005: 326)).
Furthermore, Chapter 5 also proposes that it is likely that the relationship between pre-aspiration and glottalisation is subject to social conditioning.

The last question discussed in this thesis falls within the scope of sociolinguistics. Is pre-aspiration sensitive to social constraints as well, namely those of age and gender/sex?

1.6. Pre-aspiration as a social phenomenon

Since pre-aspiration has been recently observed in more languages and varieties thereof, a question that calls for an answer is whether this is because pre-aspiration is a recently innovated phenomenon in these languages and varieties. Clayton indeed proposes that because the pre-aspiration found in Tyneside English is sharply constrained, appearing only prepausally, [this] is likely to inhibit its phonologization as a contrastive feature. Moreover, preaspiration is most common among younger females, strongly suggesting that the innovation has occurred very recently (Clayton 2010: 82).

Evidence presented in Chapters 3-7 nevertheless suggests that pre-aspiration is not a linguistic feature innovated in Aberystwyth English in the last few decades.

These chapters show that not only is pre-aspiration a fairly robust phenomenon in English spoken in Aberystwyth, but it is furthermore also sensitive to the phonological conditioning by vowel height and it is a systematic acoustic correlate of the fortis-lenis contrast in plosives (/p/, /t/, /k/ vs /b/, /d/, /g/). We could argue that a newly innovated linguistic feature would not show this behaviour unless it was a result of dialect borrowing.

Whilst not being a newly innovated linguistic feature in English spoken in Aberystwyth, Chapter 7 demonstrates that pre-aspiration is nonetheless undergoing an advancing sound change and this tendency is strongest in the male population: it

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14 The word “recent” is ambiguous. Here it is used to refer to innovation in one of the generations younger than the oldest who are analysed in this thesis.
becomes more frequent with the decreasing of age. This suggests that pre-aspiration in English spoken in Aberystwyth demonstrates Labov’s Principle II.

This principle states that “[i]n linguistic change from below, women use higher frequencies of innovative forms than men do” (Labov 2001: 292). Labov suggests that the fact that so many sound changes below the level of awareness are found to be led by women can be explained by the asymmetry of the caregiving situation (1990: 244) and predicts that female dominated changes will see a faster transmission than male dominated changes because children’s caretakers tend to be females in the vast majority of cases (2010: 254). Furthermore, Labov predicts that “[g]ender differentiation does not continue indefinitely. On the contrary, the difference between males and females disappears as the change continues” (2010: 255). This allows for a convenient test of whether pre-aspiration is indeed conditioned by physiological sex rather than social gender. If it is strictly conditioned by physiological sex, this conditioning should persist irrespective of how old a phenomenon is in a language.

The findings of Chapter 7 thus only partially support the proposal that females are more likely to pre-aspirate more frequently and with longer durations than males for physiological differences in the vocal tract, or in the laryngeal structures (e.g. Helgason 2002: 231; van Dommelen, Holm & Koreman 2011: 602). One more specific suggestion is that women “may actually spread their vocal fold processes in order to de-emphasise the fact that they radiate at higher frequencies than men do” (Helgason 2002: 230, quoting Titze 1989) or because of differences in vocal fold size (Helgason 2002: 229). The radiation at higher frequencies discussed in Titze deals with the prediction that “the female voice could be 25% more efficient than the male voice, primarily due to higher F0” (1989: 1706), which could be negated by spreading the vocal processes and thereby increase the spectral slope. It has been shown that females/women are breathier (RP and a northern accent of BrE – Henton & Bladon 1985; Dutch – Borsel, Janssens, De Bodt 2007; English speakers originating in Chicago, St Louis, New Jersey, and California – Price 1989), which is caused by – mainly posterior – glottal gaps (Hanson & Chuang 1999; Chen, Kreiman, Shue, Alwan 2011; for Swedish – Södersten, Hertegård, Hammarberg 1995), and we know that pre-aspiration is closely related to breathiness. However,
the studies related to breathiness quoted here used English and Dutch for the analyses, and a wider range of languages would be appreciated to confirm whether it is females that are breathier than males or women that are breathier than men in some cultural contexts, i.e. whether the breathiness is physiological or social in its origin.

It has also been put forward that children and women are more likely to pre-aspirate for physiological reasons: Helgason mentions a study of Tyneside English by Foulkes, Docherty & Watts (1999) and that of Senja Norwegian by Iversen (1913). The first study found pre-aspiration was more frequent in adult females than males and that it was also very frequent in children. This was interpreted as a change in progress by the authors, i.e. as an effect of social and not biological age. The latter study found that pre-aspiration was “most noticeable in the speech of children” (Helgason 2002: 95). For the suggestions on possible effects of biological age and sex, see Helgason (2002: 73, 95, 229-31).

Chapter 7 however shows that although older speakers show the generally reported sex/gender pattern regarding the frequency of occurrence of pre-aspiration, this difference disappears in the youngest speakers, and irrespective of age no gender difference is found concerning the frequency of occurrence of breathiness or regarding the duration of either pre-aspiration or breathiness. Age on its own affects all four variables: pre-aspiration and breathiness are longer with the younger speakers and they are also more frequent.

This thesis, like the study of Sienese Italian (Stevens 2010; Stevens & Hajek 2004b: 58) and that of Trøndelag Norwegian (Ring & van Dommelen 2013: 485),\textsuperscript{15} shows that if in some varieties of languages pre-aspiration is indeed influenced by a different laryngeal physiology of females and males, this is not something that speakers cannot override by either social or phonological behaviour.

\textsuperscript{15} This does not agree with other studies of pre-aspiration in Norwegian (Stavanger and Trondheim Norwegian – van Dommelen, Holm & Koreman 1999; Trøndelag Norwegian – van Dommelen & Ringen 2007).
What follows comments on the choice to answer the four questions with data from English spoken in Aberystwyth and on the label “Aberystwyth English”.

1.7. Aberystwyth English

The analyses of pre-aspiration on which this thesis rests are all based on data collected from speakers of English who grew up and spent most of their life in Aberystwyth, mid Wales (Figure 1.1.).

![Figure 1.1. Location of Aberystwyth within Wales](http://en.wikipedia.org/wiki/Aberystwyth#/media/File:Ceredigion_UK_location_map.svg).

Welsh English, i.e. English spoken in Wales, was chosen because pre-aspiration has been reported to occur in the variety (Morris 2010 for Northern Welsh and North Wales English) and because my own data from Cardiff and Aberystwyth suggested the phenomenon may be widespread throughout the whole country of Wales. Indeed, collection of data from 103 speakers from various parts of Wales confirmed that pre-aspiration is found in at least some speakers from the areas that the 103 speakers came from. As Figure 1.2. shows, excepting Welshpool, for which one speaker was
recorded, pre-aspiration was found in all the other places for which respondents were recorded. Thus, regarding the specific place or area within Wales, any variety was seen as equally interesting as to what can be learnt about pre-aspiration.

Figure 1.2. Pre-aspiration within Wales

Locations where speakers were recorded by the author: pre-aspiration has been found in all the locations apart from one speaker from Welshpool

Aberystwyth English in particular was selected for several reasons. Firstly, I had already established links in the place prior to embarking on the study of pre-aspiration, and it was convenient to take advantage of these links. Secondly, if Welsh English in general is understudied, this is even more so for English spoken in Ceredigion (highlighted in red in Figure 1.1.). In fact, we do not know anything
about Ceredigion English apart from its fitting under the label of Welsh English. It is therefore not possible to judge to what extent Aberystwyth English differs from English spoken elsewhere in Ceredigion or even Wales as such. The position and character of Aberystwyth further render the place an apt choice for analyses of language variation and change. The town has been undergoing demographic changes and the mixture of locals and incomers provides a window into how the social variation is reflected in the speech of the inhabitants of Aberystwyth. The National Library and Aberystwyth University attract a number of incomers to the place from other parts of Wales. In the academic year 2011/2012, “[…] there were 9,130 full-time students and 6,480 part-timers registered with Aberystwyth University […] – although some of these will be studying remotely and not living in the area.” (Aberystwyth Population Statistics) This makes Aberystwyth a town with the highest population within Ceredigion, with 25% of the whole population of Ceredigion as of 2011, which increased by 12% between 2001 and 2010 (Aberystwyth Population Statistics).

Aberystwyth is furthermore of interest to the study of language variation and change because the place is in between the North and the South of Wales, with strong communities of L1 Welsh as well as L1 English speakers, and not isolated from other parts of Wales or the UK culturally. Concerning the situation of the Welsh language in Aberystwyth, it is in no way unusual to hear Welsh in the streets of the town – the census from 2011 reports that 31% of the population speaks Welsh (Aberystwyth Population Statistics).

Just how much Aberystwyth English presents a variety of its own is subject to further research. Although it may be more correct to refer to the English analysed in this thesis as “English spoken in Aberystwyth”, for convenience sake the label “Aberystwyth English” will be used throughout as shorthand.

1.8. Summary of questions

This thesis considers four questions:

1. Is the usual definition of pre-aspiration adequate? Namely the definition according to which pre-aspiration consists of two components: a period of
voiced glottal friction, or breathiness, and a period of voiceless glottal friction, or (voiceless) pre-aspiration. This question is addressed mainly in Chapter 3, but Chapters 4, 6 and 7 also offer some answers.

2. Are pre-aspiration and glottalisation mutually exclusive in the same environment? This is discussed in Chapter 5.

3. Is pre-aspiration a phonetic or also a phonological phenomenon in Aberystwyth English? This is the focus of Chapters 4 and 6.

4. Is pre-aspiration conditioned socially in English spoken in Aberystwyth? Chapter 7 presents a sociolinguistic study concentrating on the variables of age and gender/sex.

The conclusions are summarised in Chapter 8. The next chapter presents the type of the data which are used in the thesis to answer these four questions.
Chapter 2 – Methodology

The purpose of this chapter is to describe the type of the data used to answer the questions this thesis asks. The speakers are discussed first. Next, information is provided for the recording procedure and further processing of the material. Finally, the linguistic properties of the data are commented on in detail.

2.1. Speakers

The thesis relies on data recorded from twelve female and six male speakers born and raised in Aberystwyth, who are L1 Welsh speakers and also proficient in English. Not all chapters use the data collected for all eighteen speakers for reasons of time. The number of speakers used is always specified in the individual chapters.

In the majority of the speakers the parents are or were L1 Welsh speakers. One parent of three speakers either learnt Welsh as an adult (in case of ABE37 and ABE41) or spoke it but did not use it at home or elsewhere (ABE52).

The parents of all speakers grew up in Wales (During his childhood, one parent of ABE45 had been moving between Wales and London.). Most of the parents grew up in Ceredigion, mid Wales, if not in Aberystwyth itself. This criterion was not always possible to meet, especially for the male speakers, who were generally less willing to volunteer. Those with one parent who grew up in an area of Wales other than Ceredigion are ABE11 (one parent from South Wales), ABE18 (one parent from South Wales), ABE24 (one parent from North West Wales, one from North East Wales), ABE25 (one parent from South Wales: near Cardiff), ABE29 (one parent from South Wales), ABE31 (one parent from North West Wales), ABE37 (one parent from North East Wales: Wrexham).

The age of the respondents ranged from 22 to 90 years (See Chapter 7 for more details.). All participants attended Welsh-medium primary and secondary schools.

16 The coding used for the individuals is explained further below (2.2.).
2.2. Recording procedure and further processing

The speakers were recorded in a quiet room in their homes or at Aberystwyth University (in an anechoic room, Department of Psychology), but occasionally in other quiet environments (e.g. libraries). An H4 Zoom Handy Recorder was combined with the head-mounted AKG C520 Microphone, which was attached to the speaker’s head and ensured a constant distance from the mouth irrespective of the speaker’s movements.\textsuperscript{17} The recordings were sampled at 44.1 kHz.

The target items were presented on a laptop screen and the speakers were left to proceed through the slides at their own pace. The author was present during the recording sessions and ensured that the pace was neither too slow nor too quick. The target items as well as the distractors occurred in a randomised order, which was obtained using a randomising programme available online (Haahr 1998-2015). The recording session was preceded by a brief interview during which personal information was collected. The word-list part had two compulsory breaks and the subjects were encouraged to take more breaks at any point if they felt the need, and when the author noticed they were getting tired, they were prompted by the author to take a break as well.

The data comes from a bigger corpus. In total, 53 Aberystwythians were recorded together with another 47 speakers from other parts of Wales. This is why the speakers are referred to as e.g. ABE14. The first three letters of the area where the speaker comes from were used with a number, which was assigned chronologically in the order of the recording. Hence, ABE14 was the 14\textsuperscript{th} speaker from Aberystwyth who was recorded.

The segmentation, and the phonetic and statistical analyses, were done using Praat (Boersma & Weenink 2014) and R (R Core Team 2015, R Studio Version 0.98.1049 – 2009-2013), using R packages blme 1.0-3 (Dorie 2015), Diptest (Maechler 2015), Effects (Fox 2015), lme4 1.1.-7. (Bates, Maechler, Bolker & Walker 2014), and lmerTest 2.0-25 (Kuznetsova 2015).

\textsuperscript{17} The speakers often said that they had forgotten they had been wearing the microphone, unless they were wearing glasses.
2.3. Data

The Aberystwythians were recorded reading a list of words. The material was recorded primarily in order to assess the segmental conditioning of pre-aspiration in detail. As mentioned in Chapter 1, pre-aspiration is typically studied in the plosive context, and this is why a wide range of segmental factors was controlled for in the plosive environment. However, pre-aspiration is also attested in the fricative context, and so a more limited data was obtained to allow basic differences between the plosive and the fricative contexts to be explored. Finally, with the exception of Stevens & Hajek (2004b), pre-aspiration studies concentrate only on stressed syllables. A limited amount of data was also collected to test whether pre-aspiration is indeed limited to stressed syllables. The tokens with obstruents in unstressed syllables always appeared in isolation and not in a carrier sentence.\(^{18}\)

The three datasets are described in more detail in what follows.

The word lists for the plosive and the fricative data are available in Appendix A.1, and the distractors in Appendix A.3.

2.3.1. Segmental and prosodic variability in tokens with plosives

For the female speakers, the items analysed in this study include 'CVC and 'CVCV structures. These structures present a combination of /a/, /e/, /ɪ/, /ʊ/, /ɒ/, /ʌ/ with /p/, /t/, /k/ to the extent to which such combinations were possible. The plosive is thus found either word-finally or word-medially and is always post-tonic. This yields words such as \textit{bap, bat, back; lapper, latter, lacquer}. With the exception of two speakers, /ʊ/ was recorded only in 'CVC words (e.g. \textit{look}). The long vowels /aː/ and /oː/ were similarly recorded only in 'CVC words (e.g. \textit{part, port}). For reasons of time, for two female speakers (ABE17, ABE50) tokens with /ʌ/ were not coded for the analyses.

For the same reasons, the male data was coded and analysed only for words combining /a/ and /u/ with /p/, /t/, /k/ in 'CVC and 'CVCV structures. These two vowels have been targeted because they represent the lowest and the highest vowels,

\(^{18}\) The fact that the obstruents in unstressed syllables are limited to the isolation condition does not however have an effect on the comparison between the stressed and the unstressed conditions.
and as shown above pre-aspiration has been reported to be conditioned by vowel height in terms of its duration and frequency in a number of related and unrelated languages (McRobbie-Utasi 1991: 10, McRobbie-Utasi 2003: 3, Stevens & Hajek 2004b: 59, Gordeeva & Scobbie 2007, Nance & Stuart-Smith 2013: 11).

In total, this resulted in 500-615 plosive tokens per female respondent and 245-250 tokens per male respondent.

Each word type was obtained once in isolation and twice in a carrier sentence Say X once. This was opted for for two reasons. Firstly, Chapter 6 focuses on the acoustic correlates of the fortis-lenis contrast in plosives (/p/, /t/, /k/ vs /b/, /d/, /g/) and in the word-initial position (pat vs bat) it is crucial whether the plosive is preceded by a pause or a (voiced) segment (e.g. Lisker & Abramson 1964; Docherty 1992: 140, 167). Secondly, Chapter 5 focuses on the relationship between pre-aspiration and glottalisation, and glottalisation is often found domain-finally (Catford 1977: 100; Huffman 2005: 351; Slifka 2006). It would have been optimal to contrast words in a carrier sentence which places them in its middle (Say X once.) with those occurring at the end of a carrier sentence (Say X.). However, as this would have resulted in a rather time-consuming recording session and because the analyses of the correlates of the fortis-lenis contrast focused on plosives preceded a pause as opposed to a voiced segment through comparisons of words in a carrier sentence as opposed to words in isolation, words in isolation were also used as a different prosodic condition for tests of glottalisation.

2.3.2. Segmental and prosodic variability in tokens with fricatives

The speakers were also recorded for words with a post-tonic fricative (CVC structure). These words contained /æ/, /ɛ/, /ɪ/, /ɒ/ and /ʌ/ combined with /θ/, /ð/, /ʃ/, and /ʃ/ in the female data to the extent to which this was possible, and the male data was again coded and analysed only for /æ/ and /ɪ/ combined with the same fricatives (e.g. mass, mess, moss, miss, fuss). For two females, tokens with /ʌ/ were again not analysed.

As with the plosive tokens, each word type was obtained once in isolation and twice in a carrier sentence Say X once. This resulted in 60-70 tokens per female speaker,
and 30-35 tokens per male speaker. In total, the plosive environment is represented with 8,555 tokens and the fricative environment with 992 tokens.

2.3.3. Segmental variability in tokens with obstruents in unstressed syllables

Only seven of the speakers (all females) volunteered to be rerecorded for additional analyses of pre-aspiration in unstressed syllables ('CVCVP and 'CVCVF; e.g. frolic and Wallace). The procedure was the same as for the recording session focusing on pre-aspiration in stressed syllables, as described above (including the distractors, randomisation, and breaks; but excluding the interview). In total, 460 tokens were obtained, ranging from 56-67 tokens by speaker. The target items can be found in Appendix A.2.

Tokens with ambiguous glottal activity and tokens with signal dysfluencies were excluded from the analyses.

2.3.4. Nuisance variables

None of the word lists were controlled for an equal distribution of lexical frequency, and a concern arises as to whether lexical frequency could affect pre-aspiration in a way interfering with the segmental and the prosodic conditioning. This would be the case only if there are any correlations between lexical frequency and the vowel or the consonant phoneme.

The tokens were therefore coded for lexical frequency based on SUBTLEX-UK (van Heuven, Mandera, Keuleers & Brysbaert 2014). A single speaker was analysed regarding whether the vowel phoneme or the place of articulation of the consonant conditions lexical frequency, and because the lexical items appear just once in isolation and twice in a carrier sentence, only the isolation context was used for the tests. No correspondences have been found either for vowel phoneme or the place of articulation of the following consonant and lexical frequency (Kruskal-Wallis, p > 0.05). Furthermore, lexical frequency was never significant in any models presented in the entire thesis, and so it is not commented on further.
In addition, because smoking could affect pre-aspiration or breathiness, only life-long non-smokers are analysed throughout the thesis.

2.4. Aspects of pre-aspiration

Two aspects of pre-aspiration are looked into in this thesis: 1. frequency of occurrence (How often does pre-aspiration occur in context A as compared to context B?); and 2. duration (How long is pre-aspiration in context A as compared to context B?). Every chapter focuses on the frequency of occurrence of pre-aspiration. Chapters 3-4 and 7 also deal with its duration. The two aspects are further commented on below. All the aspects of pre-aspiration were subject to manual segmentation and it was thus the research’s decision where pre-aspiration started and ended, which is outlined in more detail in Chapter 3.

2.4.1. Duration

The duration of pre-aspiration was measured in ms.\(^{19}\) Although the author did her best to ensure that the speaking rate was as comparable as possible across speakers, to make sure that differences in speaking rate do not represent a confound, the durational measurements were normalised.

Many researchers investigating pre-aspiration do not use any normalisation (e.g. Clayton 2015; van Dommelen & Ringen 2007; Helgason & Ringen 2008; Jones & Llamas 2007; McRobbie-Utasi 2003; Morris 2010; Stevens & Hajek 2004c; Stevens 2010) and in a handful of studies this is because only one speaker is analysed (Helgason 1999a). McRobbie-Utasi analyses two speakers and the difference in the duration of pre-aspiration is not significant for them (2003), which renders normalisation unnecessary. Like McRobbie-Utasi, Pétursson (1972) describes pre-aspiration of two Icelandic speakers, discussing each of them separately.

\(^{19}\) Following the manual segmentation described fully in Chapter 3, the durational results were extracted automatically with scripts designed by Shigeto Kawahara (modified by James Kirby and Wendell Kimper) and Olga Gordeeva, measuring the distance between the boundaries established by the author.
Although these studies do not normalise pre-aspiration duration, some of the authors refer to ratios. For example, Jones & Llamas briefly mention that “[p]re-aspiration of a duration approximately equal to the duration of the preceding modal voicing of the vowel was evident for all 3 [Middlesbrough English] speakers before /t/ […]. Similar durations of pre-aspiration were also seen for the two phonological fricatives” (2007: 656). Similarly, McRobbie-Utasi provides comparisons of the raw measurements between pre-aspiration duration, vowel duration, and consonant duration for a number of different syllabic contexts.

Nance & Stuart-Smith (2013) use ratios to normalise for speaking rate. To normalise durational values of pre-aspiration and breathiness word-medially and word-finally, they take vowel duration and pre-aspiration as 100% and quantify the duration of pre-aspiration and breathiness as a proportion of the interval including vowel duration and pre-aspiration. As the authors note, for some analyses this seems to be ineffective (2013: 134). It is not stated explicitly why, but they do mention analyses involving phonologically short and long vowel in particular in connection to this ineffectiveness. However, in the analyses not contrasting phonological vowel length, the authors report no difference in the results between the normalised and the non-normalised measurements (2013: 143).

In this thesis, the following formula was used to normalise durational measurements:

\[
\frac{\text{Pre-aspiration duration (ms)}}{\text{(Word duration (ms))/100}}
\]

In other words, the interval in question was quantified as a percentage of the duration of the word in which it was measured. Throughout the thesis, variables other than pre-aspiration also had to be normalised durationally, and the same procedure was applied to these (duration of breathiness, vowel, voicing, release, voiceless closure, and glottalisation). One of the reasons why Nance & Stuart-Smith’s normalisation method was not adopted is because many of the analyses in this thesis include phonologically short and long vowels.

The question nevertheless remains whether this normalisation method is appropriate. In particular, since the words analysed here are monosyllabic (e.g. pat) and disyllabic (e.g. patter), it is in place to ask whether the difference in the syllable count may not skew the results since it has been found that the duration of segments
is shorter as the number of syllables of words gets higher (e.g. Klatt 1974).\textsuperscript{20} However, the fact that disyllabic words are associated with shorter segments than monosyllabic words is relevant both for raw and normalised measurements, and as long as the number of syllables is included in the statistical analyses as a possible factor and as long as its interactions with other factors are taken into consideration, it should remain clear which patterns are due to segmental conditioning and which are due to prosodic conditioning.

The chapters which include durational measurements therefore all consider interactions between the number of syllables and various other, segmental and prosodic, factors which may have an effect on pre-aspiration or breathiness duration. This is of relevance for Chapters 3, 4, and 7. Yet, for many of the analyses, the differences in the syllabic structure are irrelevant. For example, in Chapter 4 the analyses of vowel duration across phonologically short and long vowels are done on ‘CVC words only and separately for each individual (using raw measurements). Distributional analyses are similarly done separately for each individual (using again the raw data). In Chapter 6, durational analyses are done separately for ‘CVC and ‘CVCV words. Furthermore, there is no difference in the results using raw vs normalised data in Chapter 7, and since the speakers do not differ in the number of ‘CVC and ‘CVCV words, any differences found are either individual, generational, or sex/gender-based.

Finally, many of the remaining analyses (Chapter 3 and vowel height and vowel backness analyses in Chapter 4) were done both on the raw and the normalised measurements and, where this was done, the results were the same. This is shown in Figures 2.1. and 2.2. below:

\textsuperscript{20}I am thankful to Francis Nolan for raising this issue.
Figure 2.1. Normalised and raw durations of pre-aspiration and breathiness and the effect of the type of utterance

Durational differences across tokens uttered in isolation (e.g. pat, 'abs') vs in carrier sentence (e.g. Say pat once, 'in')
Figure 2.2. Normalised vs raw durations of pre-aspiration and breathiness across different stress conditions and segmental conditions

The segmental factor shown in the figure is manner of articulation of the consonant conditioning pre-aspiration and/or breathiness (plosive vs fricative)

The only visually striking difference in these two figures is that between the duration of normalised and raw pre-aspiration in plosives in unstressed syllables (e.g. frolic); however, the statistical analyses produce the same results irrespective of whether raw or normalised measurements are used.

Within the analyses used in Chapter 3, only one of the (many) analyses is different for the raw and the normalised data, and this is where the effect with the raw data is
already very small.21 One last discrepancy between the raw and the normalised measurements is related to two of the (many) analyses in Chapter 4. These two differences are as follows: within /i/ and /aː/, the duration of breathiness is affected by F2 only if normalised. However, this discrepancy does not have bearing on the issues discussed in the chapter, since the conclusions are the same with the normalised as well as non-normalised data.

On the whole then, the normalisation used is seen as appropriate to ensure that no speaking rate differences present a confound since most of the analyses are done on both raw and normalised data with no difference in the vast majority of the cases.

2.4.2. Frequency of occurrence of pre-aspiration

The frequency of occurrence of pre-aspiration and breathiness was coded in the following way: pre-aspiration values of 0ms were labelled with “no” (Pre-aspiration is absent.), and any other values were labelled with “yes” (Pre-aspiration is present as long as its duration is higher than 0ms.). This methodology is different from that adopted by Helgason, who counted tokens as pre-aspirated only if pre-aspiration reached at least 15ms (2002: 152).

The next chapter addresses the question of whether it is appropriate to treat pre-aspiration and breathiness as the same phenomenon through the phonetic analyses of the segmental, and to some extent also prosodic, conditioning of each. It therefore also serves as an overview of the segmental factors that condition pre-aspiration.

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21 The only difference between the analyses using normalised as opposed to raw measurements is found when comparing the effects of phonological vowel length in /a/ vs /aː/. With the normalised data, only pre-aspiration duration is affected, whereas breathiness duration is not – on the whole, the effect of length on the duration of breathiness is smaller than its effect on the duration of pre-aspiration. With the raw data, pre-aspiration and breathiness duration are both affected by vowel length, but it is still the case that the effect is stronger for pre-aspiration.
Chapter 3 – Pre-aspiration and breathiness

3.1. Introduction

The first chapter presented a broader definition of pre-aspiration as (primarily) glottal friction found in the sequences of sonorants and phonetically voiceless obstruents (matt [maʰt], mass [maʰs]), where pre-aspiration commonly follows the modal portion of the vowel. It was also said that pre-aspiration is generally seen as consisting of two components: voiced glottal friction, or breathiness, and voiceless glottal friction, or (voiceless) pre-aspiration. Previous research into pre-aspiration has treated breathiness as its necessary component. Voiceless pre-aspiration and voiced breathiness therefore tend to be added up in research looking into the effects on the duration of pre-aspiration (Helgason 2003; Helgason & Ringen 2008; Karlsson & Svantesson 2011; Ringen & van Dommelen 2013; Stevens 2010, 2011; Stevens & Hajek 2004b, 2004c), or we do not know if breathiness is measured as part of pre-aspiration (Helgason 1998; McRobbie-Utasi 2003; Tronnier 2002), and they are distinguished only sometimes (Kingston 1990; Ní Chasaide 1985; Nance & Stuart-Smith 2013), in which case differences in the segmental and the social conditioning are found.

In line with Kingston (1990), Nance & Stuart-Smith (2013), and Ní Chasaide (1985), this chapter shows that the two should be distinguished. This is demonstrated on their sensitivity to a number of conditioning factors, adopting the assumptions that if pre-aspiration and breathiness are two components of a single phenomenon, they will

1. either show the same tendencies regarding their conditioning (e.g. the higher the vowel, the shorter the pre-aspiration; and the higher the vowel, the shorter the breathiness)

2. or they will show complementary tendencies, a trading relationship (e.g. the higher the vowel, the shorter the pre-aspiration; but the higher the vowel, the longer the breathiness).

22 For an example of such a trade-off, see e.g. Beddor (2007) for the behaviour of the duration of vocalic nasalisation and that of a nasal in VN sequences.
Although pre-aspiration and breathiness show consistent similarities regarding some conditioning factors this chapter looks into, with others they exhibit consistent differences, and considering the remaining conditioning factors, there is an equal mixture of similarities and dissimilarities.

More specifically, pre-aspiration and breathiness agree in that they are affected in the same way by vowel height, vowel backness/roundness, and the type of utterance the token in question appears in (isolation vs carrier sentence: pat vs Say pat once.). Each is more frequent with a mid rather than a high vowel and each is longer with a mid rather than a high vowel. As will be shown, this is not due to correlations between vowel height and vowel duration and this is not due to the normalisation used either. Additionally, neither pre-aspiration nor breathiness is sensitive to vowel backness/roundness. Finally, they are both longer in words uttered in isolation (in the plosive context) rather than in a carrier sentence and their frequency of occurrence is not affected by this factor.

Pre-aspiration and breathiness most clearly differ regarding their conditioning by the manner of articulation of the consonant they are associated with (plosive vs fricative – ‘CVP(V) vs ‘CVF: matt vs mass), by whether they are in stressed or unstressed syllables (‘CVP(V), ‘CVF vs ‘CVCVP, ‘CVCVF: matt, matter, mass, vs gullet, Wallace), and also by the place of articulation of the fricative in ‘CVF words (/f/ vs /θ/ vs /s/ vs /ʃ/: if, myth, miss, fish). The first two factors are intertwined: whilst pre-aspiration is more frequent in stressed than unstressed syllables, it is also less frequent with fricatives than plosives in unstressed syllables (‘CVCVF vs ‘CVCVP: Wallace vs gullet). In contrast, regardless of whether it appears in stressed or unstressed syllables, breathiness is found more frequently with fricatives. Another difference is that, unlike pre-aspiration, breathiness is obligatory in fricatives in stressed syllables (‘CVF: mass) and in fricatives and plosives in unstressed syllables. In addition, pre-aspiration is sensitive to the place of articulation of the fricative in ‘CVF words, but breathiness is not.

The disagreeing patterns do not offer a complementary relationship between pre-aspiration and breathiness, excepting one. A possibly complementary pattern is found regarding the conditioning by the manner of articulation of the consonant in unstressed syllables (‘CVCVP vs ‘CVCVF: gullet vs Wallace). As noted above in the
discussion of the three main differences in the conditioning of pre-aspiration and breathiness, pre-aspiration is less frequent with fricatives than with plosives and breathiness is more frequent with fricatives than plosives.

What is apparent from the conditioning of the frequency of pre-aspiration and breathiness is that pre-aspiration in principle co-occurs with breathiness: it holds that where pre-aspiration is found, breathiness is found as well in the vast majority of cases. Nevertheless, it is not the case that where breathiness is found so is pre-aspiration. This points to breathiness being a precursor to pre-aspiration.

The next section reviews in more detail the treatment of pre-aspiration and breathiness as a single phenomenon in the existing literature.

3.1.1. Pre-aspiration and breathiness in previous research

Previous research into pre-aspiration has usually treated breathiness and pre-aspiration as a single unit. Especially in phonological discussions, the reader does not know whether pre-aspiration refers to voiceless pre-aspiration and breathiness or just the former (e.g. Árnason 1986, Keer 1998). Thráisson describes pre-aspiration as voiceless (1978: 4), but leaves the reader with the impression that Icelandic pre-aspiration is only ever voiceless and we do not know if this is supposed to reflect the phonetic observations. In fact, evidence presented in Helgason (2002: 13) suggests that there is at least a brief interval of breathiness in Icelandic pre-aspiration and that offered by Kingston (1990: 419) shows an example in which breathiness can be longer than pre-aspiration in the same language.

Pre-aspiration and breathiness tend to be analysed as a single interval in phonetic studies as well. Some studies add the two up in analyses of duration of pre-aspiration (in addition to those mentioned above, van Dommelen 1999; van Dommelen 2000; van Dommelen, Holm & Koreman 2011: 600; Morris 201023). In other studies, we simply do not know if breathiness is considered part of pre-aspiration (Helgason

23 In Morris (2010), this was done because no instances of breathiness without pre-aspiration were found in his data (personal communication).
McRobbie-Utasi presents an explicit statement that breathiness and pre-aspiration are not the same phenomenon: “Even though in the case of preaspiration the cessation of voicing after the vowel may not be always abrupt, the voicing period is but a short interval and definitely not to be associated with the preaspiration period itself” (1991); however, the readers are not informed why. This may seem a primarily methodological issue, but the answer may be relevant for both synchronic and diachronic analyses of pre-aspiration.

Firstly, Chapter 1 touched upon unabated debates related to the question of whether pre-aspiration is affiliated with the vowel \(C|V|h|C: [m|a|h|s]\), the consonant \(C|V|h|C: [m|a|h|s]\), both \(C|V|h|C: [m|a|h|s]\), or neither \(C|V|h|C: [m|a|h|s]\). One common method to approach this question is through analyses looking for strong and consistent correlations between the durations of various intervals, such as part-whole correlations comparing correlational relationships of [vowel + pre-aspiration duration] with [pre-aspiration duration] as opposed to [pre-aspiration + consonant duration] with [pre-aspiration duration] (e.g. Kingston 1990).

Another possibility is that employed by Stevens & Reubold (2014), who determine the affiliation of pre-aspiration through C/V ratios. They compute three ratios: 1. C/V without pre-aspiration; 2. \(C_{pre}+V\); and 3. \(C/V_{pre}\). The first ratio is associated with geminate plosives lacking pre-aspiration, and the latter two with geminate plosives with pre-aspiration. If \(C/V_{pre}\) in the geminates was smaller than C/V in the singletons, pre-aspiration was seen as part of the consonant. If the same ratio was bigger, then pre-aspiration was seen as patterning with the vowel. Finally, if including pre-aspiration produces no difference when the pre-aspiration inclusive ratio is compared to the singleton ratio (\(C/V_{pre} \sim C/V\), pre-aspiration is seen as independent.

However, even studies concerned with the affiliation of pre-aspiration do not always distinguish breathiness and pre-aspiration in the analyses themselves, although breathiness is commented on in methodology sections as part of pre-aspiration in...
production analyses (e.g. Stevens & Reubold 2014: 472). Kingston’s study (1990) stands out because ultimately he distinguishes pre-aspiration and breathiness and finds that they are co-ordinated with the vowel and the consonant differently (1990: 420).26

Secondly, certain sound changes could benefit from distinguishing pre-aspiration and breathiness. For the historical development of Mongolic languages, it has been proposed that pre-aspiration affiliated to the post- tonic plosive has shifted its affiliation to become post- aspiration of the pre-tonic plosive, which had originally been unaspirated: TV^bT > T^bVT (Svantesson & Karlsson 2012: 462). This could happen either through misperceiving post-tonic pre-aspiration as the post-aspiration of the onset plosive, or through a gradual regressive assimilation whereby the vowel becomes more breathy and the friction generated by the glottis could spread to the onset plosive. The two could also be combined.

If vowels and consonants are thought of as two ends of the same scale, the fact that breathiness is articulatorily and acoustically closer to the vowel end and pre-aspiration to the consonant end could explain why in some languages/varieties pre-aspiration (as usually understood in phonological literature, i.e. in the broad sense, including breathiness) is part of the consonant, part of the vowel, both, or neither. This does not mean that breathiness and pre-aspiration are unrelated phenomena: as will be shown in Chapter 6, they are comparably strong acoustic correlates of the fortis- lenis contrast in plosives word-medially and word-finally, and there is no doubt that they are closely related. It is their associations with one another that vary in strength. These associations and their variable strength must be due to the similarities and differences in their segmental and prosodic conditioning, the latter of which includes the topic of their segmental affiliation.

Ní Chasaide considered the question of whether breathiness is just a necessary component of pre-aspiration in more detail (1985: 71, 96, 134, 137, 185, 356, 365-7, “clear friction of relatively strong amplitude” as more important than presence of voicing in distinguishing the two (1998: 2037), similarly to Gordeeva & Scobbie (2010: 178-9).

26 Van Dommelen distinguishes pre-aspiration and breathiness, but his analyses focus only on the affiliation of pre-aspiration, not breathiness. In one of the three correlational analyses, and the only one showing at least a moderate and a significant correlation, pre-aspiration duration is found to correlate positively with that of the interval starting with the vowel onset and ending with the end of the closure [= vowel duration + breathiness duration + pre-aspiration duration + closure duration]. This is interpreted as evidence that pre-aspiration is a segment in its own right (1999: 2039).
She carried out perceptual experiments using Icelandic data with three Icelandic respondents and two phonetician respondents. The subjects were played the stimuli and had to decide whether pre-aspiration was present or absent. The author concluded that “[…] the breathy voiced transition belongs perceptually to pre-aspiration, and should not be apportioned to the vowel” (1985: 185) because on its own it is sufficient to cue the pre-aspirated stop (1985: e.g. 373, 392). There is thus no or little doubt that breathiness on its own can cue the contrast between pre-aspirated plosive and a plosive without pre-aspiration (i.e. fortis-lenis contrast).

Nonetheless, if two things cue the same contrast, this does not necessarily render them two parts of the same phenomenon. For example, it has been shown that in languages not thought of as pre-aspirating, the duration of the preceding vowel suffices on its own for the respondents to perceive the fortis-lenis contrast (e.g. Denes 1955; House 1961; Krause 1982; Raphael 1971; Raphael, Dorman & Freeman 1975). Because pre-aspirated plosives in Icelandic are found only with phonologically short vowels, which are also phonetically shorter than the long vowels, we could similarly expect that both vowel duration and pre-aspiration cue pre-aspirated plosives in the language and yet this does not lead to the conclusion that pre-aspiration is part of the vowel rather than the plosive. We could similarly ask if the type of the plosive can predict the type of the vowel that precedes this plosive.

The problem could be formulated yet in the following way as well: both post-aspiration and voicing or pre-aspiration and voicing may function as cues to the fortis-lenis contrast in the same language (Helgason & Ringen 2008), and release duration and the following vowel duration can similarly distinguish a laryngeal plosive contrast (Choi 2011: 487), but that does not mean that vowel duration and voicing duration or vowel duration and release are the same phenomenon. It means that these individual aspects share the same function.

The next section lists the factors reported to condition pre-aspiration.

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27 The author specifically asked the participants to listen for whether the consonant was pre-aspirated. “It was not thought suitable to phrase the question as one of deciding between the linguistic options available in Icelandic, the problem being that the contrasts in Icelandic involve additional parameters other than preaspiration.” (Ni Chasaide 1985: 364).
3.1.2. Factors conditioning pre-aspiration

The most relevant, or at least the most often discussed, factors conditioning pre-aspiration\textsuperscript{29} are those of vowel height (e.g. Stevens & Hajek 2004b: 59), the place of articulation of the plosive with which pre-aspiration is found (e.g. Nance & Stuart-Smith 2013: 10), and vowel length (e.g. Helgason 2002: 48-9). Svantesson & Karlsson also report the effect of the laryngeal specifications of the prevocalic consonant on the duration of pre-aspiration (2012: 461-2). Furthermore, the position within the word has been found important (Hejná & Scanlon 2015). Finally, three possible factors are mentioned in the literature either impressionistically or they are implied: vowel backness/roundness (McRobbie-Utasi 1991), stress, and the manner of articulation of the consonant pre-aspiration occurs with (Hansson 2001: 157). Each of these factors is commented on in more detail in the sections discussing the results for the Aberystwyth data.

The next section presents 1. how pre-aspiration and breathiness were identified in the plosive and the fricative environments; 2. exactly how the potential vocalic factors were identified and teased apart (or not); 3. how some of the consonantal factors were identified; and 4. a summary of the factors analysed in this chapter.

3.2. Methodology

3.2.1. Identifying pre-aspiration and breathiness

The identification of pre-aspiration and breathiness is discussed first for the plosive environment and next for the fricative environment because the two contexts present slightly different challenges in this respect.

\textsuperscript{28} However, it does lead to the conclusions that pre-aspiration duration and vowel duration interact in a complementary way to preserve a higher-order invariant of vowel-to-rhyme ratio (Pind 1996a, 1996b, 1998).

\textsuperscript{29} Pre-aspiration in the broader sense, i.e. including breathiness and voiceless pre-aspiration.
**Plosives**

Pre-aspiration is defined and identified here as a period of voiceless friction found in the sequences of sonorants and phonetically voiceless obstruents, as illustrated in Figure 3.1., in which “pre” stands for voiceless pre-aspiration, “clo” for closure, and “post” (visible as “po”) as post-aspiration. The label “pre” always stands only for voiceless pre-aspiration throughout this thesis.

![Figure 3.1. Voiceless pre-aspiration in the plosive context](image)

*Illustrated on the word backing, a female speaker of 24 years (ABE45). ‘Pre’ stands for voiceless pre-aspiration, ‘clo’ for voiceless closure, and ‘post’ for post-aspiration (visible as ‘po’ in the figure)*

When identifying pre-aspiration (or indeed most of the linguistic aspects analysed in the thesis), the dynamic range was reduced to 50-65dB, depending on the speaker/recording, and the view range was set to 0-8,000Hz rather than the default 5,000Hz.

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30 The phonological categories of e.g. /b/, /d/, or /g/ can be realised as phonetically voiced or voiceless, and because phonetic voicing during the closure is incompatible with pre-aspiration, it follows that pre-aspiration is only found with phonetically voiceless obstruents.

31 The amount of post-aspiration is not particularly high in the illustration, but pre-aspiration frequently co-occurs with post-aspiration in the data.

32 What Figure 3.1. also shows is that pre-aspiration is labelled as part of the consonant. This decision is a practical one – the boundary between the vowel and the consonant had to be placed somewhere. This boundary is however considered carefully where this may affect analyses including vowel and consonant duration.
Reducing the dynamic range helped when the silent periods of the signal were grey rather than white. This frequently helped to differentiate between pre-aspiration and background noise, as illustrated in Figures 3.2 and 3.5. (“br” stands for breathiness, which is discussed further below).

Figure 3.2. Identification of pre-aspiration with the default dynamic range setting (70dB)

Illustrated on the word back, a female speaker of 58 years (ABE46). ‘br’ stands for breathiness, ‘pre’ stands for voiceless pre-aspiration, and ‘clo’ for voiceless closure.

Figure 3.3. Identification of pre-aspiration with the dynamic range reduced to 50dB

Illustrated on the word back, a female speaker of 58 years (ABE46). ‘br’ stands for breathiness, ‘pre’ stands for voiceless pre-aspiration, and ‘clo’ for voiceless closure.
Figure 3.4. Identification of pre-aspiration with the default dynamic range setting (70dB) II

Illustrated on the word sit, a female speaker of 58 years (ABE46). ‘br’ stands for breathiness, ‘pre’ stands for voiceless pre-aspiration, and ‘clo’ for voiceless closure.

Figure 3.5. Identification of pre-aspiration with the dynamic range reduced to 50dB II

Illustrated on the word sit, a female speaker of 58 years (ABE46). ‘br’ stands for breathiness, ‘pre’ stands for voiceless pre-aspiration, and ‘clo’ for voiceless closure.
The view range was set to 0-8,000Hz because sometimes friction could be seen, or seen better, in frequencies above 5,000Hz, as shown in Figures 3.6. and 3.7.

Figure 3.6. Identifying pre-aspiration with the default view range (0-5,000Hz)

Illustrated on the word sit, a female speaker of 58 years (ABE46). 'br' stands for breathiness, 'pre' stands for voiceless pre-aspiration, 'clo' for voiceless closure, and 'post' for post-aspiration

Figure 3.7. Identifying pre-aspiration with the view range of 0-8,000Hz

Illustrated on the word sit, a female speaker of 58 years (ABE46). 'br' stands for breathiness, 'pre' stands for voiceless pre-aspiration, 'clo' for voiceless closure, and 'post' for post-aspiration
The examples of pre-aspiration seen in Figures 3.4.-3.7. could rather be seen as instances of pre-affrication (Laver 1994). Although pre-aspiration and pre-affrication can be conceived as two different phenomena, in many of such cases in the data analysed here, it was very difficult, if not impossible, to reliably establish whether the friction was produced solely in the oral cavity and was due to the narrow constriction especially in the sequences of /t/ and /t/, or whether this was also combined with glottal aspiration. As seen in Figure 3.7., for example, the voiceless friction is preceded by a breathy interval, and this complicates the decision making between pre-affrication and pre-aspiration. These instances, although not numerous, are considered cases of pre-aspiration in this thesis.

Pre-aspiration is often accompanied by breathiness, which presumably serves as a transition from the modal voicing of the vowel to the voiceless pre-aspiration, as illustrated in Figure 3.8. Breathiness is distinguished from pre-aspiration by presence of voicing. “br” stands for breathiness, “voice” for voicing, and “unpost” (seen as “un”) as an unaspirated release.33

Figure 3.8. Breathiness in the plosive context

Illustrated on the word bat, a female speaker of 22 years (ABE52). ‘br’ stands for breathiness, ‘pre’ stands for voiceless pre-aspiration, ‘clo’ for voiceless closure, ‘post’ for post-aspiration, ‘voice’ for voicing, and ‘unpost’ for unaspirated release.

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33 Breathiness was labelled as part of the vowel. Again, this is a decision based on the need to place the VC boundary somewhere, but this is taken into consideration in the analyses of the effects of vowel and consonant duration.
Although the graphs presented in this thesis most often show the pitch tracker (blue line, as in Figure 3.8.), the pitch tracker was not relied on to determine whether voicing is present or absent in the acoustic signal. In fact, it was often switched off as it could obscure the spectrographic information at lower frequencies inspected to identify the left boundary of breathiness (as discussed further below). The presence of voicing was decided primarily by the waveform information and its identification determined the right boundary of the breathy interval, as illustrated in Figures 3.9 and 3.10.

![Figure 3.9. Determining the right boundary of breathy intervals](image)

*Illustrated on the word Huck, a female speaker of 58 years (ABE46). 'br' stands for breathiness and 'pre' for voiceless pre-aspiration*
As can be seen especially in Figure 3.9., increasingly less quasi-sinusoidal ripples in the waveform were considered indicators of an articulatory gesture associated with voicing cessation, and the right boundary of breathy intervals was placed where these (sometimes highly) quasi-sinusoidal ripples came to an end. In some cases, however, it can be expected that different labellers would have placed the boundary at slightly different places. One such case is shown in Figure 3.10.: it is conceivable that another researcher would have placed the boundary further to the right, depending on the interpretation of the ripples. One such example is illustrated in Figure 3.11.
Even after zooming in (Figure 3.12.), we could still argue whether one more ripple should be included. The difference in the segmentation would amount to 8 ms in this case.
With the segmentation of every data token, various scaling was employed to inspect the waveform to identify voicing.

In comparison to the right boundary of breathy intervals, its left boundary, or the onset, is not always straightforward to determine. This has been explicitly commented on by Nance & Stuart-Smith as “the most challenging division to the [consonantal] segment” (2013: 134), but they add that zooming in enabled consistent segmentation. On the other hand, Kingston explicitly states that the breathy interval and the voiceless pre-aspiration interval “[…] could be identified consistently by eye” in his Icelandic data (1990: 418). We could hypothesise that this difference of opinions on the matter could be caused for example by whether the onset of breathiness, or indeed the whole breathy interval, is caused by the fact that the vocal folds may be coming further apart throughout the breathy interval with consistently increasing degrees in some languages, whilst in other languages the increase could be less gradient, and yet in others it could be very abrupt indeed. Iosad informs me that in his Welsh data breathiness tends to be incredibly short and sets off very abruptly (personal communication, 2015).

The Aberystwyth data is representative of the second possibility of relatively abrupt, or less gradient, breathy onset (Figure 3.13.).
Figure 3.13. Relatively abrupt / less gradient breathy onset

Illustrated on the word bat, a female speaker of 22 years (ABE52). ‘br’ stands for breathiness, ‘pre’ stands for voiceless pre-aspiration, and ‘clo’ for voiceless closure.

The Aberystwyth data rarely offers the first possibility (Figure 3.14. and 3.20.).

Figure 3.14. Gradient offset of breathiness & considerably breathy vowel

Illustrated on the word chapter, a female speaker of 24 years (ABE45)
Indeed, in some cases the breathiness affects most of the vowel in a more or less uniform way (Figure 3.15.) or the entire vowel (3.16.).

![Figure 3.15. Breathiness affecting most of the vowel](image)

*Illustrated on the word otter, a female speaker of 22 years (ABE52)*

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34 This phrasing implies that breathiness is part of the vowel. Most likely, this may be very difficult, if not impossible, to decide on production data. However, the fact that breathiness can be found throughout the vowel in speakers who do not generally have breathy phonation (or breathy to such a degree) would suggest that it must be part of the vowel because otherwise there would be instances of vowel-less words. There are also infrequent instances of words in which there is only voiceless glottal friction in place of the vowel (or the vowel is realised as voiceless glottal friction entirely). This would suggest that pre-aspiration must be part of the vowel; however, further research interested in breathiness or pre-aspiration affiliation needs to consider how common such examples are.
Figure 3.16. Breathiness affecting the whole vowel II

Illustrated on the word *pact*, a female speaker of 22 years (ABE52)

Although onsets of breathiness more abrupt than in Figure 3.13. are not generally found in the Aberystwyth data, there seem to be more cases of pre-aspiration with no breathiness in those speakers who have a tendency to glottalise (Figure 3.17.), which renders the onset of the voiceless pre-aspiration rather abrupt. See also Figure 3.1.
Figure 3.17. Pre-aspiration preceding by no breathy interval

Illustrated on the word tacker, a female speaker of 24 years (ABE45), ‘pr’ stands for vowel-initial breathiness, ‘pre’ stands for voiceless pre-aspiration, ‘clo’ for voiceless closure, ‘post’ for post-aspiration, and ‘GSfin’ for glottalisation associated with the end of the vowel (further discussed in Chapter 5)

A variety of cues are generally applied in pre-aspiration studies to determine the left boundary of breathy intervals:

1. The waveform is less complex than in modal intervals and quasi-sinusoidal. This is a result of the opening of the vocal folds and its effect on the intensity of the harmonics (Kingston 1990: 418). The amplitude is lower as well.

2. The spectrographic information reflects the same information. There is a variable amount of friction across a range of frequencies brought about by the increased glottal friction generated by the vocal folds. In consequence, the formants are more difficult or impossible to identify because of the low intensity.

The role of these cues can be seen in the figures presented in this chapter. However, the segmentation is most likely to differ depending on the researcher by
approximately 10ms. In this thesis, the boundary was most often placed where the first two formants become less intense. This was done in conjunction with paying attention to the soundwave. In some cases, although a more abrupt decrease in formant amplitude could be identified, this was preceded by a short interval that could be possibly included in the breathy interval (Figure 3.18.).

![Figure 3.18. Two possible boundaries for breathiness onset](image)

*Figure 3.18. Two possible boundaries for breathiness onset*

*Illustrated on a batter, a female speaker of 58 years (ABE46). 'BR' stands for one possible segmentation of breathiness (involving 'BR' and 'br') and 'br' stands for another possible segmentation of the feature (involving just 'br'); 'pre' stands for voiceless pre-aspiration, and 'clo' for voiceless closure*

In such cases, the information in the spectrogram was preferred to that presented in the waveform. Only the “br” proportion as shown in Figure 3.18. was segmented as breathiness, not “br” as well as “BR”.

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35 This is estimated for the Aberystwyth English data.
In rare instances, breathiness occurs on its own without pre-aspiration. This is shown in Figure 3.19.\textsuperscript{36}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3_19.png}
\caption{Breathiness on its own in the plosive context}
\end{figure}

Illustrated on the word dip, a female speaker of 48 years (ABE24). ‘br’ stands for breathiness, ‘clo’ for voiceless closure, ‘post’ for post-aspiration, ‘(af)’ for affrication

The identification of breathiness was also more difficult in tokens with high vowels (e.g. sit), including /oː/.\textsuperscript{37} In some cases, the identification of breathiness was as challenging as that of the other vowels (Figure 3.20.).

\textsuperscript{36} In this figure, the left boundary of the breathy interval is based on the spectrographic information; however, this is masked by the presence of the pitch tracker and also by the presence of the red line of the highlighted interval. Another factor is also the scaling.

\textsuperscript{37} This vowel is in fact phonetically the highest of the eight vowels included in the analyses in this thesis.
Figure 3.20. Breathiness segmentation in high vowels

Illustrated on the word kick, a female speaker of 58 years (ABE46). ‘br’ stands for breathiness, ‘pre’ for voiceless pre-aspiration, ‘clo’ for voiceless closure, and ‘post’ for post-aspiration.

In others, it was more challenging because high vowels generally tend to have simpler waveforms. The whole vowel was labelled as breathy only if friction was observed also in the area of the second formant (Figure 3.21.).
Figure 3.21. Breathiness segmentation in high vowels II

*Illustrated on the word kicker, a female speaker of 58 years (ABE46). 'br' stands for breathiness, 'pre' for voiceless pre-aspiration, 'clo' for voiceless closure, and 'post' for post-aspiration*

Finally, where the plosive was fully spirantised, these cases were excluded from the analyses. With partially spirantised or semi-spirantised plosives (see Chapter 6), however, pre-aspiration could still be identified. Very often, semi-spirantised plosives lacked a discernible burst, but were otherwise identical to pre-aspirated plosives with visible bursts. In rarer cases, the spirantisation was more advanced, but the pre-aspiration friction was still clearly separable from that of the release.

**Fricatives**

The criteria to segment breathiness and pre-aspiration before fricatives are the same as those for plosives; however, the right boundary of pre-aspiration may be less straightforward to determine, especially in the context of fricatives other than sibilants. In the vast majority of cases, spectral information could be employed in
that usually two different centres of acoustic energy were visible, as shown in Figure 3.22. below:

As seen in Figure 3.22., even such cases presented transitions from one centre of energy to the other, and the right boundary was placed where that transition ends.

In some tokens there was a relatively long period of low-intensity friction as far as could be determined from the spectral information, as illustrated in Figures 3.23. and 3.24. These were considered realisations of pre-aspiration, in which the glottis does not generate a particularly high amount of noise.

See also Ní Chasaide & Ó Dochartaigh (1984: 146) for a related observation of apparently frictionless pre-aspiration in the plosive context. Similarly, one of the five speakers analysed in Hejné & Scanlon (2015) exhibited frictionless pre-aspiration (The authors do not mention this in the study.).
Figure 3.23. Low friction pre-aspiration in the fricative context

Illustrated on the word mash, a female speaker of 72 years (ABE31). ‘Br’ stands for breathiness and ‘pre’ for voiceless pre-aspiration.

Figure 3.24. Low friction pre-aspiration in the fricative context II

Illustrated on the word bosh, a female speaker of 54 years (ABE12). ‘Br’ stands for breathiness, ‘pre’ for voiceless pre-aspiration, and ‘unpost’ for unaspirated release.
3.2.2. Phonological classification of vowels

This part outlines how vowels were classified phonologically for the analyses of vowel height, backness/roundness, and length. Classifying vowels into phonological categories in a variety not previously researched presents a number of challenges (McMahon 2001: 84) and several aspects could be taken into consideration. Because of the issues outlined further below, only comparisons between the following pairs were done:

1. /ɪ/ and /e/ for the effects of height (KIT and DRESS)
2. /ʊ/ and /ɒ/ for the effects of height (BOOK and LOT)
3. /ɪ/ and /ʊ/ for the effects of backness/roundness (KIT and FOOT)
4. /a/ and /ɑː/ ~ /ɒː/ for the effects of length (TRAP and BATH)
5. /ɒ/ and /oː/ for the effects of length (LOT and FORCE/NORTH)

The advantage of limiting the analyses to the pair comparisons is that irrespective of our understanding of phonology, and thus how contrasts should be coded and what should be privileged in such coding, they provide clear evidence on whether there is a difference between vowels which differ in one dimension in case of 1.-2. In Aberystwyth English, backness and rounding cannot be teased apart. Finally, the long counterparts given in 4. and 5. may differ in F1 and F2 (and this is indeed consistently so for 5) and thus also in the qualitative representation at the phonological level.

There are three other possible approaches to classify the vowels for phonological height, backness/roundness, and length. First, the phonological labels can be based on where the vowel phonemes are in the phonetic space. Thus, if /ʌ/ is phonetically mid central and /a/ low central, it should be assigned the same labels for backness in the phonology. However, it has been reported that although a vowel can be phonetically central, it can still behave as phonologically back (Lees 1961, quoted by Shahin 2011: 322), and without having convenient phonological processes at our

39 It has been suggested to me that in Welsh English this may also include GOAT. The speakers were not recorded for GOAT; however, based on the impressionistic observations of this vowel, although it may be less diphthongal in Aberystwyth English than in some Southern English English accents, it does not seem to merge with the FORCE/NORTH vowel, and for some speakers the quality seems
disposal, it is impossible to know how accurately the phonetic patterning reflects the phonological system of the vowels. The assignment of phonological labels becomes even more problematic if we take into account inter-speaker variation. Whilst for the majority of the respondents analysed in this chapter the BATH vowel is realised as /ɑː/, for some it is qualitatively the same as or very similar to the TRAP vowel, /aː/. Although /u/ is phonetically back for the vast majority of the speakers, it is central for one. Finally, we can observe vowel lowering in the youngest speakers, whereby /e/ merges with /a/ regarding F1, and /ɪ/ lowers towards /e/. Would the speakers with these changes have different phonological categories? It is impossible to answer this question for this variety with the present state of knowledge.

Another possible approach would be adopting a system of a previously well-documented variety of English. Nevertheless, this approach faces some problems as well. We do not know to what extent Aberystwyth English and, for example, Received Pronunciation share the same underlying phonological representation of vowels. It is rather dubious that speakers of one variety should have the same mental representation as speakers of another variety: indeed, why should a speaker who realises the FLEECE vowel as a diphthong and hears the diphthongal realisation around himself or herself have the same mental representation as a speaker with a monophthongal phonetic realisation (McMahon 2001: 84)?

Another criterion could be the diachronic behaviour of the vowels. For example, /uː/ is often classified as a back upgliding vowel, i.e. a diphthong, in the American tradition (Labov, Ash & Boberg 2006: chapter 2) because in sound changes it patterns together with the other diphthongs (namely /ou ~ əʊ/, ow, GOAT). However, such evidence is not available for Aberystwyth English.

3.2.3. Phonological classification of prevocalic consonants

One of the potential conditioning factors of pre-aspiration and breathiness is the type of the prevocalic consonant. As discussed further below, it has been demonstrated that the laryngeal specification(s) of a prevocalic consonant are important for our understanding of pre-aspiration in Mongolic languages. The following categories of

lower as well. This needs to be analysed acoustically, but the impressions agree with Wells (1982:
prevocalic consonants are distinguished in this chapter for 'CVP(V) words (matt, matter):

a. /p/, /t/, /k/; /h/ [+spread glottis]
b. /b/, /d/, /g/ [-spread glottis] / [+voice] / underspecified / lenis\(^\text{40}\)
c. /l/, /m/, /n/, /r/ sonorants

\(/p/, /t/, /k/\) are grouped with /h/ because previous research has shown that /h/ often patterns with post-aspirated plosives in phonetic and phonological processes (American English and Korean – Davis & Cho: 2003; Korean – Kang: 2014). [+spread glottis] plosives and lenis plosives are distinguished as two separate categories because these are contrasted in the variety, and the distinction for English is generally accepted to be that of [spread glottis]. These two categories are distinguished from sonorants as well. Voicing is a redundant feature in nasals in most languages,\(^\text{41}\) whereas plosives show a high degree of phonetic and phonological variability in this regard. For English, there is no voicing contrast relevant for sonorants. Sonorants may thus pattern differently from either fortis or lenis plosives because it is not clear if they are specified as [-spread glottis] and because they are different in further respects as well.

Other consonants were not included in the analyses. These involve /f/, /s/, and /ʃ/ for up to 15-18 tokens by speaker. Such tokens were excluded from the analyses related to the laryngeal specification of the prevocalic consonant because the limited amount of tokens with pre-tonic fortis fricatives would not lead to any conclusive results.

The effect of the pre-tonic consonant is tested in the plosive environment. In the fricative environment, the word-initial consonant was controlled for as much as possible, and in most cases included the sonorants /m/ or /l/.

\(^{382, 384-5}\).  
\(^{40}\) The label lenis will be used in the rest of the chapter because it is convenient and also consistent with Chapter 6, where the term is explained in more detail.  
\(^{41}\) See Solé (2009) and page 223 in particular.
3.2.4. Summary of the conditioning factors considered

Two aspects of pre-aspiration and breathiness are analysed with respect to the phonological factors: frequency of occurrence, i.e. how frequently pre-aspiration and breathiness are found, and duration. Table 3.1 summarises the factors taken into consideration in the comparisons of pre-aspiration and breathiness.

<table>
<thead>
<tr>
<th>VOCALIC</th>
<th>CONSONANTAL</th>
<th>PROSODIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vowel height</td>
<td>Manner of articulation</td>
<td>Stress</td>
</tr>
<tr>
<td>Vowel backness/roundness</td>
<td>Place of articulation</td>
<td>Position within word</td>
</tr>
<tr>
<td>Vowel length</td>
<td>Laryngeal specifications of prevocalic consonant</td>
<td>Type of utterance</td>
</tr>
</tbody>
</table>

*Table 3.1. Summary of the factors possibly conditioning pre-aspiration and breathiness which are looked into in this chapter*

The results reveal some major differences as well as similarities between pre-aspiration and breathiness. Furthermore, they show that pre-aspiration in principle co-occurs with breathiness: where pre-aspiration is found, breathiness is found as well in the vast majority of cases. However, it is not the case that where breathiness is found, so is pre-aspiration, which points to breathiness being a precursor to pre-aspiration.

The consistent differences and similarities in the conditioning of pre-aspiration and breathiness are presented first, and these are followed by factors that show a mixed bag of results.

3.3. Manner of articulation and stress

The greatest difference between pre-aspiration and breathiness is found in their frequency of occurrence in plosives as opposed to fricatives (’CVP(V) vs ’CVF: matt
vs *mass*\(^{42}\) and stressed as opposed to unstressed syllables (*CVC*, *CVCV* vs *CVCVC*, e.g. *lack*, *lacquer* vs *frolic*; *mass* vs *solace*).\(^{43}\)

Pre-aspiration is found more frequently in stressed than unstressed syllables (\(p < 0.0001\)) and it is also more frequent with plosives than fricatives, but only in unstressed syllables (\(p < 0.001\)).\(^{44}\) In comparison, breathiness is more frequently found with fricatives than plosives (\(p < 0.0001\)), irrespective of whether the syllable is stressed or unstressed. These tendencies are summarised in Figure 3.25.\(^{45,46}\)

\(^{42}\) This was analysed for 12 female speakers for the plosive context and 18 female and male speakers for the fricative context.

\(^{43}\) This was analysed for 7 female speakers, who were the only ones who volunteered to be rerecorded for the unstressed environment.

\(^{44}\) R package lmer4 is used for linear and logistic Mixed Effects Models (Bates, Maechler, Bolker & Walker 2014) in conjunction with the lmerTest package to obtain the \(p\)-values (Kuznetsova 2015) throughout the thesis. The lmerTest package uses Satterthwaite approximations to degrees of freedom to obtain the \(p\)-values. In all the models used for the analyses in this chapter, the dependent variables are those of pre-aspiration and breathiness duration, respectively, or the presence of pre-aspiration or breathiness, respectively (with two levels: present and absent), with “speaker” and “word” included as random effects and a step-down procedure. For the analyses of how the manner of articulation and stress condition pre-aspiration and breathiness, the independent variables are “manner of articulation of the consonant” (with two levels: plosive and fricative) and “stress” (with two levels: stressed and unstressed). The full statistical information is available in Appendix B. A mixture of forward difference and treatment coding were used throughout the models as seen fit. This leads to different interpretations of the co-efficient value signs; however, the Effects package was used in conjunction to ensure that the coefficient signs were interpreted correctly (Fox 2015). Unless a variable has more than two levels, treatment coding is used in all models in this thesis.

\(^{45}\) The width of the bars reflects the number of tokens per condition. For example, in the stressed condition far fewer tokens with a fricative were included than those with a plosive.

\(^{46}\) See Appendix B for the statistical information related to all the analyses in this chapter.
On the other hand, pre-aspiration and breathiness durations agree in being longer in stressed than unstressed syllables (p < 0.0001). Unlike pre-aspiration, however, breathiness is longer in duration with fricatives than with plosives (p < 0.05). These tendencies are demonstrated in Figure 3.26.
Figure 3.26. Pre-aspiration and breathiness duration (normalised) by manner of articulation and stress

The top row shows the stressed context (‘CV(V)’) and the bottom row shows the unstressed context (‘CVCV’); the figures on the left show the duration of pre-aspiration (normalised) across the two manners of articulation (fricatives vs plosives) and the figures on the right show the duration of breathiness (normalised) across these two contexts.

Comparing the co-occurrence of pre-aspiration and breathiness across the two manners of articulation, plosives and fricatives, we find that with plosives (pat, patter) they occur together and each occurs on its own relatively infrequently, as shown in Figure 3.27.
Breathiness is however obligatory in fricatives in stressed syllables (*mass*) and in both fricatives and plosives in unstressed syllables (*Wallace*, *gullet*). It follows that when pre-aspiration is found with fricatives in stressed syllables or in unstressed syllables, it always co-occurs with breathiness since the latter is obligatory in these environments. This is further illustrated in Figures 3.28. and 3.29. For each speaker, the total number of tokens is provided at the top of the appropriate column. The y-axis of the graphs represents percentages (100% = 1.0, 20% = 0.2, etc.).
Figure 3.28. Breathiness and pre-aspiration occurrence in fricatives by speaker

Each column represents one speaker (e.g. ABE11, as indicated at the bottom); the number at the top stands for the number of tokens available for the analyses for each speaker (e.g. 33 for ABE11); the figure itself shows the percentage of pre-aspiration occurring on its own, breathiness occurring on its own, neither occurring, or the two co-occurring within each speaker.
Figure 3.29. Breathiness and pre-aspiration occurrence in unstressed syllables by speaker

Each column represents one speaker (e.g. ABE12, as indicated at the bottom); the number at the top stands for the number of tokens available for the analyses for each speaker (e.g. 67 for ABE12); the figure itself shows the percentage of pre-aspiration occurring on its own, breathiness occurring on its own, neither occurring, or the two co-occurring within each speaker.

Individual differences are also found: two speakers produce hardly any pre-aspiration in the fricative context (ABE11, ABE15), but for them breathiness is obligatory in this environment. Neither pre-aspiration nor breathiness are found very frequently on their own in the plosive environment in stressed syllables.

The results from Aberystwyth English nevertheless do not confirm the tendency for pre-aspiration to be associated primarily with plosives (Hansson 2001: 157; Clayton 2010; Silverman 2003). In the Aberystwyth data, pre-aspiration is indeed found more often with plosives than fricatives, but only in unstressed syllables. In stressed syllables, there is no difference between how frequently pre-aspiration occurs with
each manner of articulation. These results are thus also of interest to the theory of Articulatory Binding.

Kingston articulates this principle based on two observations provided by Maddieson (1984) that plosives are more often contrasted for laryngeal phenomena than fricatives cross-linguistically, and that the laryngeal specification is most frequently associated with the release rather than the onset of the oral closure (1990: 407). Kingston therefore proposes the principle of Articulatory Binding to explain these patterns: because the articulation of plosives includes a bigger obstruction resulting in a burst, there is a very salient moment in the acoustic signal, which is lacking in fricatives (1990: 408), and is more salient than closure onset. “The opening of the glottis binds to the release, because it is the acoustic character of the burst which the glottal articulation is intended to modify” (Kingston 1990: 425).

Kingston acknowledges that pre-aspiration presents a challenge for the principle because the principle predicts that glottal gestures should be associated with the release of the plosive. He analyses Icelandic pre-aspiration as a test for whether the principle is correct. Importantly, he claims that pre-aspiration no longer poses a problem if divided into breathiness and pre-aspiration because only pre-aspiration is bound to and co-ordinated with the oral articulation of the plosive (1990: 422-3). The analyses presented here do point to the fact that pre-aspiration and breathiness should be treated separately, but the data nevertheless does not confirm that laryngeal phenomena would be primarily associated with plosives rather than fricatives.

The findings are also indirectly in agreement with studies that have focused or commented on pre-aspiration before voiceless obstruents in general (Jones & Llamas 2003; McRobbie-Utasi 1991; Roos 1998: 30), and more recently research has concentrated on pre-aspiration before fricatives in Scottish English as well (Gordeeva & Scobbie 2007, 2010, 2011, 2013; Gordeeva 2007; Helgason 2002: 138). This agreement is indirect because the studies focus primarily or only on fricatives and do not contrast pre-aspiration based on the manner of articulation.

Some studies further suggest that it is not the case that plosives should be associated with pre-aspiration more than fricatives. Gordeeva & Scobbie report pre-aspiration only with fricatives and glottalisation with plosives in Scottish English (2013 & personal communication) and Hejná & Scanlon find obligatory pre-aspiration with
fricatives, which contrasts with pre-aspiration being obligatory with plosives only word-medially and obligatorily absent with plosives word-finally (2015). This does not necessarily disagree with the principle of Articulatory Binding because for most of the studies of pre-aspiration in plosives and fricatives, it is not known if pre-aspiration is contrastive. The only studies which undoubtedly pose a problem to Articulatory Binding are that by Gordeeva (2007) and Gordeeva & Scobbie (2010, 2011, 2013), which show that the fortis-lenis contrast in fricatives is distinguished by pre-aspiration.

Lastly, the analyses presented here do not suggest that pre-aspiration is only limited to stressed syllables, as might seem to be the case considering that studies of pre-aspiration tend to focus only on stressed syllables. Furthermore, various aspects of pre-aspiration and breathiness are sensitive to whether they occur with a voiceless obstruent in stressed or unstressed syllables. This is not what Stevens & Hajek have found for the duration of pre-aspiration in Sienese Italian, which is not affected by stress (2004b: 59).

3.4. Place of articulation

Pre-aspiration and breathiness are not conditioned by the place of articulation of the post-tonic fricative in the same way (‘CVF: if, myth, miss, fish), either in terms of their duration or occurrence. Because breathiness occurs obligatorily in the fricative context, its frequency of occurrence is not sensitive to any segmental factors. In comparison, pre-aspiration is less frequent with /f/ than /θ/ in ‘CVF words (p < 0.0001).47 Furthermore, pre-aspiration is shorter with /f/ than with /θ/ (p < 0.05), which is not observed for breathiness. These effects are shown in Figure 3.30.

47 In any analyses dealing with the context of post-tonic fricatives, the independent variables are “place of articulation of the post-tonic fricative” (with four levels: /f/, /θ/, /s/, /ʃ/), “vowel type” (with five levels: /a/, /e/, /ɪ/, /ɒ/, /ʌ/), and “position” (with two levels: isolation and a carrier sentence). Forward difference coding is always used to make the following comparisons: /f/ vs /θ/, /θ/ vs /s/, /s/ vs /ʃ/ (i.e. from the least to the most posterior place of articulation), and /a/ vs /e/, /e/ vs /ɪ/, /ɪ/ vs /ɒ/, /ɒ/ vs /ʌ/. Because fewer vocalic contexts were obtained for ‘CVF words, vocalic effects were not analysed in a binary way as was done for ‘CVP(V) words because the only comparable binary comparison would be that of /e/ vs /ɪ/, and this comparison was done for the words with fricatives regardless.
Figure 3.30. Place of articulation and pre-aspiration in 'CVF words; duration (normalised) on the left and frequency of occurrence (%) on the right

With respect to the place of articulation of the post-tonic plosive (CVP(V): map, matt, mac; mapper, matter, lacquer), pre-aspiration and breathiness agree in that /p/ is associated with the least frequent application of each and also with the shortest durations (p < 0.05-0.0001). Where occasional mismatches are found, this concerns whether /t/ or /k/ is associated with the most frequent application and the longest durations. The frequency of occurrence of pre-aspiration is conditioned in the same way as that of breathiness (p < 0.05-0.0001).

\[\text{In any analyses dealing with the context of post-tonic plosives (CVP(V)), the independent variables are “place of articulation of the post-tonic plosive” (with three levels: /p/, /t/, /k/), “laryngeal specification of the pre-tonic consonant” (with three levels: [-spread glottis / +voice / underspecified], [+spread glottis], sonorant), and “position” (with two levels: isolation and a carrier sentence), unless otherwise specified. Forward difference coding is always used to make the following comparisons: /p/ vs /t/, /t/ vs /k/ (i.e. from the least to the most posterior place of articulation). “Laryngeal specification of the pre-tonic consonant” is always coded so that the following comparisons are made: [-spread glottis / +voice / underspecified] vs [+spread glottis], [+spread glottis] vs sonorant. Furthermore, the dependent variable of “vowel type” is also included. In theory, this variable has eight levels (/a/, /æ/, /æ/, /ɒ/, /ʌ/, /ʌ/, /o/, /o:/); however, these levels of “vowel type” are contrasted differently depending on the purpose of the analyses, and these comparisons are specified where the individual analyses are presented. What the analyses share is that they only contrast two levels of “vowel type”}.\]
Figure 3.31. Place of articulation and pre-aspiration (left) and breathiness (right) in 'CVP(V) words; duration (normalised) at the top and frequency of occurrence (%) at the bottom

In unstressed syllables in the fricative context ('CVCVF: sheriff, Wallace, Polish), pre-aspiration and breathiness agree in not being affected by the place of articulation of the fricative in terms of their frequency. Nevertheless, unlike pre-aspiration breathiness duration is affected by the place of articulation (p < 0.05). Figure 3.32. shows that the duration of breathiness increases with the increasing posteriority of the place of articulation (/ʃ/ < /s/ < /f/).49

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49 Where pre-aspiration and breathiness are analysed in unstressed syllables ('CVCVC, frolic, solace), the independent variables are “place of articulation of the consonant” (with six levels: /p/, /t/, /k/, /f/, /s/, /ʃ/) and “manner of articulation of the consonant” (with two levels: plosive and fricative). Forward difference coding is always used to make the following comparisons: /p/ vs /t/, /t/ vs /k/, and /f/ vs /s/, /s/ vs /ʃ/ (i.e. from the least to the most posterior place of articulation).
Figure 3.32. Place of articulation and breathiness duration (normalised) in 'CVCVF words

With unstressed plosives ('CVCVP, frolie), the place of articulation predicts the occurrence of pre-aspiration and breathiness in a similar way. Figure 3.33. shows that pre-aspiration is more frequent as the place of articulation gets more posterior: /p/ < /t/ < /k/ (p < 0.0001), but this is not so neat for breathiness, which follows this order: /p/ < /k/ < /t/ (p < 0.0001).
Although Figure 3.33 shows that pre-aspiration is longer in duration with the increasing posteriority of the place of articulation and the same is the case for breathiness duration, for which however there is a significant difference only between /p/ and /t/, as suggested both by the figure and the statistics.  

The tendencies shown in the figures presented in this section agree with the research into pre-aspiration. Research looking into the effect of place of articulation of the post-tonic plosive has repeatedly demonstrated that pre-aspiration is shortest before /p/ (Helgason & Ringen 2008: 623; Nance & Stuart-Smith 2013: 10; Ní Chasaide 1985: 126; Stevens & Hajek 2004b: 58; 2004c: 342; Stevens 2010: 101). Some studies have found that pre-aspiration increases in duration in the following order: /p/ < /t/ < /k/ (Helgason & Ringen 2008: 623; Stevens & Hajek 2004b: 58; Stevens

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50 As Francis Nolan points out to me, what might be more relevant than statistical significance would be JNDs (just-noticeable difference).
2010: 101), i.e. the more posterior the plosive, the longer the duration.\textsuperscript{51} Other studies have shown different ordering of the non-labial plosives, with /h/ sometimes having the longest pre-aspiration durations (Morris 2010: 10; Nance & Stuart-Smith 2013: 10), or with the front-to-back prominence relationship holding, but not quite straightforwardly so: Ní Chasaide (1985: 126) found higher values with velars and palatals than labials and dentals, and the palate-alveolar plosive patterned with the labial and dental ones.

3.5. Vowel height

Pre-aspiration and breathiness show the same tendencies considering vowel height. Each is more frequent with the lower vowel phoneme (p < 0.0001), as shown in Figure 3.34.\textsuperscript{52} Their duration and occurrence were compared for the effects of vowel height through the following comparisons: /e/ vs /i/, /ɒ/ vs /ʊ/ in 'CVF and 'CVP(V) words (\textit{pe}\textsuperscript{h}t, \textit{pi}\textsuperscript{h}t, \textit{me}\textsuperscript{h}ss, \textit{mi}\textsuperscript{h}ss, \textit{pe}\textsuperscript{h}tter, \textit{pi}\textsuperscript{h}ty).\textsuperscript{53}

\textsuperscript{51} A notable exception among these studies is McRobbie-Utasi, who has reported no effect of the place of articulation on the duration of pre-aspiration in Skolt Sámi (2003: 3).

\textsuperscript{52} In the following graphs, <i> represents /i/, <o> represents /ɒ/, and <u> represents /ʊ/.

\textsuperscript{53} Two types of models were used. In the former, only /e/ and /i/ were involved as the levels of “vowel type”. In the latter, only /ɒ/ and /ʊ/ were included.
Figure 3.34. Vowel height and the frequency of occurrence (%) of pre-aspiration (left) and breathiness (right) in 'CVP(V) words

The top row shows one of the two pairs contrasted for height: /e/ and /i/, the latter vowel phoneme being represented with '/i/'; and /o/ and /u/, the first being represented with '/o/' and the latter with '/u/'

Similarly, the lower phoneme is associated with longer durations than the higher phoneme (p < 0.0001), which is shown in Figure 3.35.
Figure 3.35. Vowel height and the duration (normalised) of pre-aspiration (left) and breathiness (right) in 'CVP(V) words

As stated above, because breathiness is obligatory in the fricative context ('CVF: mass), it is not sensitive to any segmental conditioning and differs from pre-aspiration in this regard: /e/ is associated with more pre-aspirated tokens than /i/ (p < 0.0001). However, durationally pre-aspiration and breathiness follow the same pattern, being longer with /e/ than /i/ (p < 0.0001 & 0.01, respectively), as illustrated in Figure 3.36.
Other studies have reported a strong tendency for the duration of pre-aspiration (often including the breathy component in the reports) to be shortest with high vowels and for pre-aspiration to be less frequent with high vowels (Gordeeva & Scobbie 2007: 1; Nance & Stuart-Smith 2013: 11; Stevens & Hajek 2004b: 59). In line with Gordeeva & Scobbie (2007) or Stevens & Hajek (2011), McRobbie-Utasi claims pre-aspiration is not attested following /u/ in Skolt Sámi and, if it does occur, the durations are very short (1991: 10; 2003: 3). Furthermore, it has been claimed that there is no pre-aspiration following /i/ and /u/ in Western Yugur (Roos 1998: 32). Vowel height is thus one of the main effects to which pre-aspiration and breathiness can be subject to: the effect of vowel height on pre-aspiration is found across a number of unrelated languages, which points to physiological or aerodynamic motivations. This furthermore implies that pre-aspiration and vowel
deoicing are two different phenomena, as the latter is known to target high vowels in particular (e.g. Ohala 2011: 65).  

Moxness also mentions the effect of vowel height within phonologically long vowels on the duration of pre-aspiration: /aː/ is found with longer durations than /iː/ or /uː/ in Trønder Norwegian (Moxness 1997, quoted in van Dommelen 2000).

### 3.6. Vowel backness/roundness

Pre-aspiration and breathiness duration and occurrence were further subject to comparisons regarding phonological vowel backness (/ɪ/ vs /ʊ/ in 'CVP words, e.g. *pit, put*). They are not conditioned by phonological backness and the two therefore agree in this regard. This is so for both the frequency of occurrence and the duration. Vowel backness and roundness are not exactly in the spotlight of pre-aspiration studies. It has been proposed that rounded vowels do not favour pre-aspiration (Wolter 1964, quoted in McRobbie-Utasi 1991), but the only reason given for this is that the vocal tract has a different shape in the articulation of rounded vowels. Crucially, the rounded vowels also tend to be back vowels, and so it is difficult to tease apart potential effects of backness and roundness. The Aberystwyth results are in agreement with McRobbie-Utasi (1991), who notes that if roundness plays any role, this cannot be a universal tendency because no effect of roundness is confirmed by her Skolt Sámi data (where the rounded vowels are also back vowels).

Other dimensions of pre-aspiration and breathiness could nevertheless be affected by vowel backness/roundness. Helgason refers to frontness and backness in relation to glottal versus oral friction associated with pre-aspiration (2002: e.g. 162). This dimension is nevertheless intertwined with that of height: high front vowels are more likely to be associated with oral friction whereas low central or back vowels are most commonly associated with purely glottal friction.

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54 I am grateful to Yuni Kim for drawing my attention to this.
55 In the models used, /i/ and /o/ were involved as the levels of “vowel type”.
3.7. Type of utterance

Pre-aspiration and breathiness were also compared for whether they pattern in the same or a complementary way regarding the conditioning by the type of utterance (isolation vs carrier sentence: *pat* vs *Say pat once*). Pre-aspiration and breathiness reveal the same tendencies with respect to the conditioning by the type of utterance in ‘CVP(V) words (*pat*, *patter*, p < 0.05-0.0001). Each is longer in tokens uttered in isolation than those inserted in a carrier sentence. This is also found for the duration of pre-aspiration in ‘CVF words (*mass*; p < 0.05-0.0001). The frequency of occurrence of neither is affected.

![Graph](image)

*Figure 3.37. Type of utterance and pre-aspiration and breathiness duration (normalised)*

*Isolation is represented by ‘abs’ and carrier sentence by ‘in’ in each graph*

3.8. Vowel length

Pre-aspiration and breathiness agree only partially in their sensitivity to phonological vowel length. Phonologically short and long pairs of vowels were compared (/a/ vs /aː/ and /ɒ/ vs /oː/ in ‘CVC words, e.g. *pat* and *part*) for the effect of vowel length on
pre-aspiration and breathiness occurrence and duration. The duration of breathiness is not affected by phonological length, but that of pre-aspiration is: pre-aspiration is shorter with phonologically long vowels ($p < 0.0001$). However, pre-aspiration and breathiness are equally more frequent with /ɒ/ rather than /oː/ and neither is sensitive to length with /a/ and /aː/ ($p < 0.001-0.0001$). These effects are shown in Figures 3.38. and 3.39.

![Figure 3.38. Vowel length and the duration (normalised) of pre-aspiration (left) and breathiness (right)](image)

The top row shows one of the two pairs contrasted for length: /a/ and /aː/, the bottom row shows the other of the pairs: /o/ and /oː/; within the second pair, '/o/' represents /ɒ/ in the graphs.

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56 Two types of models were used for the analyses. The former involved /a/ and /aː/ as the two levels of “vowel type” and the latter included /ɒ/ and /oː/.
It is rather surprising that pre-aspiration and breathiness occurrence are affected only by one of the pairs. This may possibly be due to durational differences between the two pairs. However, considering that vowel quantity and vowel quality are inseparably intertwined in most varieties of English, the frequency of occurrence could also be conditioned by vowel quality as well as phonological length. See also Iosad (in press) for a discussion of vowel quality, mainly height, and pre-aspiration duration in Southern Welsh. Thus, it is likely that quantity and quality both affect pre-aspiration (and breathiness) and that quality is reflected in the analyses of quantity.

On the whole, the findings for Aberystwyth English generally agree with other studies in that phonological length affects pre-aspiration (and breathiness): pre-
aspiration is longer with short vowels. This would be in line with Nance & Stuart-Smith, who have found that pre-aspiration is shortest following phonologically long vowels in Scottish Gaelic (2013: 11). This complementarity has also been observed for Faroese and Swedish (Helgason 2002: 121-2, 165), and Irish and Scottish Gaelic (Ni Chasaide 1985).

McRobbie-Utasi (1992) found an interaction between pre-aspiration duration and consonantal length: pre-aspiration duration is longer with the over-long consonant (Grade III) rather than the long one (Grade II), and the shorter the vowel, the longer the pre-aspiration. It is also of interest that the short consonant (Grade I) does not occur with pre-aspiration at all (McRobbie-Utasi 2003: “Voiceless stops and affricates in Grades II and III occur with preaspiration in Skolt Sami.”).

What the graphs and the statistical information show consistently is that the Aberystwyth English pre-aspiration behaves differently from that found in Icelandic, where it does not occur after phonologically long vowels (e.g. Helgason 2002: 48-9).

3.9. Laryngeal specification of the prevocalic consonant

Pre-aspiration has not been previously subject to analyses including the laryngeal specifications of the prevocalic consonant as a possible factor purposely, but the effect of the laryngeal specification of the prevocalic consonant has been reported for Mongolian pre-aspiration. This effect is that of dissimilation: the longer the post-aspiration in the pre-tonic consonant, the shorter the pre-aspiration in the post-tonic consonant. Because this effect is less known, before the results are presented, the dissimilation effects found in Mongolian post-aspiration and pre-aspiration are discussed.

Many Mongolic languages, such as Chahar, have been reported to have undergone aspiration dissimilation, whereby sequences of post-aspirated stop + vowel + post-aspirated stop (/TʰVTʰ/) changed into the sequences of unaspirated stop + vowel + post-aspirated stop (/TVTʰ/) (Svantesson, Tsedina, Karlsson & Franzén 2005: 205-6). This dissimilation process is known as Grassmann’s Law (e.g. Anderson 1970). However, Old Mongolian had word-final pre-aspiration rather than post-aspiration, and so /TʰVTʰ/ was really [TʰVɪɾT] (Svantesson & Karlsson 2012: 461) and the
dissimilation is that between the post-aspiration of the prevocalic consonant and the pre-aspiration of the post-tonic consonant.

Deaspiration in the other direction is also attested in some other Mongolic languages, such as Gansu-Qinghai: /TʰVTʰ/ (i.e. [TʰVVT]) > TʰVT (Svantesson & Karlsson 2012: 462). In addition, not all Mongolic languages exhibit this phonological dissimilation. For example, in Halh TʰVTʰT words, the post-aspiration duration of the prevocalic plosive is only 2/3 of the post-aspiration in TʰVsonorant words (2005: 205-6), and so Halh provides an example of (presumably) phonetic dissimilation. Pre-aspiration can thus be affected by the prevocalic post-aspiration and/or affect the prevocalic post-aspiration as well.

A similar dissimilatory effect is indeed found for the duration of pre-aspiration and breathiness in the Aberystwyth data, although rather than on the post-aspiration of the prevocalic consonant, this is demonstrated on the pre-aspiration and breathiness occurring at the junction of the vowel and the post-vocalic consonant. This is more consistent for pre-aspiration. The effect of the laryngeal specification of the pre-tonic consonant was analysed through the comparison of lenis (bdʰt), [+spread glottis] (pʰt), and sonorant (mʰt) 'CVP, 'CVPV words. Pre-aspiration duration exhibits a very consistent pattern regarding the laryngeal specification of the prevocalic plosive: it is always the shortest with the [+spread glottis] consonant (p < 0.0001). Breathiness shows the same behaviour, but it is less sensitive to this factor in that the [+spread glottis] condition was significantly different only in comparison to the sonorant condition in some models (p < 0.05-0.0001). The frequency results show comparable patterns for pre-aspiration and breathiness as well (Figure 3.40.), suggesting a dissimilatory tendency.

The effect of the pre-tonic consonant confirms that the Aberystwyth data agrees with the Mongolian data and that pre-aspiration and breathiness are influenced in a comparable way.57

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57 I would like to thank Adèle Jatteau for fruitful discussions on Mongolian dissimilation and how it relates to the Aberystwyth English data.
The three types of prevocalic consonants are represented as follows: ‘lenis’ stands for lenis plosives (/b/, /d/, /g/), ‘SG’ for [+spread glottis] consonants (/p/, /t/, /k/, /h/), and ‘sonorant’ for sonorants (/m/, /n/, /l/, /r/)

The existing literature also offers sporadic mentions of a process which is difficult to classify as either dissimilatory or assimilatory because not much is known about its interactions with the prevocalic or the postvocalic consonants. In the descriptions of Western Yugur pre-aspiration, Roos notes that pre-aspiration can sometimes permeate the whole vowel, which may result in the vowel becoming voiceless (1998: 30). This is also reported for Bethesda Welsh (Morris & Hejná, in prep) and in the Aberystwyth data analysed here, but extremely rarely (5 tokens in Bethesda Welsh\(^{58}\)). Roos quotes previous research on Western Yugur treating the phenomenon as a type of metathesis resulting in vocalic devoicing (1998: 32).

\(^{58}\) Unfortunately, these cases were not specifically coded in the Aberystwyth data and no systematic account was taken of them. The coding has to be gone through word by word to see exactly how many tokens exhibited complete devoicing. The instances should not exceed 10-20 cases in all the data analysed in this thesis.
3.10. Position within word

Pre-aspiration and breathiness reveal comparable, but not the same, tendencies with respect to the conditioning by the position within the word (p < 0.05-0.0001). This was compared through words with word-final (pat) and word-medial plosives (patter). Both pre-aspiration and breathiness are longer word-finally than word-medially.

![Box plots showing duration of pre-aspiration and breathiness in CVP(V) words](image)

*Figure 3.41. Position in the word and the duration (normalised) of pre-aspiration (left) and breathiness duration (right) in 'CVP(V) words*

'1' stands for the word-final context (e.g. pat) and '2' word the word-medial context (e.g. patter).

Inconclusive results are available for the frequency of occurrence.\(^{59}\) Despite the variability of the frequency results, we can conclude that they are not in line with what has been reported for Manchester English for the same type of data (Hejná & Scanlon 2015). In Manchester English, pre-aspiration and breathiness are obligatory word-medially in the plosive context (patter) but they are never found word-finally.

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\(^{59}\) The models used in this chapter once show that both pre-aspiration and breathiness are less frequent word-finally than word-medially, but once they also show that only breathiness is sensitive to this factor and it is more frequent word-finally than word-medially. Chapter 5 revisits this issue.
The speaker who was exempt from the analyses presented in this chapter (ABE37) nevertheless exhibits the Manchester pattern.

In the next section, all the results are summarised and the differences are further inspected for whether these are of a complementary type or not.

3.11. Discussion

The introduction of this chapter laid out the assumption that pre-aspiration and breathiness are two components of the same phenomenon either if they are subject to the same conditioning (e.g. the higher the vowel, the shorter the pre-aspiration; and the higher the vowel, the shorter the breathiness) or if they are subject to the same conditioning in a complementary way (e.g. the higher the vowel, the shorter the pre-aspiration; but the higher the vowel, the longer the breathiness). It will be shown that only one potentially complementary pattern is found.

We have seen that pre-aspiration and breathiness disagree in three aspects. Firstly, their frequency of occurrence and duration are conditioned by the manner of articulation of the consonant and, secondly, by stress. Pre-aspiration is more frequent in stressed than unstressed syllables and, in unstressed syllables, it is less frequent with fricatives than plosives ('CVCVF vs 'CVCVP: Wallace vs gullet). On the other hand, breathiness is more frequent with fricatives irrespective of whether it is found in stressed or unstressed syllables and, unlike pre-aspiration, breathiness is obligatory with fricatives and with fricatives and plosives in unstressed syllables. Although both pre-aspiration and breathiness are shorter in stressed rather than unstressed syllables, breathiness is in comparison also longer with fricatives than with plosives. The third consistent dissimilarity is that pre-aspiration and breathiness also behave differently regarding the conditioning by the place of articulation of the fricative in 'CVC words (mass): the frequency of occurrence and the duration of pre-aspiration are sensitive to the place of articulation of the fricative, but neither the frequency of occurrence nor the duration of breathiness is. These three consistent differences lend themselves to the conclusion that pre-aspiration and breathiness can behave rather differently. The three major differences are highlighted in red in the
following table, which summarises all the differences and the similarities. The consistent similarities are highlighted in blue.

<table>
<thead>
<tr>
<th>AGREE</th>
<th>DISAGREE</th>
<th>FEATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>duration</td>
<td>frequency</td>
<td>duration</td>
</tr>
<tr>
<td>br shorter with P than F; pre not affected</td>
<td>pre less frequent with F than P; br less frequent with P than F</td>
<td>manner of articulation ('CVCVC)</td>
</tr>
<tr>
<td>br longer with F than P; pre not affected</td>
<td>br more frequent with F than P; pre not affected</td>
<td>manner of articulation ('CVC)</td>
</tr>
<tr>
<td>pre: /f/ &lt; /θ/ &gt; /s/; br not affected</td>
<td>pre: /f/ &lt; /θ/; br not affected</td>
<td>place of articulation ('CVF)</td>
</tr>
<tr>
<td>longer with the lower V than the higher V</td>
<td>more frequent with the lower V than the higher V</td>
<td>vowel height ('CVP(V))</td>
</tr>
<tr>
<td>not affected</td>
<td>not affected</td>
<td>vowel backness/roundness ('CVP)</td>
</tr>
<tr>
<td>longer in isolation than in a carrier sentence</td>
<td>not affected</td>
<td>type of utterance ('CVP(V))</td>
</tr>
<tr>
<td>longer in stressed syllables</td>
<td>pre more frequent in stressed syllables; br not affected</td>
<td>stressed vs unstressed syllables</td>
</tr>
<tr>
<td>more frequent with /ɒ/ than /oː/; not affected by the other pair</td>
<td>pre shorter with the long vowel; br not affected</td>
<td>phonological length ('CVP)</td>
</tr>
</tbody>
</table>
The major similarities are as follows. Firstly, pre-aspiration and breathiness are not conditioned by vowel backness/roundness in any of the two aspects (frequency or duration). Secondly, the frequency with which they occur in 'CVP(V) words (pat, patter) is not affected by the type of utterance (pat vs Say pat once.), but they are longer in words uttered in isolation than in a carrier sentence. Finally, they are more frequent and longer with the lower than the higher vowel.

These two groups of results, which show that pre-aspiration and breathiness are consistently sensitive to the conditioning factors differently on one hand and
similarly on the other hand, are complemented with a third group, which presents a mixed bag of agreeing and disagreeing effects on pre-aspiration and breathiness.\textsuperscript{60} Regarding this third group, pre-aspiration and breathiness are conditioned in the same/different way considering only their duration or only their frequency of occurrence, and sometimes there are no consistent tendencies even when it comes to one aspect of each (i.e. frequency or duration).

3.11.1. Complementarity between pre-aspiration and breathiness

It was noted in the introduction that dissimilarities do not entail that pre-aspiration and breathiness are not two components of the same phenomenon if such dissimilarities present complementary patterns. For example, pre-aspiration could be shorter with longer vowels but breathiness could be longer with longer vowels. However, such complementarity is not confirmed by the Aberystwyth data. Although there are many cases of differences in the conditioning of pre-aspiration and breathiness, most often (in five such instances) instead of complementarity we find that only pre-aspiration or breathiness is sensitive to the conditioning factor and the other is thus not affected by the same factor at all.

In four other cases which show differences in the conditioning of pre-aspiration and breathiness, the two on the whole exhibit the same tendencies, but these do not match neatly or consistently. For example, pre-aspiration is more consistently affected by the laryngeal specifications of the prevocalic consonant than breathiness is. These instances therefore do not reveal complementary patterns either.

One possibly complementary pattern is found regarding the conditioning by the manner of articulation in unstressed syllables ('CVCVC; gullet, Wallace). Pre-aspiration is less frequent with fricatives than with plosives and breathiness is more frequent with fricatives than with plosives. When the size of those differences is compared, we find that breathiness is obligatory with fricatives but pre-aspiration is rather infrequent, although not quite obligatorily absent (breathiness: 99%; pre-aspiration: 12%), and that breathiness is less frequent with plosives than fricatives and pre-aspiration is now more frequent than in fricatives (breathiness: 85%; pre-

\textsuperscript{60} This is not a result of the normalisation used since the raw data show the same patterns, as discussed in Chapter 2.
aspiration 67.5%). Nonetheless, this complementarity is not ideal, e.g. we could expect one in 30% of the cases and the other in 70%, and vice versa.

3.11.2. Newly reported effects on pre-aspiration and breathiness

Finally, there are also some newly reported tendencies, which cannot be directly compared with other studies.

Firstly, pre-aspiration is found in unstressed syllables, which has been reported only by Stevens & Hajek for Sienese Italian (2004b). With unstressed plosives ('CVCVC: *frolic*), pre-aspiration and breathiness are longer and more frequent as the place of articulation becomes more posterior (/p/ > /t/ > /k/).

Secondly, the duration of pre-aspiration is affected by the place of articulation of the post-tonic fricative ('CVC: *mass*). Pre-aspiration is the longest with /θ/ rather than /f/ or /s/ and it is more frequent with /θ/ than /f/. It is not clear why this should be the case. This cannot be explained by sibilance, the active articulators involved, or by the area of the active articulator involved.

Thirdly, vowel backness/roundness does not affect pre-aspiration or breathiness.

Finally, this chapter presented a first systematic study of the effect of the manner of articulation of the consonant associated with pre-aspiration. Pre-aspiration is found with both plosives and fricatives in stressed and unstressed syllables. In stressed syllables, the manner does not affect the frequency at which pre-aspiration is found. However, in unstressed syllables, pre-aspiration is found more frequently with plosives than fricatives. It has been mentioned at several places above that pre-aspiration tends to be associated with plosives. Nevertheless, it is rather surprising that plosives should exhibit more pre-aspiration than fricatives, especially considering that the production of fricatives requires a more prominent glottal opening gesture (Hoole 1997: 91, and the references therein). An important contribution to this topic is that of Maddieson (1984) and Kingston (1990), which has been mentioned above and which is discussed in more detail in what follows.
3.11.3. Pre-aspiration and laryngeal typology

Kingston notes that, based on Maddieson’s overview (1984), cross-linguistically plosives are more often contrasted for laryngeal aspects than fricatives, and the laryngeal specification is most frequently associated with the oral closure rather than the oral onset (1990: 407). Pre-aspiration does not present a typologically typical phenomenon for two reasons: 1. it can distinguish fortis and lenis fricatives (Gordeeva & Scobbie 2007, 2011, 2013); and 2. it is found prior to the closure of plosives and prior to fricative constriction. Once pre-aspiration and breathiness are distinguished, although pre-aspiration is still typologically unusual, it is less frequently found with fricatives than plosives in unstressed syllables in Aberystwyth English.

Kingston proposes the principle of articulatory binding to explain the typological tendencies reported by Maddieson, according to which if oral and glottal articulations are bound we can predict how (1990: 416). At first, he suggests that in plosives “[…] the opening of the glottis binds to the release, because it is the acoustic character of the burst which the glottal articulation is intended to modify (1990: 425). He acknowledges that pre-aspiration is a problem for the principle and uses Icelandic pre-aspiration as its test. When he finds that pre-aspiration is correlated with the duration of the closure and that the duration of the closure is not correlated with that of the release, he adjusts the principle and states that “[g]lottal abduction is coordinated with the closure rather than the release of the stop in voiceless unaspirated stops, and with the beginning of the constriction in voiceless fricatives […]” (1990: 425). He furthermore finds that when pre-aspiration is divided into two components: “breathiness” and “noise” (voiceless pre-aspiration), whilst breathiness correlates negatively with the preceding vowel, noise/voiceless pre-aspiration, and closure; noise/pre-aspiration correlates positively with the closure duration.

The principle has not been tested on a wide range of phenomena and languages. To some extent, it has been challenged by Bird, Caldecott, Campbell, Gick & Shaw (2008) in their analyses of glottalised resonants. The authors show that although the principle would predict for glottalisation in resonants to be more variable in terms of its position with respect to the resonant than glottalisation associated with plosives, although they find variability across three languages, within two of these languages
the glottalisation is consistently found as pre- or post-glottalisation of the resonants. In the third language, the glottalisation is found as far from the adjacent vowel as possible, and so although there is variability, this variability is predictable (2008: in particular page 505).

One last point that needs to be mentioned here is that since vowel height and vowel duration tend to correlate negatively (e.g. Lisker 1974), the results related to vowel height may be confounded: rather than vowel height, it could be vowel duration which conditions pre-aspiration duration. Although Gordeeva & Scobbie have found significant correlations between vowel duration and pre-aspiration duration for Standard Scottish English, vowel duration is not strongly correlated with phonological height in their data (2007: 31). Moreover, Stevens reports that vowel duration does not interact with pre-aspiration duration in Italian (2010: 100). The possibility of this confound had been considered in the analyses presented here as well, and because the correlations were either weak or very weak, vowel duration was not considered a possible confound.

Chapter 4 follows up on the question of whether pre-aspiration and breathiness are subject to the same or a complementary conditioning through analyses contrasting phonetic and phonological factors. Similarly, Chapters 6 and 7 offer comparisons of pre-aspiration and breathiness regarding their function as an acoustic correlate of the fortis-lenis contrast in plosives and their social patterning. Each chapter shows similarities as well as differences in the behaviour of pre-aspiration and breathiness.

3.11.4. Pre-aspiration and breathiness of 0ms

In this chapter, pre-aspiration and breathiness were analysed for two aspects: their frequency of occurrence and their duration.

The durational analyses included zero durations of pre-aspiration and breathiness, which is in line with Gordeeva 2007, Gordeeva & Scobbie 2010, Helgason 1998; Helgason 1999a; Helgason, Stölten & Engstrand 2003; Nance & Stuart-Smith (2013). The authors do not explicitly state that they included zero values in the
durational analyses, but the graphs show inclusion of zeroes. However, not all studies of pre-aspiration include pre-aspiration of 0ms in the analyses of the conditioning of its duration. The exclusion of zero values is explicitly stated or can be inferred in Iosad (in press), Morris (2010), Stevens & Hajek (2004c), Stevens (2010), and Tronnier (2002). The reasons for the decision to include or exclude the values of 0ms are not provided.

Iosad (in press, personal communication) excludes zero values from his analyses of Welsh pre-aspiration; however, in his data pre-aspiration is obligatory, which practically means that excluding or including the low number of zero values is not very likely to influence the analyses irrespective of which of the two choices is more correct. With the Aberystwyth data analysed in this thesis, on the other hand, we have speakers pre-aspirating at different rates, e.g. in 58% to 97% of their tokens (These percentages refer to the female plosive data.). This is problematic because the decision of including or excluding zero values is likely to influence the analyses.

Morris & Hejná (in prep), who face the same problem in their study of Bethesda Welsh pre-aspiration, suggest that, if pre-aspiration and breathiness are coded for their presence or absence, investigating their durational aspects including the zero values provides just another angle of the same analysis and may not truly tell us more about the durational behaviour of pre-aspiration and breathiness where it does occur. If the suggestion of Morris & Hejná (in prep) is on the right track, the inclusion of zero values is possibly problematic for this chapter for the durational comparisons of pre-aspiration and breathiness in contexts where one occurs considerably less frequently than the other. Where the two occur at comparable frequencies, the inclusion of zero values is not problematic.

On the other hand, if we wanted to explore the question of whether there is a trading relationship between the duration of pre-aspiration and breathiness, including zero durations would be crucial. Thus, there seems to be two conflicting a priori reasons to decide whether zero values should or should not be included in durational analyses.

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61 The authors work with a voicing offset ratio, which means that the zeroes are included.
One possible solution is a post-hoc decision based on two separate analyses, one without zero values, one with zero values. This may not be problematic if one of the analyses results in a pattern which can be expected considering physiological effects. However, this can be resorted to only if it is known which physiological effects can be expected. This was indeed done for some of the analyses involving 'CVP(V) and 'CVF words, and the exclusion of the zero values resulted in the same patterns, except that they were smaller in magnitude.

Another solution to the problem is discussed in the next chapter, in section 4.4.
Chapter 4 – Phonological aspects of pre-aspiration and breathiness

“[…] indeed the gritty details are always messier than the abstractions on the linguist’s desk.”

4.1. Introduction

One of the claims raised in Chapter 1 was that pre-aspiration is rarely phonological (Clayton 2010: iii). This may be because pre-aspiration is sometimes seen as phonological only if it applies obligatorily (Helgason 1999b: 1854; 2002: 8; Wretling, Strangert & Shaeffler 2002) and/or because it is seen as phonological only if contrastive (Ladefoged & Maddieson 1996: 73). It is not obvious why pre-aspiration should be seen as contrastive only in the languages mentioned by Ladefoged & Maddieson, i.e. Icelandic, Scottish Gaelic, Faroese, and Sámi, because it is not clear what criteria are used to establish contrastiveness. What these languages do share is obligatory pre-aspiration. Additionally, Icelandic pre-aspiration has been shown to carry a unit of weight (Keer 1998).

This chapter investigates whether pre-aspiration is sensitive to the phonological conditioning in Aberystwyth English and it concludes that pre-aspiration duration forms two categories, but they do not lend themselves to a straightforward explanation – no one phonetic or phonological phenomenon predicts one or the other. Instead, a mixture of phonetic and phonological factors seems to conspire to give the categorical output. The previous chapter revealed that a number of factors affect pre-aspiration duration. For many of these, it is not always easy or possible to decide whether they are phonetic or phonological in nature. Nevertheless, the presence of two categories strongly suggests phonological conditioning of some sort, and this chapter proposes that this is mainly that of phonological height. These conclusions are reached primarily through the diagnostics of gradience and categoricity, which are discussed in section 4.1.1.
4.1.1. Gradient and categorical phenomena

Recent research has now frequently shown that a phenomenon does not have to apply obligatorily in order to be phonologically relevant (Coetzee & Pater 2011; Sebregts 2014: Chapter 6, also page 13). Exactly what should and what should not be considered phonological is at the core of the debates related to what the distinction between phonetics and phonology is. The present thesis assumes that a distinction between phonetics and phonology does exist and it furthermore assumes that the main criterion to diagnose whether a phenomenon pertains to a co-field of phonetics or also that of phonology is whether a certain phonetic aspect of its phonetic implementation can be accounted for by a physiological, aerodynamic, or acoustic explanation. This is along the lines of Cohn (1998, 2006), Keating (1990, 1996), Strycharczuk (2012), and Turton (2014, 2015).

To give an example, it has been shown multiple times that post-aspiration duration is affected by the place of articulation of the plosive in question (e.g. Cho & Ladefoged 1999, among many others). More specifically, the more posterior the place of articulation, the longer the post-aspiration: /p/ < /t/ < /k/. A number of explanations have been proposed, which are reviewed in Cho & Ladefoged (1999). To mention some of them for illustration purposes, it has been suggested that the lip movement is quicker than that of the jaw, which in turn results in post-aspiration being shortest for /p/. Moreover, the bigger the extent of the articulatory contact, the larger the Bernoulli force that sucks the articulators together and the slower the decrease in the intra-oral pressure. Furthermore, the more posterior the articulation of a plosive, the more air pressure builds up behind the constriction point. This may cause the glottis to open more for /k/ than /p/, and in consequence it takes longer for the vocal folds to reach the state needed for vibration (if there is a voiced sound following the post-aspiration).

If these aerodynamic factors are behind the patterns that post-aspiration duration exhibits, then within each place of articulation it should also hold that the more posterior the plosive is (e.g. /k/), the longer the post-aspiration of that plosive. However, previous research has shown that VOT is not always correlated with the degree of the posteriority of a plosive (Docherty 1992: 25; quoting Peterson & Lehiste 1960), which suggests an abrupt, or categorical, effect of place of
articulation. This could be interpreted as an effect of phonology if the patterns can no longer be accounted for by the aerodynamic mechanisms.\textsuperscript{62}

In this sense, categoricity is synonymous with phonetic abruptness, which is the output of the phonological properties of a language. This is opposed to phonetic gradience (See further Cohn 1998: in particular 28 and 35, 2006; Keating 1990; Strycharczuk 2012; Turton 2014, 2015; among many others.). This thesis thus adopts the distinction between gradient and categorical effects in the temporal-spacial domain, in which the former are the result of phonetics and the latter that of phonology.\textsuperscript{63}

Gradience and abruptness therefore differ from optional and obligatory application (further discussed in Chapter 5). In what follows, the two most common diagnostics of categoricity are discussed which are used in this chapter: unimodality and sensitivity to phonetic or phonological conditioning.

\subsection*{4.1.2. Unimodality}

The use of unimodality tests in establishing the number of categories is not new. One of the most well-known examples related to plosives is that of Lisker and Abramson (1964: in particular 400-2, 404-6, 408), who plot the distributions of the VOT values they had measured and find several peaks. Another study using the unimodality test to establish the number of categories is that by Scobbie (2002). Figure 4.1., taken from Scobbie (2002: 378), illustrates bimodal distribution in the VOT values of /b/ (pooled across all the subjects). We can see that there are two peaks around which the VOT values cluster: one around -80 to -50ms, one around 10 to 20ms. The presence of these two peaks is not a result of aerodynamics but that of a cognitive process.

\textsuperscript{62} Whether a possible effect of the positioning on vocal fold tension could lead to this seemingly arbitrary pattern is an open question. Many thanks to Francis Nolan for drawing my attention to this.\textsuperscript{63} However, see Derrick & Gick (2011) for a case of categorical phonetics.
To apply this to pre-aspiration, if histograms of its duration (or other continuous aspects such as noisiness) show a single mode or peak, that means that there is only one category; however, two or more modes suggest more categories and thus that pre-aspiration is subject to phonological effects.

4.1.3. Conditioning

Apart from the test of unimodality, careful analyses of the conditioning of a continuous variable (such as VOT or pre-aspiration duration) can be used to establish whether that variable is sensitive to phonetic or phonological factors.

For example, a continuous variable could be sensitive to phonological height or to its phonetic correlate (F1), to phonological backness or again to its phonetic correlate (F2), to categorical place of articulation (/p/, /t/, /k/) as opposed to the more fine-grained “places” of articulation within each of these broad categories (a more or less anterior /k/ as discussed above), or to phonological length as opposed to phonetic vowel duration. To apply this to pre-aspiration, the following predictions can be made:

Figure 4.1. Bimodal distribution of VOT in Shetland English /b/ (Scobbie 2002: 378)
1. If pre-aspiration duration is conditioned by F1 rather than phonological height, a. within a vowel phoneme there should be a correlation between the duration of pre-aspiration and F1, and b. the same tendency should be found irrespective of the vowel phoneme.

2. The same can be predicted for F2 and phonological backness.

3. If pre-aspiration is conditioned by phonetic place of articulation rather than phonological place of articulation, within each place there should be a correlation between the duration of pre-aspiration and the anteriority of the oral gesture.

4. Pre-aspiration duration could be conditioned by phonetic vowel duration and/or by phonological vowel length. If pre-aspiration duration is correlated with vowel duration in different directions across the two phonological categories, short and long (e.g. positively within short and negatively within long vowels), this can be interpreted as a phonological effect. However, if within both categories the correlations are in the same direction (either positive or negative), we cannot tell whether the difference is phonetic or phonological based on the correlations themselves.

The first two and the fourth predictions can be tested with our acoustic data. Regarding the third prediction, EPG data is needed to answer if pre-aspiration is conditioned phonetically or phonologically, which is beyond the scope of this thesis.

The next two sections (4.2.-4.3.) look into whether pre-aspiration duration shows purely phonetic or also phonological patterning through the analyses of its distribution and segmental conditioning. The same analyses are carried out for breathiness duration to follow up on the question asked in Chapter 3: is it appropriate to add up pre-aspiration and breathiness in analyses of pre-aspiration? If only one of them shows sensitivity to phonological effects, the answer is no.

4.2. How many categories does pre-aspiration form?

This section looks into the distribution of pre-aspiration and breathiness durations in the plosive context (matt) and it shows that both pre-aspiration and breathiness form
two categories.\textsuperscript{64} This suggests that pre-aspiration and breathiness are conditioned phonologically. However, although this is the case for most individuals, it is not the case for all of them.

Figure 4.2. illustrates the general pattern of two categories on ABE12. The first category is the high peak at 0ms (raw measurements). These are instances of words that lack pre-aspiration. Another category is found in the positive value range and it is represented by a more widely spread mode. The two categories therefore correspond to cases in which pre-aspiration is not found as opposed to those where it is. It is noteworthy that the two categories do not overlap in any way, as they are separated by absence of values – there are no instances of pre-aspiration with the values between 1 and 5ms for ABE12. The categories are thus separated more clearly than if there were a small number of tokens with pre-aspiration of 1 and 5ms.\textsuperscript{65}

\textsuperscript{64} This is done for twelve female speakers for the plosive context.

\textsuperscript{65} It could be said that since the difference of 4ms is so small, maybe the bimodality is a result of its being impossible to reliably identify pre-aspiration which could be as short as e.g. 3ms. Even if this were the case, however, the second mode shows a gradual increase of the tokens with the main peak around 30–45ms in Figure 4.2., rather than a flat relatively high frequency of tokens above 5ms. I am grateful to Francis Nolan for pointing this out to me.
Figure 4.3. illustrates the distributions of the duration of pre-aspiration for all the individuals analysed in this chapter. The presence of the two categories is confirmed by the Hartigans’ Dip Test for Unimodality\textsuperscript{66} for eleven of the speakers (D = 0.017-0.084; p < 0.0001) and it is not confirmed for one (ABE45, p = 0.26). The speakers are arranged alphabetically. The x-axis is that of the duration of pre-aspiration and the y-axis that of the frequency of the words with a specific duration of pre-aspiration.

Patterns similar to those related to pre-aspiration are found for the duration of breathiness as well. Ten of the speakers show two categories ($D = 0.023-0.118$; $p < 0.0001$), as illustrated in Figure 4.4.

*Figure 4.3. Distribution of pre-aspiration durations (raw) in ‘CVP(V) words by speaker*
Two individuals do not exhibit two categories of breathiness duration (ABE45: $p = 0.1$; ABE52: $p = 0.98$),\(^67\) and these are illustrated in Figure 4.5.

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\(^{67}\) These two speakers are the youngest in the sample. This may point to sound change in progress.
Our first diagnostic therefore shows that pre-aspiration and breathiness are sensitive to a phonological process or phonological processes. A question that suggests itself is whether the observed two categories are caused by impossible environments, i.e. environments in which pre-aspiration or breathiness never occur as opposed to environments where they always occur. To put this differently, we can ask whether pre-aspiration occurrence is obligatorily absent in some contexts and obligatorily

Figure 4.5. Unimodal distribution of breathiness durations (raw) in 'CVp(V) words
present in others. However, looking at the conditioning in more detail reveals that the bimodality cannot be explained in such a neat way.

The only individual for whom the bimodal distribution could be predicted by a neat phonological rule is ABE37, who does not pre-aspirate or produce breathiness word-finally, where she glottalises obligatorily. The word-final glottalisation blocks pre-aspiration. Her bimodal distributions are nonetheless not caused by glottalisation blocking pre-aspiration and breathiness: the Dip Test restricted to her word-medial tokens confirms bimodality for pre-aspiration (D = 0.078; p < 0.0001) as well as breathiness (D = 0.07; p < 0.0001).

As for the other Aberystwythians, only four speakers show at least some impossible environments for pre-aspiration (ABE12: /ɪp/ in disyllables; ABE14: /ɪp/, /ɛp/; ABE17: /ɪp/ in disyllables; ABE50: /oːp/), but these do not account for all or at least most of the zero values. Breathiness exhibits some impossible contexts for three speakers, and these on their own again cannot explain all of the bimodality (ABE14: /ɪp/ in disyllables, /ʌp/ in disyllables; ABE24: /oːp/; ABE50: /oːp/).

Because the two categories cannot be explained by impossible environments (obligatory non-application as opposed to obligatory application conditioned segmentally or prosodically), they cannot be explained by a neat phonological rule. The segmental conditioning of pre-aspiration and breathiness durations is discussed in the next section, which addresses the question of whether the conditioning is purely phonetic or also phonological. ABE37 is excluded from the analyses that follow because her inclusion may skew the results.

4.3. Phonetic vs phonological conditioning

Another way to diagnose whether pre-aspiration and breathiness are sensitive to the phonological level in Aberystwyth English is related to the segmental conditioning of the duration of pre-aspiration and breathiness. This section will illustrate that neither pre-aspiration nor breathiness duration is sensitive to the phonetic correlates of height or backness and that they are conditioned by phonological height. Furthermore, for most speakers for whom the analyses could be interpreted, it is not clear whether it is phonetic vowel duration and/or phonological length that
conditions it. However, for one speaker there is a clear effect of phonological length on breathiness duration.

In order to demonstrate these patterns, vowel formant measurements had to be taken, and the methodology behind these measurements is presented below.

4.3.1. Formant measurements

In order to answer whether pre-aspiration and breathiness durations are conditioned by phonetic height and backness, F1 and F2 measurements were obtained. The measurements were taken automatically in the midpoint of the vocalic interval (which included the breathy interval) with the default 25ms analysis window. All the measurements were checked manually based on F1, F2, and F3 values and re-measured manually where necessary. For every speaker, different formant settings were used so that the formant tracker reflected the formant structure as well as possible. Tokens with whispered, i.e. voiceless, vowels were not included in the formant analyses.

Strongly breathy tokens presented a challenge. It has been previously noted that breathiness can result in formant values “beyond what can be predicted from the source parameters” (Ní Chasaide & Gobl 1988: 320), and, indeed, a high number of the tokens had to be re-measured by hand at the point of the vowel which was most modal. Sometimes the entire vowel was strongly breathy, and when this happened and it was obvious that the amount of breathiness resulted in very different formant values (such as F1 of approximately 400 Hz for /a/), these tokens were excluded from the analyses. Fant mentions the influence of glottal shunt leading to F1 lowering (1960: 105) and the influence of large glottis opening resulting in F1 raising (1960: 169), but it is not clear what the strength of these effects usually is. Where this happened, the tokens were again excluded from the analyses. This

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68 Not unrelated findings are reported in Laver (1980: 17), based on personal communication with Nolan. The low vowel is described as having lower F1 values when the larynx is lowered. This can be explained by the lowering of the larynx, which in turn prolongs the vocal tract (Thurgood 1999: 179).
nevertheless draws our attention to the connection between F1 values and phonation types to be explored in further studies.\textsuperscript{69}

Normalised values were used. Nearey formant intrinsic normalisation was opted for (Nearey 1977) and the NORM suite was utilised to carry out the normalisations within each speaker and to decide which normalisation method is suitable (Thomas & Kendall 2007-2014).\textsuperscript{70}

\textbf{4.3.2. Statistical analyses including F1 and F2}

The statistical analyses referred to in the following sections were done through Linear Mixed Effects Models in conjunction with the lmerTest package. Pre-aspiration and breathiness duration (normalised) were entered in the models as the dependent variable, respectively. The independent variables in each model were “place of articulation of the post-tonic plosive” (with three levels: /p/ , /t/ , /k/), “type of the pre-tonic consonant” (with three levels: “lenis”, “[+spread glottis]”, “sonorant”), “word position” (with two levels: “word-medial”, “word-final”), “sentence position” (with two levels: “carrier sentence”, “isolation”), “F1” (normalised), and “F2” (normalised). Interactions between F1 and F2 were added in a step-up manner. The analyses were run separately for every vowel phoneme because otherwise the effects of F1 and F2 may be conflated with phonological effects. In each model, “word” and “speaker” were set as random effects. Forward difference coding was used in the models for the “place of articulation of the plosive” and for the “type of the pre-tonic consonant”.

\textsuperscript{69} Where the formants had to be remeasured, this was where breathiness extended to the mid point of the interval delimited as the vocalic interval. In the other cases, the mid point did not overlap with the breathiness associated with pre-aspiration.

\textsuperscript{70} More specifically, Thomas & Kendall state that “Adank et al. (2004) found that the Nearey formant intrinsic method performed well in a discriminant analysis of normalized Dutch vowels in reducing physiological variation, and no worse than the other methods compared at preserving sociolinguistic variation. Disner (1980) found that it reduced scatter the best of all the methods she compared” (2007-2014). Furthermore, they mention that intrinsic (as opposed to extrinsic) methods are “immune to differences in the phonological inventories of dialects or languages”.

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4.3.3. Phonological height and F1

Pre-aspiration duration is sensitive both to phonological and phonetic vowel height. With /ɪ/ and /ʊ/, the higher the F1, the longer the pre-aspiration, i.e. the lower the vowel, the longer the pre-aspiration. However, F1 does not condition the duration of pre-aspiration or breathiness with /e/ and /ɒ/.

Breathiness duration is affected by F1 only with one other vowel, /a/, and this is so differently than in the case of the mid-high pairs. With /a/, the higher the F1, the shorter the duration of breathiness, i.e. the lower the /a/, the shorter the breathiness. With the other vowels, pre-aspiration and breathiness duration are not affected by F1. These effects are shown in Figure 4.6. (using the package “effects” – Fox, Weisberg, Friendly, Hong, Andersen, Firth & Taylor 2015) and the statistical information for the significant effects is summarised in Table 4.1.

![Figure 4.6. Correlations between pre-aspiration or breathiness duration (normalised) and F1 (normalised) by vowel phoneme and syllabic structure, represented through the coefficient size of the effect of F1 on duration](image)

The effects of F1 on the duration of pre-aspiration and breathiness are shown for the three vowel phonemes for which they were found separately: correlations between F1 and pre-aspiration duration within /ɪ/ (KIT), represented as /i/ in the graph (on the left); correlations between F1 and pre-aspiration duration within /ʊ/ (FOOT), represented as /u/ in the graph (central column); correlations between F1 and breathiness duration within /a/ (TRAP). There was a significant interaction between F1 and the number of syllables within /ɪ/, and the correlations between F1 and pre-aspiration duration are therefore shown in the graph for /ɪ/ separately for monosyllabic words (pit, ‘Syll: 1’) and disyllabic words (pity, ‘Syll: 2’).
Pre-aspiration duration

| VOWEL PHONEME | ESTIMATE | STD. ERROR | DF       | T VALUE | PR(>|T|) |
|---------------|----------|------------|----------|---------|---------|
| /ɪ/           | 7.7855   | 1.3061     | 946.0000 | 5.961   | < 0.0001 *** |
| /ɪ/: pat vs patter | -7.3574 | 1.6843     | 1018.5000 | -4.368  | < 0.0001 *** |
| /ʊ/           | 4.5844   | 2.1378     | 222.8500 | 2.144   | < 0.05 *   |

Breathiness duration

| VOWEL PHONEME | ESTIMATE | STD. ERROR | DF       | T VALUE | PR(>|T|) |
|---------------|----------|------------|----------|---------|---------|
| /a/           | -16.9014 | 3.9858     | 1206.0000 | -4.240  | < 0.0001 *** |

Table 4.1. Statistical results for correlations between F1 and pre-aspiration or breathiness duration

In the previous chapter, we saw that phonological height affects the frequency and the duration of pre-aspiration and breathiness consistently. For F1, this is the case only for the duration of pre-aspiration with the high vowels.

4.3.4. Phonological backness and F2

Pre-aspiration duration is not affected by F2. Breathiness duration is, but only with two vowels, /a/ and /ɪ/. The higher the F2, the longer the breathiness duration, i.e. the fronter the vowel, the longer the breathiness. With /ɪ/, this effect is much smaller than with /a/. The significant effects of F2 on the duration of pre-aspiration and breathiness are illustrated in Figure 4.7. and the significant results are summarised in Table 4.2.
The effects of F2 on the duration of breathiness are shown for the two vowel phonemes for which they were found separately: correlations between F2 and breathiness duration within /ɪ/ (KIT), represented as ‘/i/’ in the graph (on the left); correlations between F2 and breathiness duration within /a/ (TRAP) (on the right).

| VOWEL PHONEME | ESTIMATE | STD. ERROR | DF         | T VALUE | PR(>|T|) |
|---------------|----------|------------|------------|---------|---------|
| /a/           | -15.8988 | 5.5023     | 1205.4000  | -2.889  | < 0.01  ** |
| /ɪ/           | 10.6168  | 4.9667     | 581.6000   | 2.138   | < 0.05  *  |

Table 4.2. Statistical results for correlations between F2 and pre-aspiration or breathiness duration

Neither phonological nor phonetic backness thus affect the duration of pre-aspiration, and a very weak and consistent effect of phonetic backness is found.
4.3.5. Phonological length and vowel duration

This section shows that for most speakers for whom the results can be interpreted, the duration of pre-aspiration and breathiness are conditioned either by phonetic or phonological vowel duration and for one speaker there is a clear effect of phonological length on breathiness duration.

Vowel length and vowel duration are very useful because they allow us to see whether pre-aspiration and breathiness are conditioned phonologically or phonetically. This is so in two ways.

Firstly, presence or absence of pre-aspiration can be predicted by length in an obligatory way. For example, in Icelandic pre-aspiration is blocked if the preceding vowel is phonologically long (e.g. Silverman 2003) and it seems non-occurring in phonologically short consonants (Grade I) in Skolt Sámi (McRobbie-Utasi 1992). This is a clear instance of phonological conditioning as this can hardly be explained physiologically or aerodynamically. This is not the case for Aberystwyth English, as we have seen in Chapter 3 that pre-aspiration (and breathiness) does occur with phonologically short and long vowels.

However, an optional phenomenon can still be conditioned phonologically: pre-aspiration and breathiness may be present with both phonologically short and long vowels, but the two phonological categories can influence them differently. If pre-aspiration and breathiness duration are conditioned by phonological vowel length, the effect can be observed if the phonologically long vowels show a different effect of vowel duration than phonologically short vowels – namely, the directions of the correlations between the duration of short vowels and pre-aspiration or breathiness will not agree with those between the duration of long vowels and pre-aspiration or breathiness. If the directions agree, based on the correlations themselves we cannot tell whether it is phonetic vowel duration or phonological vowel length that matters:

1. Phonetic or phonological effect

   V: - the longer the vowel, the longer/shorter the pre-aspiration/breathiness
V - the longer the vowel, the **longer/shorter** the pre-
aspiration/breathiness

2. Phonological effect

V: - the longer the vowel, the **longer/shorter** the pre-
aspiration/breathiness

V - the longer the vowel, the **shorter/longer** the pre-
aspiration/breathiness

Both possibilities are attested. In Tohono O’odham, the duration of pre-aspiration is positively correlated with the duration of the preceding vowel, irrespective of the phonological length (Clayton 2010: 14, 182-3). The phonological pattern seems to be attested in more languages. Nance & Stuart-Smith have shown that pre-aspiration is shortest following phonologically long vowels in Scottish Gaelic (2013: 11), which has also been found for Faroese (Helgason 2002), and Irish and Scottish Gaelic (Ní Chasaide 1985).71

For most of the speakers from Aberystwyth for whom the analyses were possible (for whom the correlations were significant), the duration of pre-aspiration and breathiness, respectively, is correlated with vowel duration in the same direction across the two phonological categories. For one speaker the duration of breathiness is conditioned by phonological vowel length rather than by phonetic vowel duration because the directions do not agree.

Two variables were tested for correlations: raw pre-aspiration and breathiness duration, respectively, and raw vowel duration.72 The correlation tests were done for the individuals (eleven females) and vowel duration excluded breathiness. Because long vowels were obtained only in 'CVP words (e.g. *part*), the analyses were limited to short vowels in 'CVP words as well (e.g. *pat*); words with the 'CVPV structure

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71 Clayton comments on the pattern as follows: “This may be because in O’odham, the preaspiration cue is analyzed as part of the vowel nucleus, rather than the coda as must be the case in Icelandic or Gaelic” (2010: 14).

72 Where any of the distributions of the duration of pre-aspiration and breathiness was not normal, Spearman’s correlation coefficient was used, otherwise Pearson was applied.
were excluded. Two V ~ V: pairs were included: /a/ vs /aː/, and /ɒ/ vs /oː/.

For the analyses to be useful for the question raised in this chapter, significant correlations needed to be obtained for the same individuals within each phoneme of the two short-long pairs. Unfortunately, this was found only in a few individuals.

The results are summarised in Table 4.3., which shows that one individual (ABE14) has a phonetic or phonological conditioning of pre-aspiration duration by vowel duration: the shorter the vowel, the shorter the pre-aspiration, no matter if the vowel is phonologically short or long. The same is found for breathiness for four speakers (ABE14, ABE45, ABE46, and ABE50). Only one speaker exhibits unambiguously phonological conditioning: in the short vowel, the longer the vowel is the longer the breathiness is; in the long vowel, the longer the vowel is, the shorter the breathiness is.

<table>
<thead>
<tr>
<th>NEGATIVE IN SHORT AND LONG</th>
<th>POSITIVE IN SHORT, NEGATIVE IN LONG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-aspiration</td>
<td></td>
</tr>
<tr>
<td>/a/ vs /aː/</td>
<td>/ɒ/ vs /oː/</td>
</tr>
<tr>
<td>ABE14</td>
<td>r = -0.41·51; p &lt; 0.05·001&lt;sup&gt;73&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Breathiness</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>/a/ vs /aː/</td>
<td>/ɒ/ vs /oː/</td>
<td>/a/ vs /aː/</td>
</tr>
<tr>
<td>ABE14, ABE46, ABE46, ABE50</td>
<td>r = -0.33·61; p &lt; 0.0001</td>
<td>ABE18</td>
</tr>
<tr>
<td></td>
<td>r = -0.29·53; p &lt; 0.05</td>
<td>r = -0.47</td>
</tr>
<tr>
<td></td>
<td>0.0001</td>
<td>&amp; 0.33; p</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 0.05</td>
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<tr>
<td></td>
<td></td>
<td>&amp; 0.01</td>
</tr>
</tbody>
</table>

Table 4.3. Pre-aspiration vs breathiness duration correlations with vowel duration by short and long phoneme

<sup>73</sup> The correlational coefficient can be interpreted as follows: r = 0.00-0.19 “very weak”, 0.20-0.39 “weak”, 0.40-0.59 “moderate”, 0.60-0.79 “strong”, 0.80-1.00 “very strong”.

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The correlations between the duration of breathiness and that of the vowel are demonstrated in Figure 4.9. by individuals for /ɒ/ vs /oː/, which provided the highest number of comparisons.

![Figure 4.8](image)

This figure shows correlations which agree in their direction across the two phonological categories in red and correlations which do not agree in their direction across the two phonological categories in blue; /ɒ/ (LOT) is represented as '/o/' in the graphs and /oː/ (NORTH/FORCE) as '/oː/’

To conclude, the one comparison available for pre-aspiration duration suggests an ambiguous effect: the longer the vowel durationally, the longer the pre-aspiration duration. The same is observed for five comparisons available for breathiness
duration: the longer the vowel durationally, the longer the breathiness duration. One speaker exhibits a clearly phonological effect: the longer the short vowel duration, the longer the duration of breathiness; the longer the long vowel duration, the shorter the breathiness duration.

4.4. Discussion

This chapter started with the claim that pre-aspiration is rarely phonological. It was said that it is seen as phonological if obligatory or contrastive and that this was problematic because of two reasons. Firstly, optional phenomena can be phonological. Secondly, it is not clear what criteria are used to establish contrastiveness of a phonetic feature.

The findings of this chapter show that pre-aspiration duration generally forms two categories: pre-aspiration is either absent (0ms) or present (5ms and longer). The presence of two categories strongly suggests that pre-aspiration duration is sensitive to phonological conditioning. Indeed, for one speaker (ABE37), the two categories can be mostly predicted by a prosodic rule, whereby pre-aspiration does not apply word-finally (*pat*) because that is where glottalisation occurs obligatorily. However, for the remaining speakers, the two categories cannot be explained primarily by a single predictor and even ABE37 shows two categories when the impossible contexts are taken into account.

Together with the results presented in Chapter 3, the results of this chapter suggest that multiple factors conspire to result in the two categories found for pre-aspiration duration. Some of these are phonological (vowel height; for at least one speaker vowel length), some are phonetic (F1 for high vowels; F2 for /a/ and /ɪ/; possibly vowel duration but weakly), and for some we do not know (place of articulation, position within the word, type of the utterance, type of the pre-tonic consonant).

Individual variation primarily reflects a difference between pre-aspiration and breathiness for one of the twelve speakers: whilst pre-aspiration duration is bimodal for eleven speakers, breathiness duration is bimodal only for ten; for one individual, pre-aspiration duration is bimodal but breathiness duration is unimodal.
To follow up on the question raised in Chapter 3, whether pre-aspiration and breathiness are subject to the same linguistic effects, Chapter 4 reveals that pre-aspiration and breathiness durations agree in being sensitive to phonological height rather than F1 and F2, but minor phonetic tendencies in this regard point to some differences: F1 affects pre-aspiration duration in /ɪ/ and /ʊ/, but breathiness duration is sensitive to F1 only in /a/ and in different ways (The higher the F1, the shorter the pre-aspiration duration; but the higher the F1, the longer the breathiness duration.). F2 does not affect pre-aspiration duration at all, but it does affect breathiness duration in /a/ and /ɪ/.

4.4.1. Problem of zero values revisited

The previous chapter (3.11.4.) raised the problem of whether the durations of 0ms should be included in the analyses of the conditioning of pre-aspiration duration. One possible a priori criterion on which it could be decided whether such values should be included or excluded is that of the distribution of the durational values. For example, if the distribution is unimodal there is no objective reason to exclude zero values. On the other hand, a bimodal distribution suggests presence of two phonological categories resulting from a cognitive rule of some sort.

However, analyses using this criterion have to deal with the fact that not all speakers show two categories of pre-aspiration and that the two categories seem to be disappearing in the youngest speakers.

Although this chapter found that pre-aspiration and breathiness durations are affected by phonological as well as phonetic factors, it did not shed light on how to diagnose whether a phonetic feature is contrastive. Chapter 6 will show that both pre-aspiration and breathiness durations contribute to distinguishing /p/, /t/, /k/ and /b/, /d/, /g/, despite the fact that for some speakers pre-aspiration is not obligatory.

It was also mentioned that for one individual, ABE37, pre-aspiration is blocked by glottalisation word-finally (pat). The relationship between pre-aspiration and glottalisation is the topic of the following chapter.
Chapter 5 - Pre-aspiration and glottalisation

5.1. Introduction

In one strand of the literature relevant for the historical development of pre-aspiration, it has been pointed out that there are sister languages, in which sister A exhibits pre-aspiration in environments where sister B has glottalisation. Where such reflexes are found, some researchers argue that pre-aspiration developed from glottalisation and some propose that glottalisation developed from pre-aspiration, depending not only on the author but also on the language and/or variety in question, as discussed further below in 5.1.1. It is tacitly assumed in these studies that, at any single phonological environment at a historical stage X, there is either pre-aspiration or glottalisation, but not both (e.g. *pat* realised either as [\( \text{p}^h\text{a}^h\text{t}\)] or [\( \text{p}^h\text{a}^w\text{t}\)] but not [\( \text{p}^h\text{a}^h\text{t}\)]). However, if we assume a non-co-occurrence of the two, we run into the problem of how exactly one should develop from the other.

This chapter demonstrates that pre-aspiration and glottalisation can occur in the same language, in the same speaker, in the same token, and potentially also in the same consonantal segment. Furthermore, analyses of the segmental and the prosodic conditioning of pre-aspiration and glottalisation suggest that their relationship is most likely determined prosodically rather than segmentally, at least in Aberystwyth English and Manchester English. For some speakers, pre-aspiration and glottalisation are never found in the same environment (they are exclusive) whilst in others they are. In the exclusive, allophonic pattern, pre-aspiration is favoured word-medially (*patter*) and glottalisation word-finally (*pat*) and similarly pre-aspiration is more frequent in tokens produced in a carrier sentence (*Say pat once.*) than in those produced in isolation (*pat*) and the opposite is true of glottalisation. When they co-occur, they are both more frequent word-finally than word-medially. Finally, in the fricative context and also in one speaker in the plosive context, pre-aspiration is very frequent and glottalisation is independent from pre-aspiration, determined segmentally. However, it remains to be determined by further research whether
glottalisation is indeed associated with voiceless obstruents rather than being a generally prosodic phenomenon signalling for example discourse-related functions as opposed to cuing a specific class of segments, as is the case of pre-aspiration.

5.1.1. Pre-aspiration and glottalisation in historical literature

The historical debates draw our attention to several, although not abundant, cases of pre-aspiration corresponding historically to glottalisation. For example, pre-aspiration can be found in Western Yugur in the environments in which pharyngealisation/glottalisation can be found in Tuva and Tofalar (Roos 1998: 32). In addition, Kortland argues that Icelandic pre-aspiration corresponds to Vestjysk stød (Danish – 1988: 355), and Hansson agrees that the phonological distribution of the West-Jutlandic stød “is virtually identical” to that of pre-aspiration “elsewhere in Scandinavian” (2001: 167, also 169). Further comments come from Pentland, who states that “[m]ost Montagnais dialects show h as the reflex of [Proto-Algonquian] *ʔ- in the cluster *ʔl” (1977: 155). A hypothesis that necessarily recurs in these studies is that glottalisation may develop from pre-aspiration, and vice versa. Kortland postulates Proto-Germanic glottalised plosives (1988: 355) and thus also that Icelandic pre-aspiration may originate from glottalisation. Similarly, Page views West-Jutlandic stød as a development from Scandinavian pre-aspiration (1997: 179) and notes that other researchers have proposed a similar development for Hopi (1997: 185-6). Pentland (1977: 154-5) provides a – somewhat confusing – discussion of the reflexes of Proto-Algonquian *ʔʔt and *ʔʔc, from which it would follow that pre-aspiration develops from glottalisation. Others propose or assume that glottalisation developed from pre-aspiration in the languages in question (Page 1997: 179; Hansson 2001: 169 for the West-Jutlandic stød and pre-aspiration in Scandinavian). Kortland (1988: 353-4) and Hansson (2001: 172) refer to Bradley’s evidence from Burmish languages (1979) to point out to the fact that both developments are (claimed to be) attested in these languages equally commonly. However, these claims are not found in Bradley

74 The two terms are used synonymously in the paper.
75 Vestjysk stød is not the same phenomenon as the generally known stød found in Standard Danish and most of the West and Central Danish dialects which corresponds to Swedish word accents (Bandle, Braunmüller, Jahr, Karker, Naumann, Teleman, Elmevik & Widmark 2002: 1022).
(1979), nor is there much evidence that would support the claim based on Bradley’s work.\textsuperscript{76}

For more opinions on whether pre-aspiration developed from glottalisation or the other way round in Germanic languages, see Pedersen (1912), Jespersen (1913), both quoted in Kortland (1988: 353-4) and Hansson (2001: 172). Helgason (2002: 24, 29) furthermore draws our attention to Liberman, who discusses “pseudo-stød and related phenomena”, in which he includes Tuvinian, Ket, and Ude(ge): on page 126 these are described as having pharyngealisation, but a transcription of one pharygealised Tuvinian word on page 127 is clearly that of pre-aspiration and this is confirmed on page 300 (“Preaspiration in Tuvinian and Ket is usually called pharyngealization.”) and Liberman goes on to state that “[…] Tuvinian pharyngealization seems an almost obvious descendant of stød” (Liberman 1982: 126, 127).

Another relevant example, though arguably segmental rather than subsegmental, is that of Czech, which is one of the languages well known for glottalised onsets of vowel-initial words (e.g. Palková 1997: 325-6); however, in some dialects of Czech, a prothetic /h/ is found in the same environment (almara “wardrobe, cupboard” [ʔalmara] ~ [halmara]). More specifically, Central Mid-Moravian dialects (Centrální středomoravská – hanácká – podskupina) exhibit both variably; Southern Mid-Moravian dialects (Jižní středomoravská – hanácká – podskupina) show a very frequent prothetic /h/ even in function words (ale “but” [ʔale] ~ [hale]); and Eastern Mid-Moravian dialects (Východní středomoravská – hanácká – podskupina) do not tend to have a prothetic /v/ or /j/, but nothing is said of /h/ for this subgroup (Lamprecht 1976: 154-6, 181).

The historical literature thus assumes that pre-aspiration and glottalisation do not co-occur within an individual and in the same environment. As mentioned in Chapter 1, although it would seem that pre-aspiration and glottalisation could not possibly co-occur in the same environment, this is probably connected to another assumption implicit in the phonological features [spread glottis] and [constricted glottis]. At first

\textsuperscript{76} There is no explicit mention of pre-aspiration in the publication. <hp> does occur in multiple places, but the author explains that the phonetic transcription of these is [pʰ] (57-8). The only place where the notification might refer to actual pre-aspiration is on page 264, where both <hp> and <ph>
blush, these require two opposing states of the glottis and at a contrastive level this may well be the case (although see Chapter 6). Phonetic evidence nevertheless suggests otherwise. First, and as will be further demonstrated in this chapter, glottalisation can be realised in a number of ways, which differ in the degree of adduction of the vocal folds. For example, creaky phonation usually involves repeated adduction of the vocal folds which is irregular, i.e. the individual adduction gestures are not timed regularly. The fact that there is a sequence of irregularly adducting vocal folds means that there are also moments during which the folds are not adducted (otherwise they could not adduct more than once).

Another phenomenon shows that glottalisation can co-occur simultaneously with glottal friction: whispery creaks. Whispery creaks consist of glottalisation overlaid with aspiration (Catford 1977: 99, 100; Laver 2009: 112; Gordeeva & Scobie 2013: 257). This friction originates in glottal gaps. Posterior (and other) glottal gaps have been reported to correlate with noisiness (Chen, Kreiman, Shue & Alwan 2011: 2673; Hanson & Chuang 1999; Zańartu, Galindo, Peterson, Wodicka & Hillman 2014; Södersten, Hertegård & Hammarberg 1995; Rammage, Peppard & Bless 1992; Schneider & Bigenzahn 2003; Park & Mongeau 2008; Gorham-Rowan & Laurens-Gore 2006: 173). Females with normal (as well as pathological) voice have been found to have a posterior glottal gap fairly frequently, most often at the arytenoids, whilst the rest of the vocal folds participate in voicing.

It is perhaps not that surprising that breathiness – often accompanying pre-aspiration – has been identified as one of the possible characteristics accompanying glottalisation (Redi & Shattuck-Hufnagel 2001: 408). Stevens & Hajek generally classify glottalisation as a phonetic realisation of pre-aspiration (2004a: 335; 2007), and Karlsson & Svanstessom similarly mention that pre-aspiration in Eastern Mongolian dialects can be manifested as laryngealisation (i.e. glottalisation as understood here) of the preceding vowel (2011). Skarnitzl (2004: 56) even lists breathy voice as one of the “generally accepted categories of glottalisation”. Furthermore, Árnason notes that in his own speech “preaspiration can be glottalized, which implies that the glottis can be closed right after the end of the pre-aspiration” (Árnason 1986: 17). As discussed further below, however, Árnason’s note is based
on self-inspection and has not been looked into with acoustic or articulatory evidence.

Thus, in principle, pre-aspiration and glottalisation are not mutually exclusive, i.e. complementary or allophonic. This hypothetical example is illustrated with an instance of pre-aspiration preceded by breathiness and glottalisation in the Aberystwyth data analysed here (Figure 5.1.).

In what follows in this section, the possible relationships that the two phenomena could enter into are discussed based on what is known about the segmental and prosodic conditioning of the two. Section 5.2 defines glottalisation in more detail, the analyses are presented in section 5.3, and the results and their implications are further discussed in section 5.4.

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As discussed in 5.2., the breathy interval differs from glottalised intervals in that the $f_0$ is usually higher than that of glottalisation and the glottal pulses are still to be seen across frequencies in the spectrogram for the latter.
5.1.2. Conceivable relationships

There are two broad conceivable relationships the two phenomena could acquire: they can be mutually exclusive or allophonic in the same environment, which means that, if the fortis plosive in *batter* is pre-aspirated, it is not glottalised (*batter [paʰtʰɔ]*) and if it is glottalised, it is not pre-aspirated (*[paʰtʰɛ]*)). Mutual exclusivity is therefore equalled to complementarity. Co-occurrence refers to cases where both pre-aspiration and glottalisation are found in the same utterance of the same segment, e.g. *batter* [paʰə] or [paʰɁtʰə].

For each option there are further suboptions defined by the conditioning of the phenomena, as summarised in Table 5.1. The two could be conditioned in the same way or they could be conditioned differently. The latter option subsumes the possibility of only one of them being conditioned segmentally or prosodically.

<table>
<thead>
<tr>
<th>RELATIONSHIP</th>
<th>SAME CONDITIONING</th>
<th>DIFFERENT CONDITIONING</th>
</tr>
</thead>
<tbody>
<tr>
<td>mutually exclusive / complementary / allophonic</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>co-occurring</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Table 5.1. Scenarios of the relationships between pre-aspiration and glottalisation

**Pre-aspiration and glottalisation as mutually exclusive**

Mutual exclusivity can take on two more general shapes: it can be obligatory or optional. The two phenomena may be in an obligatorily allophonic relationship. For example, in the word-medial context, pre-aspiration might occur but not glottalisation (*batter [paʰtʰɔ]*) whilst in the word-final context, glottalisation might occur but not pre-aspiration (*bat [paʰtʰ]*) as has been found for Manchester English (Hejná & Scanlon 2015) and one of the Aberystwyth respondents analysed here (ABE37).

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78 The phonetic transcriptions given here are simplistic, and more details are provided in section 5.2., where it also becomes apparent that the symbol [ʔ] is used to cover a wider range of phonetic laryngeal gestures.
Allophony in this traditional sense may not be the only scenario of mutual exclusivity – the mutual exclusivity could be optional in that the word batter could sometimes occur with pre-aspiration ([paʰtʰə]) and sometimes with glottalisation ([paʰtʰə]), but never with both in the same token. This would then be referred to as free variation in the traditional sense (see e.g. Hymes & Fought 1975 and the chapter on History Problems, especially page 213). A more nuanced treatment of allophony nevertheless shows that the traditional “allophony” and “free variation” represent two ends of the same scale rather than two separate categories (Hall 2009). If pre-aspiration occurs word-medially in, e.g., 95% of cases, this arguably still counts as obligatory allophony. However, it could also be the case for pre-aspiration to tend to occur word-medially e.g. 70% of the time and for glottalisation to occur word-finally e.g. 89% of the time. The frequency of occurrence in various conditions may become so low that the presence of the two phenomena is no longer predictable.

**Pre-aspiration and glottalisation as co-occurring**

We could hypothesise that there is at least a logical possibility for pre-aspiration and glottalisation to be found in the same context. For example, pre-aspiration could be followed by glottalisation (batter [paʰtʰə]), glottalisation could be followed by pre-aspiration (batter [paʰtʰə]), or the two could occur simultaneously. As already mentioned, the first scenario has been reported in a passing comment by Árnason, who notes that, based on his self-inspection (and not acoustic or articulatory analyses), he produces a glottal stop following pre-aspiration (1986: 17). The second scenario is possibly found for the Aberystwyth data analysed here and also for Manchester English fricatives (Hejná & Scanlon 2015, e.g. mass [maʰs]), but analyses beyond the scope of the present chapter need to be done to shed light on whether the co-occurrence is a result of glottalisation having function different from that of pre-aspiration, i.e. not signalling fortis obstruents but perhaps prosodic boundaries. Whispey creaks are considered as realisations of pre-aspiration overlaid with glottalisation by Gordeeva & Scobbie (2013). If the two phenomena indeed co-occur to cue the same segments, their co-occurrence could be conditioned in multiple ways.

79 These numbers are selected arbitrarily for the sake of illustration.
Firstly, they could be conditioned in the same way. The more tightly similar this conditioning for each, the more often they should co-occur. For example, both could be more likely to occur if the preceding vowel is low. Hence, both pre-aspiration and glottalisation could be more frequent in the word *bat* than in the word *bit*, as might be the case in Aberystwyth English.

Secondly, they could be conditioned in different ways. For instance, pre-aspiration could be conditioned segmentally (e.g. the lower the vowel, the more frequent the presence of pre-aspiration), while glottalisation could be conditioned prosodically (e.g. the coda of a syllable which coincides with the right edge of a lexical word could be associated with more frequent glottalisation, i.e. glottalisation can be more frequent foot-finally than foot-internally). They would thus not share the conditioning, but at the same time it would not be the case that the conditioning renders them mutually exclusive. They would therefore co-occur but in fact be independent of one another, each sensitive to a different prosodic level (segment and some higher prosodic level). This scenario also subsumes the possibility of only one of the two being conditioned in any way. In this scenario, pre-aspiration could be sensitive to vowel height, for example, but glottalisation may be sensitive to nothing at all. This is especially likely if one of them is a newly emerging phonetic feature. This scenario is most likely a precursor to the scenario of mutual exclusivity: glottalisation may start off as a prosodic feature and become reanalysed as a property of a segment, although still determined prosodically as well.

Finally, neither may be conditioned in any way. We can assume that this would be the case if both were newly emerging phonetic features or if they applied obligatorily or nearly obligatorily.

The scenarios discussed could result from language-internal factors. To see whether the relationship between pre-aspiration and glottalisation can be predicted, language-internal motivations are further dealt with in what follows. First, we look into the segmental factors reported to have an effect on pre-aspiration and glottalisation and then into the prosodic ones. Language-external factors are commented on in Discussion (5.4.).
5.1.3. Segmental and prosodic factors

The chances for the two phenomena to co-occur should depend on the degree of the overlap in their segmental or prosodic conditioning. This section summarises what is known in this respect, but it will become apparent that our current knowledge makes any predictions rather difficult.

Vowel height conditions pre-aspiration and glottalisation in the same way, which points to a high degree of potential overlap. Pre-aspiration is more frequent and longer in duration following low vowels (McRobbie-Utasi 1991: 10, McRobbie-Utasi 2003: 3, Stevens & Hajek 2004b: 59, Gordeeva & Scobbie 2007, Nance & Stuart-Smith 2013: 11) and glottalisation has similarly been reported as co-occurring with low vowels (Brunner & Żygis 2011).

Pre-aspiration and glottalisation have also been reported to be conditioned prosodically in the same way; however, the tendency for glottalisation to be found domain-finally seems to be stronger. Glottalisation is favoured domain-finally (or domain-initially if in a prominent position) rather than domain-medially in a number of languages (American English – Huffman 2005: 338, 351, 356; Lehiste 1979, Standard American English – Kreiman 1989 quoted in Wolk, Abdelli-Beruh, Slavin 2012: e112; Standard American English – Wolk, Abdelli-Beruh & Slavin 2012: e114; RP – Catford 1977: 100; Italian – Di Napoli 2015 and the references therein for other languages) and pre-aspiration in Scottish English has been found more frequent and longer in duration in phrase-final position (Gordeeva & Scobbie 2010: 170, 2007: 26). Ní Chasaide has also observed longer duration of pre-aspiration in the VC# environment than in the VCV environment mainly for Irish (1985: 118-120). However, two studies report findings different from these. Firstly, in Sienese Italian, no effects of position within the word have been found for pre-aspiration (Stevens & Hajek 2007: 430) and Hejná & Scanlon (2015) have noted that pre-aspiration occurs word-medially whilst glottalisation word-finally.

The place of articulation of the post-tonic plosive does not allow any predictions. Pre-aspiration is conditioned by the place of articulation of the post-tonic plosive in a fairly consistent way cross-dialectologically and cross-linguistically: /p/ is always associated with the lowest occurrence of pre-aspiration and with the shortest durations as well (e.g. Morris 2010: 10; Nance & Stuart-Smith 2013: 10). The place
of articulation of the post-tonic plosive has been found to condition glottalisation as well. Importantly, however, the phenomenon is not generally conditioned by the place of articulation and depends on the variety examined.

A proper overview of the conditioning of glottalisation by the place of articulation within varieties of English is complicated by the fact that the varieties differ with respect to the conditioning of glottalisation (glottal reinforcement, i.e. reinforcement of the oral gesture by a glottal gesture: [pa̰t] or [paʃ] bat) and glottalling (glottal replacement, i.e. replacement of the oral gesture by a glottal gesture: [pa] or [pa] bat), and often show presence of both. Discussing one without the other cannot present the full picture and may miss crucial parts of the conditioning portrayal because if one is omitted from the description, it may appear as if e.g. glottalisation hardly ever occurred with /t/, although this could be an artefact of the fact that glottalling may frequently affect /t/ (see Hejná & Scanlon 2015). A comprehensive study dealing with the relationship between glottalisation and glottalling is not known to the author. As said, although the place of articulation is a conditioning factor of glottalisation as well as glottalling, this factor is highly dependent on the variety in question (Huffman 2005: 337).

For Newcastle English, glottalisation has been reported as more frequent with /p/ than with /t/ or /k/ (Watt & Milroy 1999: 30). In Sheffield English, although /p/ and /t/ can be glottalised, this is mainly the case for /t/ (Stoddart, Upton, Widdowson 1999: 75-76). For Sandwell, glottalisation is reported as less frequent with /p/ than /k/ (Mathisen 1999: 110). South East London English shows glottal reinforcement and replacement with /p/ and /k/, but most frequently with /t/ (Tollfree 1999: 170). In Edinburgh English, /p/, /t/, and /k/ are glottalised word- and syllable-finally (Chirrey 1999: 226). In Belfast English, the commonly glottalised plosives are /p/ and /t/ (Wells 1982: 445).

In British English, the manner of articulation seems to condition complementary patterns between pre-aspiration and glottalisation, with pre-aspiration being favoured more by the fricative environment. Two studies have also considered the relationship between pre-aspiration and glottalisation depending on the manner of articulation of the consonant the gestures are associated with. In Manchester English, pre-aspiration and glottalisation are mutually exclusive in the plosive environment but pre-
aspiration is obligatory with fricatives and in this context it therefore always co-occurs with glottalisation (Hejná & Scanlon 2015). On the other hand, Gordeeva & Scobbie’s study reports glottalisation in plosives and pre-aspiration in fricatives (2013). The authors do mention a rare occurrence of whispery creaks in the fricative context in their data (2013: 257), but they treat these as instances of pre-aspiration. They are interested in whether more pre-aspiration in fricatives leads to less glottalisation or ejectivisation in plosives and conclude that “less preaspiration [in fricatives] does not necessarily mean more glottalisation [in plosives] or the other way round” (2013: 262).

The manner of articulation does not restrain the patterns between pre-aspiration and glottalisation only when it comes to plosives and fricatives. Glottalisation is less limited than pre-aspiration because it can affect any usually voiced segment and be associated with both voiced and voiceless segments. Furthermore, it can stretch across a number of segments if it is a feature of the higher levels of prosody rather than of the syllabic level of prosody or of the segmental level of a language. Although pre-aspiration can affect sonorants and obstruents, it occurs only with phonetically voiceless obstruents. If glottalisation is conditioned prosodically above the level of the syllable, we can expect it to co-occur with pre-aspiration more frequently.

The following section provides a more detailed definition of glottalisation and outlines how it is identified.

5.2. Methodology

The analyses in this chapter involve all the eighteen speakers described in Chapter 2 (twelve female and six male speakers). See Chapter 2 for the details on the recording procedure, further processing of the data, and the type of the data analysed.

For the fricative data, all twelve female and six male speakers are analysed, yielding 991 fricative tokens in total (793 tokens for twelve females and 198 for six males).
6,028 tokens are analysed for the plosive data for ten female speakers and 1,479 tokens for six male speakers.

5.2.1. Defining pre-aspiration

For examples of pre-aspiration and the definition of the phenomenon, see Chapter 3. It has been shown in the previous chapter that breathiness and pre-aspiration are not necessarily subject to the same conditioning and pre-aspiration thus refers only to voiceless (primarily) glottal friction.

5.2.2. Defining glottalisation

The term glottalisation has been used to subsume different phenomena in different studies. Detailed classifications of laryngeal phenomena have been proposed (e.g. Huber 1988, in Redi & Shattuck-Hufnagel 2001), which is undoubtedly a result of the high variability individual speakers can exhibit, possibly due to the individual properties of the laryngeal structures (Redi & Shattuck-Hufnagel 2001: 426) as well as due to the relevant specificities of individual languages and varieties. In this study, the following phenomena are subsumed under the term glottalisation:

1. aperiodic creak = a series of irregular glottal pulses
2. periodic creak = relative lowering in \( f_0 \); this lowering differs from breathy voice in that the glottal pulses are still visible across a range of frequencies in the spectrogram and the \( f_0 \) tends to be lower for glottalisation than breathy voice
3. glottal squeak = a sudden shift to relatively high sustained \( f_0 \), with a considerably low amplitude (Redi & Shattuck-Hufnagel 2001)\(^{80}\)

Classifying these examples as instances of glottalisation is in line with other studies (e.g., Bird, Caldecott, Campbell, Gick & Shaw 2008: 494; Dilley, Shattuck-Hufnagel, Ostendorf 1996; Kingston 1984: e.g. 146-7), but researchers generally
vary in what phenomena they consider realisations of glottalisation (e.g. Batliner, Burger, Johne & Kießling 1993; Hanson, Stevens, Kuo, Chen & Slifka 2001: 455; Laver 2009: 126). Examples of what phenomena were identified as glottalisation are illustrated in what follows. It was not a straightforward task to distinguish the three types of glottalisation, but the primary goal of this chapter was the identification of glottalisation and not that of the various types of glottalisation.

**Aperiodic and periodic creaks**

Aperiodic creaks were identified on the basis of the sound wave as well as the spectrogram (Figures 5.2. and 5.5.). In either visual representation in Figure 5.2., observable glottal pulses occur at a greater or smaller distances from one another (visible as dark vertical striations), and these distances are not predictable because they do not occur in a repeated, regular, or periodic, manner. In Figure 5.5., this does not affect the whole vowel but only its end,81 and there the aperiodic creak is identifiable also in contrast to the preceding periodic pulses.

In the following figures, “GF” stands for glottal friction resulting from whispery creak, “pre” for pre-aspiration, “br” for breathiness, “clo” for closure, “post” for post-aspiration, “GS” for glottal stop, “CRper” for periodic creak, and “CRaper” for aperiodic creak, which are further discussed in what follows.

80 Redi & Shattuck-Hufnagel (2001) distinguish aperiodicity (irregular periods), creak (lowering of fundamental frequency with near-tonal damping), diplophonia (alternation in the shape, amplitude, or duration of successive periods), and glottal squeak.

81 We do not actually know whether glottalisation should be considered part of the vowel, but assuming that it is part of the vowel makes the description of its position with respect to the vowel easier.
Figure 5.2. Aperiodic creak ("CRaper")

Illustrated on the word bap, produced by a male speaker of 26 years (ABE28). It is possible that the glottalisation found in this word also involves harsh phonation produced in the epilarynx. 'CRaper’ stands for glottalisation (‘aperiodic creak’), ‘br’ for breathiness, ‘pre’ for voiceless pre-aspiration, ‘clo’ for voiceless closure, and ‘post’ for post-aspiration.

Periodic creaks, on the other hand, show a higher degree of regularity in the spacing of the individual glottal pulses with respect to one another and were identified using a number of indicators. One of these was lowering in $f_0$ relative to the $f_0$ in other portions of the vowel (Bird, Caldecott, Campbell, Gick & Shaw 2008: 497; Dilley, Shattuck-Hufnagel & Ostendorf 1996: 428-9). The shape of the sound wave and an auditory assessment of the author were also employed to identify periodic creaks. An example of periodic creak is given in Figure 5.3.
Glottal squeaks

To the best of my knowledge, the term “glottal squeak” has been coined by Redi & Shattuck-Hufnagel (2001). Glottal squeaks, hardly ever co-occurring with any laryngeal features other than aperiodic creaks and glottal stops/minimal aperiodic creaks (further discussed below), were identified mainly on the basis of the sound wave, which showed a quasi-sinusoidal shape with low amplitude. Spectrogram information was also used: the voicing bar could be observed as the most prominent feature in the spectrographic information. Two examples are given in Figures 5.4 and 5.5.
Glottal squeaks are only found in the plosive environment and they are never followed by other glottal phenomena. Moreover, they only occur in the female data. Since glottal squeaks co-occur with other laryngeal phenomena and are not conditioned by aspects such as vowel height or the place of articulation of the post-tonic plosive, it seems they do not have a linguistic function.
**Glottal stops**

The IPA defines [ʔ] as a voiceless glottal plosive (IPA 2005). Plosives consist minimally of a period of closure and a burst. In the case of the glottal stop, there should therefore be a closure of the glottis resulting in its release. However, as Garellek notes, “[…] there are several unique phonetic and distributional peculiarities about glottal stops: remarkably, it is still unclear whether glottal stops are really glottal, really stops, and why they occur ‘optionally’ before word-initial vowels” (2013: 1).

The term “glottal stop” often covers in fact what the term glottalisation is intended to cover here. In many languages in which the term glottal stop is traditionally used, the “stop” is realised as a form of glottalisation other than a stop; most often, the realisation is that of aperiodic creak. The difficulty of identifying “true” glottal stops and whether the label “glottal stop” is appropriate in many languages and their varieties have been directly expressed before by some (Docherty, Foulkes, Milroy, Milroy & Walshaw 1997: 280; Ladefoged & Maddieson 1996: 75) and indirectly observed or noted by others (e.g., Kingston 1984: 219; DiCanio 2012b: 171, 173; Bassiri, Lecumberri, Cooke & Volín 2011: 1). Docherty, Foulkes, Milroy, Milroy & Walshaw mention that, in their data, where instances of glottal stops can be identified, the “stop gap” is dramatically shorter than what is traditionally described in the literature (1997: 280). Their description corresponds to the instances of glottal stops that can be identified as a single glottal pulse which is spaced irregularly with respect to the other glottal pulses.

Without articulatory evidence, it is fairly difficult to identify true glottal stops in the acoustic signal. Glottal stops as defined by Docherty, Foulkes, Milroy, Milroy & Walshaw (1997) were identified on the basis of the sound wave as well as the spectrogram (Figures 5.6-5.8.). In either visual representation, we can observe a single glottal pulse occurring at a greater distance from the surrounding glottal pulses (visible as dark vertical striations). Additionally, the sound wave corresponding to the presumed glottal stop usually shows a different shape from that of the

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82 For a discussion of the terms glottalisation, laryngealisation, and creak, see Garellek (2013: in particular 4-6) and the references therein.
surrounding pulses. These instances could nevertheless be subsumed under aperiodic creaks and would then present minimal aperiodic creaks.

**Figure 5.6. Glottal stop (‘GS’) in the plosive context**

Identifiable as a single glottal pulse which is irregular with respect to the surrounding glottal pulses illustrated on the word *lip*, produced by a female speaker of 24 years (ABE45). ‘Pre’ stands for voiceless pre-aspiration and ‘clo’ for voiceless closure.

**Figure 5.7. Glottal stop (‘GS’) in the fricative context**

Identifiable as a single glottal pulse which is irregular with respect to the surrounding glottal pulses illustrated on the word *bosh*, produced by a female speaker of 24 years (ABE45). ‘Pre’ stands for voiceless pre-aspiration, ‘GS’ is specified as ‘ini’ or ‘fin’, referring to the position with respect to the vowel (initial and final).
Arguably a glottal stop (“GS”), illustrated on the word back, produced by a male speaker of 26 years (ABE50). ‘Pre’ stands for voiceless pre-aspiration, ‘clo’ for voiceless closure, and ‘post’ for post-aspiration.

The identification of glottalisation presents a number of other problems. These are commented on in what follows.

**Position of glottalisation**

One glaring problem is the fact that glottalisation can occur in several positions within the vowel: vowel-initially, vowel-medially, vowel-finally, spread across the whole vowel (continuous glottalisation), or at multiple non-contingent parts of the vowel (e.g. in the middle there may be a creaky interval, followed by an interval of modal phonation, followed by another interval of creaky phonation). Should instances of glottalisation been included in the analyses irrespective of position?

A clear instance of glottalisation which is not induced by the post-tonic obstruent is word-initial vowel-initial glottalisation (as in *ass, at, off*). Tokens starting with a vowel could contain glottalisation induced by prosody (Garellek 2013: e.g. 2-3; Pompino-Marschall & Žygis 2011). Such word-initial glottalisation are therefore not counted as instances of glottalisation if the word in question also started with a vowel, irrespective of the duration or the type of the glottal gesture.
Vowel-initial glottalisation nevertheless does occur even if the vowel is preceded by a consonant. These cases are included in the analyses because there is no objective reason that suggests they cannot be induced by the post-tonic obstruent. But the position of glottalisation within the vowel is possibly an important methodological issue, although no correlations were found between the type of the pre-tonic consonant and vowel-initial glottalisation (See Appendix A.1 for the types of the pre-tonic consonant.). This is very important because it may be the case that pre-aspiration and glottalisation only co-occur if glottalisation is for example vowel-initial. This is however not the case: Appendix D.1 shows that pre-aspiration and glottalisation co-occurrence is not restricted only to certain positions of the glottalisation within the vowel.

**Periodicity-aperiodicity continuum**

Although there are many examples of clearly periodic and clearly aperiodic creaks, there are also many intermediate cases somewhere along the continuum of periodicity-aperiodicity. This problem has been identified before (Docherty & Foulkes 1999: 57-61, Pierrehumbert & Talkin 1992: 100-101). This would be a problem for the purposes of the present chapter if pre-aspiration only co-occurred with either periodic or aperiodic creak. However, this is not the case (See Appendix D.1.).

As further discussed in section 5.4., another, more important, problem is that further analyses are needed to shed light on whether it is fortis plosives and fricatives specifically which are associated with glottalisation as well as pre-aspiration, or whether the glottalisation is a generally prosodic phenomenon, occurring with a range of segments in the variety.

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83 The problem of the periodicity-aperiodicity continuum is furthermore connected to another issue. Not infrequently, a vowel contained a series of periodic and aperiodic creaks, or an aperiodic creak and a glottal stop. In such instances, it was not obvious if these should be counted as a series of two or three different glottal gestures or just one gesture of aperiodic creak.
Whispery creaks

One speaker especially showed a high number of whispery creaks (Catford 1977: 99, 100; Laver 2009: 112; Gordeeva & Scobbie 2013: 257), in which aperiodicity is overlaid with aspiration, as illustrated in Figure 5.9.

These are a composite of glottalisation and glottal friction. Such instances of whispery creaks are not considered simultaneous realisations of glottalisation and pre-aspiration in this speaker because, rather than glottalisation overlaid with pre-aspiration, the speaker presumably exhibits a constant leak of airflow coming through a glottal gap (e.g. Gorham-Rowan & Laures-Gore 2006: 173), and this airflow leak is especially well visible when the vocal folds do not vibrate with the usual frequency. We can see that this is the case because the same glottal friction is found in other contexts inducing glottalisation, e.g. intervocally (Say | arm) and in the sequences of sonorants (Milky Way). This is illustrated in Figures 5.10 and 84.

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84 For more examples of whispery creaks, see Appendix D.2.
85 Gordeeva & Scobbie (2013) treat whispery creaks as instances of pre-aspiration due to the prevalent noisiness in the signal, which gives rise to an auditory impression of whisper rather than creak in their data. It is not easy to decide in the same way if pre-aspiration or glottalisation is auditorily or visually more prevalent than the other in the Aberystwyth data.
5.11. Figure 5.10. shows *Say arm once* with intervocalic glottalisation between *Say* and *arm* – glottal friction can be seen throughout the vowel as well. Figure 5.11. illustrates word-final and utterance-final glottalisation on *Milky Way*, not followed by a consonant (or other sounds).

![Figure 5.10. Intervocalic glottalisation overlaid with friction](image1)

*Illustrated on Say arm once, produced by a female speaker of 28 years (ABE37).*

![Figure 5.11. Word-final and utterance-final glottalisation overlaid with friction](image2)

*Illustrated on Milky Way, produced by a female speaker of 28 years (ABE37).*

If we decided to consider these cases as instances of pre-aspiration, this speaker would pre-aspirate even before segments that do not cause pre-aspiration, e.g. intervocalically or utterance-finally followed by a pause.
5.3. Results

The results repeatedly show that both the mutually exclusive or allophonic patterns and those of mutual co-occurrence are determined prosodically rather than segmentally, and where glottalisation is independent of pre-aspiration, this is only when pre-aspiration is not sensitive to segmental or prosodic conditioning.

First, it is shown how frequently the speakers pre-aspirate and glottalise, and, where the speakers produce both, whether these show a mutually co-occurring or a mutually exclusive pattern. The speakers with the co-occurring and the mutually exclusive patterns are further analysed for the segmental and prosodic conditioning of the two phenomena. This is done first for the speakers with the co-occurring pattern, next for those with the mutually exclusive one.

5.3.1. How frequently do pre-aspiration and glottalisation co-occur in the same environment?

The first step towards understanding the relationship between pre-aspiration and glottalisation is establishing how much the individual speakers pre-aspirate and glottalise, and how often the two phenomena co-occur in the same environment in the same tokens.

In the plosive context, every speaker pre-aspirates and the majority pre-aspirate most of their tokens. In the fricative context, two speakers pre-aspirate less than 5% of their tokens (ABE11 and ABE15). Except for these two male Aberystwythians, then, everyone is a pre-aspirator in both contexts. On the whole, glottalisation is fairly infrequent in comparison to pre-aspiration, with the exception of ABE37, the monosyllabic glottaliser with the same pattern reported for Manchester English.

Figures 5.12.-5.14. show the number of tokens with pre-aspiration and glottalisation by speaker within the female plosive data, the male plosive data, and the fricative data, respectively. For each speaker, the total number of tokens is provided at the top of the appropriate column, because the y-axes of the graphs represent percentages (100% = 1.0, 20% = 0.2, etc.).
Figure 5.12. Pre-aspiration and glottalisation occurrence in female plosive data

Each column represents one speaker (e.g. ABE12, as indicated at the bottom); the number at the top stands for the number of tokens available for the analyses for each speaker (e.g. 591 for ABE12); the figure itself shows the percentage of pre-aspiration occurring on its own, glottalisation occurring on its own, neither occurring, or the two co-occurring within each speaker.

The two genders are given separately solely because of the differences in the datasets used for the analyses, which are especially noticeable in the plosive context.
Figure 5.13. Pre-aspiration and glottalisation occurrence in male plosive data

Each column represents one speaker (e.g. ABE11, as indicated at the bottom); the number at the top stands for the number of tokens available for the analyses for each speaker (e.g. 248 for ABE11); the figure itself shows the percentage of pre-aspiration occurring on its own, glottalisation occurring on its own, neither occurring, or the two co-occurring within each speaker.
Figure 5.14. Pre-aspiration and glottalisation occurrence in the fricative context

Each column represents one speaker (e.g. ABE11, as indicated at the bottom); the number at the top stands for the number of tokens available for the analyses for each speaker (e.g. 33 for ABE11); the figure itself shows the percentage of pre-aspiration occurring on its own, glottalisation occurring on its own, neither occurring, or the two co-occurring within each speaker.

Most female speakers show glottalisation in the plosive context, but four stand out (ABE14, ABE37, ABE45, and ABE46). Within the male plosive data, ABE28 stands out as a glottaliser, and ABE25 follows the suit (but the numbers of glottalised tokens are closer to those of the other male speakers, who glottalise very little). In the fricative context, four speakers stand out (ABE14, ABE28, ABE37, and ABE50). The rest show a variable degree of glottalisation, which on the whole co-occurs with pre-aspiration in the same environment in the same tokens.

The speakers who do not glottalise (ABE15 and ABE41 in fricatives) must be excluded from the analyses of the segmental and the prosodic conditioning of glottalisation because the lack of the two phenomena may skew the overall results. However, we cannot straightforwardly call the remaining speakers glottalisers.
because for some of them the amount of glottalisation is fairly infrequent, and the same is the case for pre-aspiration for some speakers (ABE11 and ABE15 in fricatives). Dividing the speakers into glottalisers and pre-aspirators presents us with the difficulty of where to draw the line between who glottalises and who pre-aspirates because there is a continuum and some speakers are naturally impossible to put a label on as either glottalisers or non-glottalisers. This is shown in Figure 5.15. on the female plosives, which illustrates the number of glottalised tokens (x axis) and the number of speakers associated with the different amounts of glottalised tokens (y axis). 

![Figure 5.15. Distribution of female glottalisers](image)

*Figure 5.15. Distribution of female glottalisers*

*Within the plosive context, excluding ABE37. The y axis represents number of speakers with a particular number of glottalised tokens.*

There are three major peaks of those who glottalise 0-10 of their tokens, those who glottalise 30-40 tokens, and finally one female who glottalises 50-60 tokens. However, even if distributions are drawn to see how the individuals are grouped depending on the number of glottalised tokens, the methodological issue is not resolved. Although there are three peaks, there are nevertheless two speakers who fall in between these two peaks, and for those we simply cannot decide whether they pattern with the 0-10 tokens females or the 30-40 tokens females.

87 ABE37, a heavy glottaliser, is excluded so that the less pronounced differences between the less glottalising speakers are more obvious.
To avoid any risk of the analyses being skewed by the inclusion of non-glottalisers, only the speakers that stand out are discussed further (plosive context: ABE14, ABE37, ABE45, ABE46; ABE25, ABE28; fricative context: ABE14, ABE28, ABE37, ABE45, ABE50, ABE52), i.e. the intermediate speakers are excluded (such as those glottalising between 10-30 tokens in the plosive data as shown in Figure 5.15.).

These seven speakers all show at least some tokens with pre-aspiration and glottalisation co-occurring in the same environment. There are nevertheless two different patterns. In the plosive context, three females exemplify mutual exclusivity (ABE14, ABE37, ABE46) in that the glottalised tokens are more frequently unaccompanied with pre-aspiration; and one female exhibits co-occurrence of the two (ABE45). Within the male plosive data, ABE25 and ABE28 show co-occurrence: the glottalised tokens are much more frequently accompanied with pre-aspiration. Considering the fricative context, three speakers present a co-occurring pattern (ABE28, ABE37, and ABE50) and one that of mutual exclusivity (ABE14).

What follows (5.3.2.) focuses on what conditions the mutual exclusivity of the two phenomena.

5.3.2. Mutual exclusivity in the plosive environment

The relationship of mutual exclusivity, or complementarity, between pre-aspiration and glottalisation is determined by prosody and not by the segmental factors. The strongest effect is that of the position within word (word-medial: *batter*; word-final: *bat*). This is illustrated on three speakers (ABE14, ABE37, and ABE46).

This is strongest for ABE37, who exhibits an obligatorily complementary pattern, in which pre-aspiration is found word-medially (*batter* [paːtə]) and glottalisation word-finally (*bat* [paːtɛ]), as shown in Figure 5.16. (The width of the bars reflects the
number of tokens per condition.\textsuperscript{88} ‘1’ stands for monosyllabic tokens with word-
final plosives and ‘2’ for disyllabic ones with word-medial plosives.

\textsuperscript{88} Throughout this chapter, the analyses are carried out using logistic Mixed Effects Models for most
of the analyses and Fit Bayesian Models for analyses of data involving quasi-complete separations
resulting from obligatorily allophonic patterns. For each group of speakers, there are two models for
each consonantal context (plosive, fricative). The first model looks into the conditioning of pre-
aspiration, the second deals with that of glottalisation, with “subject” and “word” as random effects
unless the model was run only on one speaker. The dependent variables are therefore pre-aspiration
and glottalisation, respectively (with two levels: “present” and “absent”). The independent variables
are as follows: “vowel type”, “place of articulation of the post-tonic plosive”, “utterance type”, and
“word position”. Vowel type had eight levels for the female data (/a/, /aː/, /e/, /ɪ/, /ɒ/, /oː/, /ʊ/, /ʌ/), for
some nine (/uː/), and two for the male data (/a/, /ɪ/).

Forward difference coding was applied to “vowel type”, meaning that the vowels were compared to
each other successively in the alphabetic order. This enabled analyses of vowel length as well as some
analyses of vowel height and backness. For “place of articulation of the post-tonic plosive” (with
three levels: /p/, /t/, /k/), forward difference coding was also applied, comparing /p/ to /t/ and /t/ to /k/.
“Utterance type” had two levels: “isolation” and “carrier sentence”. “Word position” had two levels
as well: “word-final” and “word-medial”. Presence of glottalisation and pre-aspiration (with two
levels: “present” and “absent”) was included in the models in which pre-aspiration and glottalisation
were the dependent variables, respectively. The statistical results with the significant effects are
summarised in Appendix C.
The speakers with optional exclusivity also show this tendency: the word-final context (*bat*) is associated with less pre-aspiration than the word-medial context (*batter*), and the word-final context is associated with more glottalisation than the word-medial context. This is reflected in the conditioning by the type of the utterance. Pre-aspiration is more frequent in words produced in a carrier sentence than in those in isolation, whilst glottalisation is more frequent in words produced in isolation than those in a carrier sentence. These patterns are shown in Figure 5.17.
Figure 5.17. Prosodic conditioning of optional exclusivity: position in word and sentence in 'CVP(V) words (top: pre-aspiration; bottom: glottalisation)

ABE14 and ABE46. ‘1’ stands for the word-final context (e.g. pat) and ‘2’ for the word-medial context (e.g. patter)

The frequency of occurrence of pre-aspiration is more sensitive to segmental conditioning. /e/ is associated with more pre-aspirated tokens than /ɪ/, which corresponds to the behaviour of glottalisation. However, glottalisation is less sensitive to the conditioning by the place of articulation of the post-tonic plosive than pre-aspiration is.

When ABE45 and ABE46 are analysed separately, some differences mainly in the segmental conditioning emerge, but pre-aspiration is consistently more frequent word-medially and glottalisation word-finally, and the former is also more frequent in tokens produced in a carrier sentence whilst the latter in those in isolation.
5.3.3. Co-occurrence in the plosive environment

The co-occurrence of pre-aspiration and glottalisation in the same environment is predictable again by prosody rather than the segmental conditioning: both pre-aspiration and glottalisation are more frequent word-finally than word-medially. This is the case for ABE25 and ABE28. For ABE45, pre-aspiration is nearly obligatory and the presence of glottalisation is not predictable in any way apparent from the data at our disposal. For ABE45, although graphs confirm the usual conditioning by vowel height and the place of articulation of the post-tonic plosive, these differences are very small indeed (Figure 5.18.). Prosodically, the graphs also suggest a negligibly higher amount of pre-aspiration word-finally and in isolation.

![Figure 5.18](image)

*Figure 5.18. Segmental conditioning of the frequency of occurrence (%) of pre-aspiration (top) and glottalisation (bottom) by the place of articulation of the post-tonic plosive and by vowel height; CVP(V) words

ABE45. /i/ is represented in the graphs as ’/i/’
For ABE25 and ABE28, pre-aspiration and glottalisation are conditioned in the same way by the position within the word: pre-aspiration and glottalisation are more frequent word-finally than word-medially. As is the case with the speakers with the pattern of optional exclusivity between pre-aspiration and glottalisation in the plosive context (5.3.2.), pre-aspiration is more sensitive to the segmental conditioning than glottalisation even in the speakers with the pattern of optional co-occurrence. Pre-aspiration and glottalisation are again conditioned by the vowel type and are more frequent with /a/ than /ɪ/. These results are shown in Figure 5.19. However, unlike pre-aspiration, glottalisation is not conditioned by the place of articulation of the post-tonic plosive.

When the two individual male speakers are compared, they each show the same patterns, although the position within word does not emerge as significant for
glottalisation and the type of utterance is significant for pre-aspiration only for ABE25 (Pre-aspiration is more frequent in the carrier sentence.).

5.3.4. Mutual exclusivity in the fricative environment

One speaker exhibits a pattern of optional exclusivity, ABE14, and this exclusivity is not predictable by the segmental or the prosodic conditioning. Pre-aspiration is, to a very limited extent, conditioned by vowel type and also by the presence of glottalisation. Glottalisation is only subject to the effect of the presence of pre-aspiration: pre-aspiration is more likely to occur where there is no glottalisation and vice versa.

5.3.5. Co-occurrence in the fricative environment

In the fricative context, the presence of pre-aspiration is not predictable because it is nearly obligatory for the speakers with the optional co-occurrence of pre-aspiration and glottalisation (ABE28 – 97%, ABE37 – 92%; ABE50 – 99%). Unlike pre-aspiration, glottalisation with fricatives is sensitive to the segmental conditioning. For ABE28, glottalisation is found more frequently with /a/ than /ɒ/, and for ABE37 it is found more frequently with /ɑ/ than /ax/ and /f/ than /ʊ/.

This means that the presence of glottalisation is determined by its segmental conditioning and this therefore also applies to when pre-aspiration and glottalisation co-occur. Glottalisation does not interact with pre-aspiration in these speakers.

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89 In the fricative context, Logistic Mixed Effects Models are used again in the same way as in the plosive context. The only differences are found in the dependent variables, which involve “vowel type”, “place of articulation of the post-tonic plosive” (with four levels: /l/, /θ/, /s/, /ʃ/), and “utterance type” (isolation vs carrier sentence). Vowel type had five levels for the female data (/a/, /e/, /ɪ/, /ɒ/, /ʌ/), four in case of ABE50 (/a/, /e/, /ɪ/, /ɒ/), and two for the male data (/a/, /ɪ/). Forward difference coding was applied to “vowel type”. For “place of articulation of the post-tonic plosive”, forward difference coding was also applied, comparing pairs successively from the most anterior to the most posterior place of articulation (/l/ to /θ/, /θ/ to /s/, /s/ to /ʃ/).

90 The speakers with optional co-occurrence of pre-aspiration and glottalisation in fricatives are ABE28, ABE37, and ABE50.
5.4. Discussion

This chapter has shown that pre-aspiration and glottalisation can co-occur in the same environment and that their relationship, when there is one, is determined prosodically and not segmentally. The generalisations and implications of these findings are further discussed in this section together with the questions they raise.

5.4.1. Pre-aspiration and glottalisation can co-occur with the same segment

First, we saw that in the plosive context all speakers pre-aspirate, but the same cannot be said about glottalisation. Similarly, in the fricative context all except for two speakers pre-aspirate, but many fewer could also be called glottalisers. Those who were seen as pre-aspirating and glottalising frequently enough are marked with ticks in Table 5.2. below.
Table 5.2. Individual patterns of pre-aspiration and glottalisation

Only speakers analysed for glottalisation in section 5.3.1. are shown as glottalisers.

Some generalisations can be made based on this table:

1. If a speaker pre-aspirates fricatives, the speaker will also pre-aspirate plosives.
2. If a speaker glottalises fricatives, the speaker will also glottalise plosives.\textsuperscript{91}

3. If a speaker glottalises, the speaker will also pre-aspirate.

More speakers need to be analysed to further support these predictions as well as point towards the historical steps leading towards the patterns found in the respondents analysed here. One thing that can be said about these generalisations is that pre-aspiration must be older than glottalisation in Aberystwyth English.

At present, the following chronology is suggested for the history of the relationship between pre-aspiration and glottalisation in the variety:

1. Initially, neither plosives nor fricatives are pre-aspirated.
2. Breathiness is found in the fricative context and spreads to the plosive context.
3. Pre-aspiration develops in the plosive context.
4. a. Pre-aspiration spreads to fricatives.
   
   b. At a similar stage, glottalisation may occur as a prosodic/discourse phenomenon. It is conditioned prosodically and is found domain-finally, especially utterance-finally, and it thus co-occurs with pre-aspiration.

5. a. Glottalisation and pre-aspiration can become mutually exclusive with plosives. This is conditioned prosodically with glottalisation having spread to the word-final position irrespective of the position within the utterance.
   
   b. Glottalisation spreads to fricatives but is not associated with fricative segments. It co-occurs with pre-aspiration.

6. Glottalisation and pre-aspiration become mutually exclusive before fricatives as well.

Historical analyses remain to be done to verify this proposal. Analyses of Manchester English would be interesting in this regard to suggest whether the history of the allophonic relationship between pre-aspiration and glottalisation can be explained in a similar way.

\textsuperscript{91} This does not match ABE50. She does glottalise in the plosive context, but less frequently than in the fricative context.
5.4.2. Emerging patterns

Both mutual exclusivity or allophony and co-occurrence were found with plosives as well as fricatives, although co-occurrence is more frequent in the fricative context.

One speaker reveals obligatory allophony between pre-aspiration and glottalisation in the plosive context (ABE37), with the former found word-medially (patter) and the latter word-finally (pat). ABE14 is an example of a speaker with the same pattern, which is nevertheless optional rather than obligatory (=optional mutual exclusivity). The conditioning by the position within the word is furthermore reflected in the conditioning by the type of the utterance: pre-aspiration is more frequent in words uttered in a carrier sentence (Say pat once.) whilst glottalisation in those uttered in isolation (pat).

Where the two phenomena co-occur, they never do so obligatorily. For two speakers (ABE25 and ABE28), the co-occurrence is again conditioned prosodically. Both pre-aspiration and glottalisation are more frequent word-finally rather than word-medially. This points to glottalisation being prosodically conditioned more consistently across the speakers than pre-aspiration, whereas the opposite is the case for glottalisation regarding the segmental conditioning. For one speaker (ABE45), the two phenomena optionally co-occur, but they are not conditioned either prosodically or segmentally based on the analyses done in this chapter.

With fricatives, one speaker exhibits a pattern of mutual exclusivity, which is not predictable (ABE14). The speakers with optional co-occurrence of pre-aspiration and glottalisation reveal that the two phenomena are not determined by one another.

5.4.3. Emerging questions

The data presented in this chapter prompt several questions.

(In)consistency of patterns within and across speakers

Firstly, why are some speakers consistent in their relationships between pre-aspiration and glottalisation in the plosive and the fricative environments and others
are not? It was suggested to me that this could be explained through a possible transfer from Welsh, which exhibits the lack of contrast in the fricative context (Albright, personal communication 2015). However, the same argument cannot be used to explain why in Manchester English pre-aspiration and glottalisation are exclusive in the plosive environment and co-occurring in the fricative environment (Hejná & Scanlon 2015).

**Is glottalisation purely prosodic and/or (sub)segmental?**

Secondly, where pre-aspiration and glottalisation co-occur, are we dealing with co-occurrence which is due to the fact that glottalisation signals a prosodic function (such as the end of the utterance), or is it a general feature of the individual’s phonation setting, or is it the case that glottalisation is, like pre-aspiration, associated with fortis obstruent segments and is this the same for all the age groups? This uncertainty could be resolved as follows.

Firstly, we could contrast two prosodic conditions, such as utterance-initial and utterance-final, in which a range of contrastive segments would be found as well:

*The rack I mentioned is over there.*

*They put the brown coat on a rack.*

The following segments could be contrasted in the two prosodic conditions:

/p/, /v/, /k/ vs /f/, /θ/, /s/, /ʃ/ vs /m/, /n/, /ɹ/, /l/

/p/, /t/, /k/ vs /b/, /d/, /ɡ/

/f/, /θ/, /s/, /ʃ/ vs /v/, /ð/, /z/, /ʒ/

*The ram I mentioned is over there.*

*They put the small ewe next to the ram.*

This would enable to determine whether glottalisation, like pre-aspiration, is a property of obstruents rather than a prosodic property which applies irrespective of
the segmental information. Furthermore, the comparison of /p/, /t/, /k/ vs /b/, /d/, /g/, and /f/, /θ/, /s/, /ʃ/ vs /v/, /ð/, /z/, /ʒ/ would determine whether both pre-aspiration and glottalisation are acoustic correlates of the “voicing” contrast in obstruents, which would clearly point to whether they have a segmental function. This question is partially answered in the next chapter, which demonstrates that in production data pre-aspiration has considerably higher cue strength than glottalisation word-medially and word-finally. However, glottalisation occurrence is systematically different between /p/, /t/, /k/ and /b/, /d/, /g/ word-finally and its cue reliability is low, i.e. it occurs infrequently (with the exception of the monosyllabic glottaliser, ABE37). There is individual variation regarding whether word-final glottalisation is more frequent with /p/, /t/, /k/ or /b/, /d/, /g/. These two observations suggest that glottalisation does have the potential of signalling segmental information, but in the data analysed it fulfils this function rather poorly.

An interesting question related to cues of contrasts is whether pre-aspiration and glottalisation would cue the contrast equally well. In a similar vein, Stevens & Hajek note that both pre-aspiration and glottalisation secure voicelessness irrespective of whether the focal folds are abducted or adducted (2007: 431). However, the analyses of the conditioning of the two phenomena in Aberystwyth English do not suggest that the primary connection between the two is that of multiple strategies to index the “voicing” contrast. If pre-aspiration and glottalisation are nevertheless equally well-equipped for this function, we cannot predict whether pre-aspiration and glottalisation will keep on co-occurring, whether one of the two takes over in the course of time, and which.

Another way to determine whether glottalisation has a segmental function has been employed in Hejná & Scanlon (2015), who show that word-finally in the plosive context glottalisation is obligatory and moreover always occurring at the end of the vowel,92 whereas where glottalisation co-occurs with pre-aspiration word-medially or in the fricative context, its position with respect to the vowel is not stable.

Yet one more method to test for whether glottalisation is a segmental phenomenon in the speakers analysed here would be investigating whether its occurrence is

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92 If it is indeed part of the vowel. We could also say that it always occurs between the vowel and the plosive or at the beginning of the plosive, depending on our stance on the affiliation of glottalisation.
conditioned by intonation in any way. For example, do the speakers with more glottalisation also produce different intonational patterns in these utterances and is the glottalisation therefore brought about by intonational differences?

**Pre-release and post-release gestures**

Thirdly, can the patterns be explained through a relationship between the pre-release and the post-release gesture? It is plausible that there is a relationship between the pre-release gesture (pre-aspiration or glottalisation) and the post-release gesture (post-aspiration or no aspiration or no release at all). This is not a novel idea (e.g. Gordeeva & Scobbie 2013, for ejective glottalic release and pre-glottalised release).

With respect to pre-aspiration, it has been shown that Spanish /hθt/ (< /st/) is perceptually confusable with /θt/ (Ruch & Harrington 2014). If pre-aspiration was connected with post-aspiration and glottalisation with the lack of post-aspiration, the lack of glottalisation in Welsh English might be explained: as noted earlier, Welsh English has been reported as heavily post-aspirating (Wells 1982: 388). To confirm this hypothesis, ABE37 (and the Manchester respondents analysed in Hejná & Scanlon 2015) would need to be analysed for co-occurrence of pre- and post-aspiration and the lack of such a correlation with glottalisation.

The pre- and post-release gesture relationship, if there is any, can also explain why there are different patterns in the plosive and the fricative contexts. Although Wells claims post-aspirated fricatives occur in Welsh English (1982: 388), within the respondents analysed here, fricatives are never post-aspirated. Thus, while plosives can be, and often are, pre- as well as post-aspirated, it is not the case that there would be pre- as well as post-aspirated fricatives, and the distinction of a post-aspirated fricative and an unaspirated fricative is missing.

**Stylistic variation**

Fourthly, it remains to be shown how stylistic variation fits in with the lab speech results presented in this chapter. It is very well possible that more informal contexts will reveal very different patterns between pre-aspiration and glottalisation. This fourth question is not unrelated to the last question raised by the reports of pre-
aspiration and glottalisation in other varieties of English: how speaker- and accent-specific is this relationship?

5.4.4. Social aspects of pre-aspiration and glottalisation

This chapter has shown that the segmental conditioning of pre-aspiration is richer and more consistent than that of glottalisation. This also seems to be the case regarding their social conditioning, although too few sociolinguistic studies of English pre-aspiration are available to allow any conclusive discussions. Moreover, it seems that accents differ in which position of the sentence as well as word is associated with pre-aspiration, although this may be an effect of the different designs used, prompting different styles.

With respect to glottalisation, social age, gender, and class generally play a role in a dialect-specific way. For example, in Newcastle English, glottalisation of /t/ is present mainly in male speech (Watt & Milroy 1999: 30; Docherty & Foulkes 1999: 61). In Sandwell English, middle-class females and generally middle class teenagers lead in glottalisation (Mathisen 1999: 110). Indeed, glottalisation and glottalling have received considerable attention in sociolinguistic studies, although the analyses are mainly auditory, not acoustic. In his thesis on lenition in Liverpool English, Watson has commented on a “plethora” of English dialects for which glottalisation is attested (2007: 114). Regarding glottalisation, Liverpool English, non-Ulster Irish English, and Welsh English have been seen as unusual because they do not participate in the general trend towards glottalisation. Liverpool English instead exhibits spirantisation (Wells 1982: 371; for the relationship of spirantisation and glottalisation see Watson 2006), as does non-Ulster Irish English (/t/ and occasionally other plosives – Wells 1982: 429-430). Finally, in Welsh English, the phenomenon has been claimed to be absent (Wells 1982: 388), with the exception of Cardiff and Newport English, where glottalisation is prestigious (Mees & Collins 1999; Wells 1982: 388). The presence of glottalisation in Cardiff English has been explained as the influence of English varieties of English (Mees & Collins 1999).

As already mentioned in Chapter 1, more recent reports from a number of English accents strongly suggest that pre-aspiration is also a fairly widespread phenomenon
in the UK. Crucially, many English accents are all strongly glottalising and glottalling ones.

The results from Aberystwyth English are however rather consistent with those reported for Manchester English (Hejná & Scanlon 2015) in that pre-aspiration and glottalisation co-occur in the fricative contexts and mutual exclusivity, or allophony, is found in the plosive context. The Manchester pattern in the plosive environment is however reflected only in ABE37 and partially also in the speaker with optional exclusivity, ABE14. This is nevertheless surprising considering that Welsh English has long been noted to be a very strongly (post-)aspirating variety of English (e.g. Wells 1982: 388) also a non-glottalising variety of English (Wells 1982: 388) with the notable exception of Cardiff English (Mees & Collins 1999). Manchester English, on the other hand, has long been reported to be a glottalising variety of English (Wells 1970: 247; Baranowski & Turton 2014). A phonological pattern could be directly transferred from the source language/variety, or it could be transferred only partially – either the conditioning could be borrowed or just the presence of the phenomenon. For example, if glottalisation is associated by the Welsh speakers with accents spoken in England, their attitude towards English English accents may be reflected in whether and how frequently they glottalise. It seems plausible that at least some speakers would adopt glottalisation, but use it differently to cue different aspects of their lives and language.

The next chapter looks into the acoustic correlates of the contrast between /p/, /t/, /k/ and /b/, /d/, /g/ and, among other things, shows that pre-aspiration has a higher cue strength than glottalisation.

93 It may be the case that L1 Welsh speakers are less prone to glottalise in their English than L1 English speakers who are Welsh, which ties in with the abundance of glottalisation in English spoken in Cardiff, where there are generally very few local L1 Welsh speakers.
Chapter 6 - The fortis-lenis contrast

6.1. Introduction

The previous chapters have shown that pre-aspiration is robustly present in words with /p/, /t/, and /k/ (bap, bat, back) and, for sixteen out of eighteen speakers, also in words with /f/, /θ/, /s/, and /ʃ/ (if, myth, miss, fish). Chapter 4 threw more light on the question of whether pre-aspiration is a phonetic or also a phonological linguistic feature in Aberystwyth English by establishing that pre-aspiration exhibits phonological as well as phonetic conditioning. This chapter also addresses this question, but from the perspective of the role of pre-aspiration in the implementation of the contrast between /p/, /t/, /k/ and /b/, /d/, /ɡ/.

The labels fortis and lenis plosives are used to refer to /p, t, k/ and /b, d, g/, respectively, and the contrast between the two series is referred to as the fortis-lenis contrast here. These labels are used in line with Ní Chasaide, among others,

“[…] as convenient phonological terms to avoid potentially confusing situation where one speaks of voiceless voiced stops, i.e. phonologically voiced stops with no phonetic voicing. The fortis/lenis labels are in no way intended to imply that either stop series is characterised by tense or lax qualities.” (1985: 105)

This chapter concludes that in production pre-aspiration functions as a strong correlate of the contrast word-medially (patter [pʰaʰtʰə]) and word-finally (pat [pʰaʰtʰ]), but although it is found word-initially when preceded by a vowel (Say patter once. [ˈseɪpʰaʰtʰə]), it does not systematically distinguish the two plosive series there. Considered in the absence of other phonetic features potentially distinguishing the contrast, it would seem to be a very strong acoustic correlate word-medially and word-finally.

However, the fortis-lenis contrast is often implemented through multiple phonetic cues and correlates (e.g. Al-Tamimi & Khattab 2011, Toscano & McMurray 2010, and the references therein as well as references in 6.1.2.) and the strength of these cues and correlates varies across environments and conditions. The presence of a
number of cues with variable cue strength must be necessary as the contrast is ideally – but not always – maintained across a number of different segmental and prosodic conditions, speaking rates, styles, and conditions with a variable degree of noise, which can all affect various phonetic features functioning as cues to or correlates of contrasts (e.g. Gósy 2001; Hazan & Simpson 2000; Miller 1981). The role of pre-aspiration therefore has to be considered in relation to other potential cues and correlates. A number of other potential correlates are considered here and, apart from the frequency of the occurrence of pre-aspiration, the following are found to be systematic correlates of the fortis-lenis contrast with variable cue strength: release duration, the duration of the preceding and the following vowel, breathiness frequency, voicing frequency, and glottalisation frequency.

In section 6.1.1., two dimensions of cue strength are discussed, following MacWhinney (2001, 2012): cue reliability and cue availability. A cue to a feature has high reliability if most tokens of the cue occur in the presence of that feature. It has high availability if most tokens of the feature are accompanied by the cue in a single linguistic environment. This understanding of cue strength is expanded here with cue availability across different prosodic contexts: if a phonetic feature distinguishes the contrast in all prosodic contexts, it is stronger than a phonetic feature limited to fewer prosodic contexts.

By these criteria, pre-aspiration in the Aberystwyth data has lower availability as a (cue to/)correlate of fortisness than release duration or the duration of the preceding and the following vowel because it does not systematically distinguish the two plosive series word-initially, whilst release duration and vowel duration distinguish the contrast in all three prosodic conditions taken into consideration. On the other hand, pre-aspiration has higher reliability than voicing or breathiness because it is limited only to the fortis series, whereas voicing and breathiness are found even in the lenis series (although not frequently). Voicing and breathiness are nevertheless more frequent within one category than pre-aspiration is, and so they exhibit higher cue availability.

Thus, whilst pre-aspiration may not be the strongest correlate of the contrast, it is nevertheless a very strong correlate, comparable to the other cues in its cue strength,
which leads to the conclusion that there is no one most important correlate at least in the production data.

Pre-aspiration is a correlate of the fortis-lenis contrast in the same way as breathiness and post-aspiration in that they are associated with the fortis series (forming one bundle of correlates) whereas voicing and vowel duration, enhancing the contrast in the same direction with respect to one another, distinguish the contrast in a direction different from pre-aspiration, breathiness, and post-aspiration, being associated with the lenis series (forming another bundle of correlates). Across the two plosive series, the two groups or bundles of correlates make up a strong amalgam of correlates. This suggests what could be seen as over-specification of the phonological contrast (Beckman, Helgason, McMurray & Ringen 2011). This is discussed in more detail in section 6.3.2.

Cue strength is defined in more detail with the criteria used to establish it in 6.1.1. Section 6.1.2. outlines how pre-aspiration serves as a correlate of phonological contrasts in the world’s languages. Section 6.1.3. presents an overview of what has been found regarding the relationship between pre-aspiration and other laryngeal cues to and correlates of contrasts. Section 6.1.4. does the same for oral cues and correlates (6.1.4.). Thus, apart from assessing cue strength of pre-aspiration in the context of the fortis-lenis plosive contrast, this chapter also presents some results related to its interactions with the other correlates, some of which are connected to the historical questions associated with pre-aspiration.

Firstly, it has been suggested that pre-aspiration correlates negatively with closure duration in the fortis series and that this may be the first step towards a process of degemination or consonantal shortening (Stevens & Reubold 2014: 455). As will be shown in what follows, Welsh English has been known to have lengthened consonants; however, a concomitant shortening of the closure duration is not observed in the Aberystwyth data. Either degemination has been completed in the variety or pre-aspiration does not present a step in degemination.94

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94 It should be noted that apart from ABE24, the impressions of the author are that the speakers lengthened their consonants considerably during the interviews but not when reading the word list data.
Secondly, it has been proposed that pre-aspiration in the fortis series becomes a prominent cue to the fortis-lenis contrast if phonetic voicing in the lenis series is lost or that the phonetic voicing in the lenis series is lost as a consequence of pre-aspiration becoming a more prominent cue (Ní Chasaide & Ó Dochartaigh 1984: 151-2; Ó Murchú 1985: 197). Nonetheless, the Aberystwyth data does not support either of the two patterns, because the individuals with more frequent pre-aspiration in the fortis series also show more frequent voicing in the lenis series. This is problematic to the asymmetrical approach of laryngeal contrasts and is in line with the findings related to Swedish VOT (Beckman, Helgason, McMurray & Ringen 2011).

Thirdly, pre-aspiration has been reported as allophonic with post-aspiration in Faroese, Icelandic, Sámi, and Scottish Gaelic (Ladefoged & Maddieson 1996: 70) and also in Mongolian (Karlsson & Svantesson 2011; Svantesson & Karlsson 2012). It is not clear how such allophony comes about historically. The Aberystwyth data differs from the patterns found for Faroese, Icelandic, Sámi, and Scottish Gaelic and agree with the reports on pre-aspiration and post-aspiration co-occurring in Italian (Stevens & Hajek 2010), Welsh (Morris & Hejná 2014), and English spoken in Bangor, Kent, and Manchester (Bramley, Maher & Paterson 2015). It may be the case that pre-aspiration only develops in a certain context if this context also shows post-aspiration, but whether the post-aspiration remains in that context is language-specific.

6.1.1. Cue strength

The definition of cue strength in this chapter is adopted and expanded from the Competition Model (MacWhinney 2001 & 2012), which has been proposed in the context of first and second language acquisition, “[...] viewing [both L1 and L2 acquisition] as constructive, data-driven processes that rely not on universals of linguistic structure, but on universals of cognitive structure. It attributes development to learning and transfer, rather than to the principles and parameters of Universal Grammar [...]” (2001: 69).
Cue strength refers to how well individual cues signal a certain function. “This strength can be expressed in terms of statistics such as significance levels, percentage variance accounted for, or numerical strength measured through maximum likelihood estimation (MLE).” (MacWhinney 2012: 101) For example, if glottalisation is only associated with fortis plosives but it is highly infrequent, it may not statistically speaking differentiate the fortis-lenis contrast. If pre-aspiration is associated with fortis plosives and applies frequently enough to differentiate the two series, then it has higher cue strength than glottalisation.

According to the Competition Model, cue strength is determined by two aspects: cue reliability and cue availability. Cue reliability is “[…] the proportion of times the cue is correct over the total number of occurrences of the cue” (MacWhinney 2012: 101). In this respect, pre-aspiration would be most reliable if it occurred only in the fortis series, less reliable if it also occurred in the lenis series but significantly less frequently, and the least, minimally, reliable if it occurred in both series and its frequency were not significantly different across the two series.

Cue availability “[…] is the proportion of times the cue is available over the times it is needed” (MacWhinney 2012: 101). Pre-aspiration would be maximally available if it applied in 100% of the fortis series and its availability would decrease with its frequency in the category. This can also be demonstrated on the example of glottalisation being less frequent in the fortis series than pre-aspiration. Pre-aspiration has higher cue availability than glottalisation and therefore also has higher cue strength.

Cue strength will thus be assessed in categorical terms where it makes sense to discuss a phonetic property as discretely present or absent (e.g. how frequently does pre-aspiration occur in one category as opposed to the other and how frequently does it apply where it is expected to apply?). However, some phonetic aspects can be analysed only in terms of phonetic gradience, e.g. the duration of the preceding or the following vowel – both fortis and lenis plosives can be preceded by a vowel and so this phonetic feature, if functioning as a cue, differentiates the fortis and the lenis series on a gradient scale (duration, F1, F2, etc.). In such cases, gradient measures are used.
Cue strength is determined in the following way for categorical and numeric, gradient phonetic features:

1. categorical phonetic features

   - significance level: does a phonetic feature distinguish the fortis-lenis categories significantly?

   - cue reliability: is a potential cue found only in one category or both?

   - cue availability: how frequent is the potential cue in the category which is (primarily) associated with it?

2. gradient phonetic features

   - significance level: does a phonetic feature distinguish the fortis-lenis categories significantly?

As defined by the Competition Model, cue availability refers to availability within an environment: given an environment where fortis plosives occur, what proportion of fortis plosives in that environment show pre-aspiration? However, cue availability has more dimensions than that applying to a single environment.

It could be enriched by considering various segmental or prosodic contexts of the fortis-lenis plosives: in how many of the environments where fortis plosives are found does pre-aspiration occur? This could be further expanded to various speaking rates, styles, and even social factors. Of these additional dimensions of cue availability to think about, prosodic conditions are considered in this chapter to a limited extent, focusing on:

   - consistency across position within word (word-initial: *pat* vs *bat*; word-medial: *copper* vs *cobber*; word-final: *cop* vs *cob*)

   - within the word-initial position, consistency across two conditions: when preceded by a voiced segment as opposed to a pause (*Say pat once.* vs *pat*)
The more consistently pre-aspiration distinguishes the fortis-lenis contrast across these contexts, the higher cue strength it has, assuming accurate auditory detection of acoustic properties by listeners.

Furthermore, the fewer the number of cues or correlates per context, the higher the cue strength is. Maximum cue strength in this respect would be exemplified by a single cue distinguishing a contrast. Assuming that listeners detect acoustic properties accurately and use acoustic information optimally, then the more cues distinguish a contrast, the weaker each of these cues because the contrast is not distinguished solely by that one cue.95

6.1.2. Pre-aspiration as a cue to contrasts in the world’s languages

The previous chapters have shown that pre-aspiration is a fairly robust feature of fortis plosives and fricatives in the production data of the speakers analysed in this thesis. It was the fortis plosives and fricatives that were subject to discussion rather than the lenis ones because pre-aspiration is primarily a feature of fortis obstruents cross-linguistically (as discussed below). This suggests that pre-aspiration can have very high cue reliability.

Its cue strength is nevertheless weakened by low availability, since it is not usually found word-initially (Horcin, Baarin, and Shiliin Gol – Karlsson & Svantesson 2011; Ulaanbaatar Mongolian – Svantesson & Karlsson 2012: in particular 457, 463). Hence, if pre-aspiration contributes to implementing a contrast, it does so word-medially and word-finally but not word-initially, which is confirmed by this chapter as well.

Looking into the prosodic contexts in which pre-aspiration is found, i.e. in stressed syllables in the word-medial and word-final positions, Ladefoged & Maddieson mention that pre-aspiration is contrastive at a surface level in only a handful of languages: Icelandic, Scottish Gaelic, and Faroese (Ladefoged & Maddieson 1996: 70), and apart from the word-initial position, in which there is no fortis-lenis contrast, also in Lule Sámi (Ladefoged & Maddieson 1996: 70). This nevertheless

95 However, not all the acoustic cues may be perceptually salient and/or their strength may vary in perception (e.g. Howell 1993: 2071-2).
does not correspond to the studies assessing pre-aspiration as a cue to the fortis-lenis contrast because Ladefoged & Maddieson’s criterion to establishing contrastiveness seems to be that of application: a phonetic feature is contrastive only if obligatory. In other words, a phonetic feature is contrastive only if its cue availability in context A is maximal.

As follows from the criteria to diagnose cue strength outlined in 6.1.1., obligatory application in a single environment increases cue strength because it presents maximum cue availability. Nevertheless, a phonetic feature does not have to be obligatory/maximally available to be systematically associated with a certain category. Accepting the role of optional phonetic features in cuing contrasts is furthermore important in the context of the emergence of new allophonic patterns.

These lines of thinking are supported by acoustic studies of pre-aspiration. Indeed, although not obligatory, pre-aspiration is “one of the constituting factors involved in the realization of the voiced/voiceless opposition” in various Norwegian dialects (van Dommelen 1999); it cues the phonological features of [voice] and [spread glottis] in Trøndelag Norwegian (Ringen & van Dommelen 2013: in particular 479, 489), and also in Central Standard Swedish (Helgason & Ringen 2008: in particular 625). Similarly, Gordeeva & Scobbie state that “[…] the function of preaspiration may be to maintain or enhance (depending on your diachronic point of view) a long-standing phonological contrast” in Scottish Standard English fricatives (2010: 38).

Van Dommelen (1998) carried out both an acoustic and a perceptual study of pre-aspiration and its role in the fortis-lenis contrast in Norwegian (intervocally for /k/ and /g/) and he concludes that the phenomenon is “[…] a constituent part of the voiceless stop [and] enhances the perceptual impression of voicelessness”.

The frequency of pre-aspiration occurrence is not the only aspect of pre-aspiration which can distinguish the fortis-lenis contrast. Pre-aspiration can also distinguish the contrast durationally. If it is found in both the fortis and the lenis categories, it can differentiate them in terms of frequency and/or durationally. Its cue reliability may thus be weakened when analysed for its frequency of occurrence, but in spite of such a weakening, it can still reliably distinguish the series durationally.
Although it is quite rare for both plosive series to be pre-aspirated, this scenario is nevertheless attested (San Martín Itunyoso Trique – DiCanio 2012a: 252-4; Bethesda Welsh – Morris & Hejná, in prep; Scottish Gaelic – Nance & Stuart-Smith 2013: 137-9). In San Martín Itunyoso Trique, fortis plosives are associated with a higher frequency of the occurrence of pre-aspiration (2012a: 252). This is also the case in Bethesda Welsh. Nance & Stuart-Smith did not look into the frequency of the occurrence of pre-aspiration, but the authors let me analyse their data with regard to this variable. The fortis and the lenis series do differ significantly in that the fortis series is associated with a higher frequency of the occurrence of voiceless pre-aspiration as well as breathiness. Morris & Hejná (2014) present preliminary analyses of the phonetic correlates of the fortis-lenis contrast in Bethesda Welsh, in which pre-aspiration is more frequent in the fortis than the lenis plosives (The analyses are limited to the word-medial and the word-final positions because they analysed words uttered in isolation.).

Where pre-aspiration is found in both the fortis and the lenis plosives, its duration can distinguish the two series. This is the case in one of the three studies discussed above: in Lewis Gaelic, pre-aspiration and breathiness are longer with the aspirated plosives when analysed individually or together (2013: 137-9). In San Martín Itunyoso Trique, no significant difference was found with respect to the duration (2012: 253), and the same result was evident in the study on Bethesda Welsh. However, there are methodological differences in the three studies that need to be borne in mind. In the San Martín Itunyoso Trique study, pre-aspiration subsumes voiceless pre-aspiration as well as breathiness, and no results are reported on the two components individually. In the Bethesda Welsh study, pre-aspiration is defined as in the present thesis, i.e. as a period of voiceless glottal friction in a sequence of a sonorant and a voiceless obstruent. But in spite of these differences, there is sufficient evidence in these studies showing that pre-aspiration as well as breathiness occur in both the fortis and the lenis series and that they can distinguish the two series either by duration, frequency of occurrence, or both.

DiCanio addresses the issue whether the contrast in San Martín Itunyoso Trique is that of singletons and geminates or that of fortis-lenis plosives (2012a). He finds that the “duration and glottal spreading are the most robust correlates to the contrast” (2012: 267), apart from reporting processes such as spirantisation, which are generally claimed not to affect geminates (e.g. Davis 2011).

Nance & Stuart-Smith refer to the two series as aspirated and unaspirated.
In section 6.1.3. below, pre-aspiration is put in the context of other laryngeal phenomena that can serve as cues to or correlates of the same contrasts and that can influence its cue strength.

### 6.1.3. Pre-aspiration and other laryngeal cues/correlates

Pre-aspiration can enter into three relationships with other laryngeal phenomena considering their role to cue contrasts and how they may affect one another regarding their frequency or duration (or other aspects).

Firstly, one of them may not be an acoustic correlate of the contrast at all: for example, pre-aspiration may systematically occur only in the fortis series but glottalisation may be found equally frequently and with comparable durations in both the fortis and the lenis series.

Secondly, laryngeal phenomena could be positively correlated, in which case they would both enhance the contrast in the same direction. Such a situation is related to what Ní Chasaide & Ó Dochartaigh mention:

“*We would view preaspiration, postaspiration and voicelessness proper (i.e. concomitant with supralaryngeal closure) as being, not disparate phenomena, but among the alternative realisations of the ‘voicing opposition’. The extent to which a particular realisation occurs depends, among other things, on such factors as word position, degree of stress, and segment type involved.*” (1984: 156)

In the Aberystwyth English data analysed here, this relationship is applicable to pre-aspiration occurrence, the release duration, and the occurrence of vowel-final breathiness. Release duration distinguishes the two series in a way very similar to that in which pre-aspiration distinguishes them: longer release and a higher frequency of pre-aspiration are associated with fortis plosives. Pre-aspiration and breathiness are similarly associated only or primarily with the fortis series.

Finally, laryngeal phenomena could enter a trading relationship (which is another possible interpretation of the comment by Ní Chasaide & Ó Dochartaigh); they could be negatively correlated and enhance the contrast in opposite directions. If a phonetic
phenomenon A is in a trading relationship with a phonetic phenomenon B, this means that the more there is of phenomenon A, the less there is of phenomenon B, and vice versa. Such trade-offs are usually discussed within the same term of the opposition such as fortis plosives. Nevertheless, they could be extended across categories (e.g. the less voicing in the lenis plosives in one speaker, the more pre-aspiration in the fortis plosives in that speaker).

Ní Chasaide & Ó Dochartaigh hypothesise that pre-aspiration and voicing could be in an inverse relationship and a loss of voicing in lenis geminates may then lead to the development and/or enhancement of pre-aspiration in fortis geminates (1984: 151-2).\(^9^9\) Gordeeva & Scobbie (2013) looked into the fortis-lenis contrast in fricatives and plosives in Scottish Standard English and into the presence of pre-aspiration and voicing in particular in fortis and lenis plosives (i.e. cue reliability). Their study revealed that the presence of voicing is more important than the presence of pre-aspiration (2013: 266-7). Nevertheless, despite the differences in cue strength between pre-aspiration and voicing the authors note that pre-aspiration “[serves as a local phonetic attribute] of phonological */voice/* in Scottish English” (2013: 266).

Laryngeal phenomena could be in a trading relationship within the same category and condition as well. Ní Chasaide speculates that pre-aspiration duration and its noisiness are in a trade-off relationship (1985: 432, 457) and trade-offs have also been discussed with respect to VOT and \(f_0\) (Kang 2014; Kingston, Diehl, Kirk & Castleman 2008; Lee, Politzer-Ahles & Jongman 2013; Repp 1982) and VOT and aspiration amplitude (Repp 1981).\(^10^0\)

Apart from its availability within a single context, pre-aspiration cue strength could be diminished by its frequent non-occurrence word-initially, i.e. by its minimally weak availability across prosodic contexts. In such cases, word-initial fortis plosives are post-aspirated and word-medial or word-final ones are pre-aspirated but not post-aspirated, as reported for example for Horcin, Baarin, and Shiliin Gol (Karlsson &

\(^9^9\) This is relevant for the hypothesis that one of the ways in which pre-aspiration innovates is via degemination – see e.g. Clayton 2010.

\(^10^0\) For more studies focusing on trade-offs between two phonetic features: F1 and VOT (Repp 1983), F2 and F3 transitions as a cue to voicing (Serniclaes 2005: 187), silence duration and presence/absence of release burst as cues to the stop manner contrast (Repp 1983), and the duration of vowel nasalisation and that of the following nasal (Beddor 2007). Campbell (1995) presents a study focusing on trade-offs between more phonetic features: duration and amplitude are discussed as trading off with spectral tilt.
Svantesson 2011) and also for Ulaanbaatar Mongolian (Svantesson & Karlsson 2012: in particular 457, 463). Icelandic pre-aspiration does not occur word-initially either and it is limited to stressed VC clusters. Additionally, it does not co-occur with post-aspiration similarly to Mongolian (Keer 1998). However, the complementarity with post-aspiration exemplified by Mongolian and Icelandic is not found in Aberystwyth or Manchester English, where pre-aspiration and post-aspiration and/or affrication co-occur. A less known allophonic distribution of pre-aspiration is that reported for Manchester English (Hejná & Scanlon 2015) and also one of the Aberystwyth speakers (ABE37): there is complementarity between the frequency of pre-aspiration and glottalisation with the former found word-medially (batter) and the latter word-finally (bat).

We have seen that pre-aspiration can interact with other potential laryngeal cues to or correlates of phonological contrasts. Section 6.1.4. shows that pre-aspiration can enter into such relationships with oral cues and/or correlates as well.

6.1.4. Pre-aspiration and oral cues/correlates

There are two important relationships between pre-aspiration and oral cues to and/or correlates of contrasts in the world’s languages. One of these is vowel duration and the other closure duration.

Since in many pre-aspiring languages pre-aspiration is associated only with fortis plosives, it is likely to co-occur with phonetically short vowels. Preceding vowel duration has been found to be an important cue to and a correlate of the fortis-lenis contrast in English in laboratory conditions: a vowel is longer when followed by a lenis obstruent (e.g. Denes 1955 for /s/ ~ /z/; House 1961; Krause 1982; Raphael 1971; Raphael, Dorman & Freeman 1975). Within the context of Welsh, preceding vowel duration/length is discussed as one of the crucial cues to the fortis-lenis contrast (e.g. Awbery 1984: the whole chapter illustrates this point; Awbery 1986: 21; Ball 1984: 13; Iosad, in press; and the references therein). The vowel
duration difference is generally referred to as pre-fortis clipping (e.g. Gonet & Stadnicka 2005; Wells 1990; among others)\textsuperscript{102}, which is analysed as allophonic in English and Welsh.\textsuperscript{103} Both pre-aspiration frequency and vowel duration can distinguish the contrast and they are both limited by being applicable in the word-medial and the word-final positions. Assuming accurate detection of acoustic properties, the speaker would thus have two cues to the contrast at his/her disposal. In Aberystwyth English, vowel duration is more available/reliable than pre-aspiration in the sense that it distinguishes the contrast in all three positions analysed (word-initial, word-medial, word-final), whereas this is not the case for pre-aspiration.

Secondly, the hypothesis according to which pre-aspiration is the first step leading to degemination (see e.g. Clayton 2010) predicts that closure duration and pre-aspiration duration are in a trading relationship. Closure duration has been repeatedly reported as an important cue and/or correlate not only in the fortis-lenis plosive contrasts cross-linguistically (e.g. Korean – Cho, Jun & Ladefoged 2002; Trøndelag Norwegian – Dommelen & Ringen 2007; San Martín Itunyoso Trique – DiCanio 2012a: 248-51; Zapotec regions and variants – Leander 1998: 5), but also as the main cue/correlate, or one of the main cues/correlates, to and of length contrasts in plosives (e.g. Arvaniti & Tserdanelis 2000: 560; Ridouane 2007: 121; for a cross-linguistic overview – Kawahara 2015: 47). Interestingly in connection with pre-aspiration, both Welsh and Welsh English have been noted to have geminates (Hannahs 2013 – but see below; Wells 1982: 388), doubled consonants (Morris-Jones 1913: 30), or lengthened consonants (Penhallurick 2004: 111), or researchers have mentioned the lengthening with phonetic diacritics without using any specific

\textsuperscript{101} Some studies argue that the duration of the preceding vowel is not necessary to distinguish the fortis-lenis contrast in connected speech (e.g. Raphael, Dormian & Freeman 1975; Wardrip-Fruin 1982).

\textsuperscript{102} For a different analysis (pre-lenis lengthening), see e.g. Roberts, Kotzor, Wetterlin & Lahiri 2014.

\textsuperscript{103} In Welsh, this presents a trade-off that includes vowel duration, pre-aspiration duration/frequency and also the quality of the vowel (Losad, in press, for the most recent analysis of Welsh). Similarly to Dutch (e.g. Botma & Oostendorp 2012), it has not been resolved whether the contrast is that of vowel quality or quantity, or both. Furthermore, regional variation is also attested (Awbery 1984: in particular 70-81).
Apart from investigating whether pre-aspiration differentiates the fortis-lenis plosives and what cue strength it has in comparison to the other correlates to the contrast, the following questions are thus addressed in this chapter:

1. Is there a trading relationship between consonant closure duration and pre-aspiration duration, perhaps as part of a long-term trajectory of fortis plosive degemination/consonantal shortening?

2. Is it the case that speakers with more frequent pre-aspiration in the fortis series are the ones with the least frequent voicing in the lenis series?

3. Are pre-aspiration and post-aspiration complementary in any way?

4. If pre-aspiration and breathiness differentiate the fortis-lenis contrast, do they do so in the same way, i.e. do they form a bundle of correlates associated with the fortis series because they are articulatorily connected? If pre-aspiration develops in the plosives that are historically post-aspirated, does post-aspiration also form a member of the same bundle as pre-aspiration and breathiness?

Authors differ in whether they call the Welsh or Welsh English phenomenon gemination or consonantal lengthening. The difference between the two is that geminated consonants contrast with singleton consonants (e.g. Tashlhiyt Berber – Ridouane 2007, 2010; Malayalam – Local and Simpson 1999; Buginese, Madurese, and Toba Batak – Cohn, Ham, and Podesva 1999; Cypriot Greek – Arvaniti 2001; among others), whereas lengthened consonants do not contrast with consonants that are shorter (e.g. Broselow, Chen & Huffman 1997). It has not been conclusively shown whether these consonants are long phonetically or phonologically either in Welsh or Welsh English. One allegedly unambiguous point is that a short vowel is or can be followed by a lengthened/geminated consonant, but this is never the case with a long vowel (Hannahs 2013: 25 – for stressed monosyllables; Jones 1984: 53-4).

The situation of the consonantal lengthening and vowel length is far from neat both inter- and intra-dialectally. For more details, see Awbery 1984 & 1986.

Although it is often assumed that it is only the fortis plosives that can undergo such lengthening/gemination (Hannahs 2013: 14, 21, 40-1 also quoting Morris-Jones 1913: 30), there are reports that suggest otherwise: like Wood, Pilch (1975) also supports a system with a perfectly complementary opposition of VC: and V:C, but crucially he reconstructs it, stating that although this is still the case in present-day Welsh, it is only so regarding plosives, and, indeed, plosives seem to be the most systematically behaving consonants in terms of weight cross-dialectally. However, according to Pilch, “Northern speakers lengthen even the lax stops and spirants […]” (Pilch 1975: 89), and both series are associated with lengthening in Bow Street Welsh (Pilch 1975: 89). Furthermore, my exploratory unpublished acoustic evidence from Aberystwyth Welsh points to both fortis and lenis plosives being optionally lengthened depending on the style and the sentential emphasis.
The next section outlines which phonetic phenomena are included in the analyses to answer whether pre-aspiration distinguishes the fortis-lenis contrast and what cue strength it has when the other potential cues/correlates are considered, and which of their aspects were measured and how.

### 6.2. Methodology

This section lays out what type of data is used to answer the questions raised in 6.1., what potential acoustic correlates were looked into and how they were identified, and how the durational aspects were normalised.

#### 6.2.1. Data

The analyses are based on items including fortis-lenis pairs word-initially (*bap* ~ *pap*), word-medially (*cabbie* ~ *capper*), and word-finally (*cab* ~ *cap*). See Appendix C.1. for the full list. Each word was produced three times: once in isolation (*pat*) and twice in a carrier sentence (*Say pat once*). This procedure allows for a comparison of the potential correlates of the fortis-lenis contrast word-initially if preceded by a pause as opposed to a voiced segment. Ten female speakers are analysed in this chapter.\(^{105}\)

The dataset is balanced regarding the number of fortis and lenis tokens per word position and utterance type and the fortis-lenis pairs are always minimal or near-minimal pairs. However, across the minimal pairs, vowel phoneme and the place of articulation were not balanced. Thus, as becomes apparent from the word list, not all vowel phonemes are represented to the same extent across the places of articulations of the plosive and pairs with word-initial bilabial plosive are more abundant than those with word-initial alveolar or velar plosive. This is taken into consideration in section 4.4., where the results are interpreted.

\(^{105}\) These ten speakers are ABE12, ABE14, ABE18, ABE24, ABE31, ABE33, ABE37, ABE45, ABE46, and ABE52. These were limited to ten because of reasons of time. These particular ten speakers were selected solely on the basis of the chronological order of the coding process.
Two possible issues were faced before the analyses were carried out.

Firstly, some of the words that appeared in the word list are not common English words (e.g. bock, guck).\textsuperscript{106} In one pair, tech vs teg, the latter word was interpreted as a common Welsh word by four participants.\textsuperscript{107} This word and its fortis counterpart were therefore not included in the analyses for these speakers (2x for ABE14, 3x for ABE12, 3x for ABE31, 3x for ABE33). We know that this word was pronounced as the Welsh word and not an English word based on three factors. Firstly, two of the speakers explicitly commented on the word being Welsh and not English after the recording session. Secondly, the vowel in the Welsh word is considerably longer than it would be in the English word. Thirdly, the vowel is also higher than it would be in English. Vowel height was measured and confirmed that this word behaves as an outlier with respect to the other /e/ tokens in the speakers in question.

Secondly, occasionally some speakers hesitated in the carrier sentence before the target word (\textit{Say} [pause] \textit{pat} once.). Such cases were at first labelled separately (\textquote{pin} = pause in a carrier sentence before the target word) and because their results did not differ from those uttered in isolation in how they affected any of the potential correlates, the two groups were merged.\textsuperscript{108} On occasion, the speakers paused in the carrier sentence after the target item (\textit{Say} \textit{pat} [pause] \textit{once}.). These instances were also labelled separately (\textquote{inp} = pause in a carrier sentence after the target word) because it could not be taken for granted that this would not affect how the potential correlates enhance the fortis-lenis contrast word-finally. Because such cases did not differ from the other tokens uttered in a carrier sentence in how they affected any of the potential correlates, they were merged with these carrier sentence tokens.

1,976 tokens were analysed in this chapter in total.

What follows presents an overview of the phenomena analysed and how these were measured and identified.

\textsuperscript{106} This is because the data was collected to test a wide range of mainly segmental and prosodic conditioning of pre-aspiration. However, rather than creating nonce words, highly infrequent or obsolete words reported in the \textit{OED} were used in order to ensure that the phonotactics is not violated.

\textsuperscript{107} The word \textit{teg}: English = \textquote{a sheep in its second year} \textit{OED} (2012); Welsh = \textquote{fair, beautiful}.
6.2.2. Identification of the potential phonetic correlates

The phenomena which are analysed as potential correlates to the fortis-lenis contrasts and their aspects are summarised in Table 6.1:

<table>
<thead>
<tr>
<th>PHENOMENON</th>
<th>RATE OF OCCURRENCE</th>
<th>DURATION</th>
<th>OTHER</th>
<th>POSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-aspiration</td>
<td>√</td>
<td></td>
<td></td>
<td>All</td>
</tr>
<tr>
<td>Voicing</td>
<td>√</td>
<td></td>
<td>√ (proportion of the overall closure)</td>
<td>All</td>
</tr>
<tr>
<td>Voiceless closure</td>
<td>(NA)</td>
<td>√</td>
<td></td>
<td>All</td>
</tr>
<tr>
<td>Release</td>
<td>(NA)</td>
<td>√</td>
<td></td>
<td>All</td>
</tr>
<tr>
<td>Breathiness/slack voice</td>
<td>√</td>
<td></td>
<td></td>
<td>All</td>
</tr>
<tr>
<td>Pre-glottalisation</td>
<td>√</td>
<td>√</td>
<td>√ (position within the vowel)</td>
<td>medial, final</td>
</tr>
<tr>
<td>Post-glottalisation</td>
<td>√</td>
<td>√</td>
<td>√ (position within the vowel)</td>
<td>initial</td>
</tr>
<tr>
<td>$f_0$</td>
<td>NA</td>
<td>NA</td>
<td>√ (Hz)</td>
<td>All</td>
</tr>
<tr>
<td>Preceding vowel</td>
<td>NA</td>
<td>√</td>
<td></td>
<td>medial, final</td>
</tr>
<tr>
<td>Following vowel</td>
<td>NA</td>
<td>√</td>
<td></td>
<td>initial</td>
</tr>
</tbody>
</table>

Table 6.1. Overview of potential correlates and their aspects analysed

*Position stands for the position of the target plosive within the word (word-initial: tack; word-medial: catty; word-final: cat). Although closure could be analysed for the rate of occurrence, this would only make sense if spirantisation occurred in the data frequently enough for such analyses to be meaningful. Similarly, because all the speakers release their plosives, it is not meaningful to look into unreleased plosives and whether the lack of bursts correlates with the enhancement of other phonetic aspects of the plosives.*

For the analyses of the frequency of occurrence, any zero durations of the phenomenon in question (e.g. pre-aspiration) were labelled as “no” (= absence of the

108 This was done through Mixed Effects and Fit Bayesian Models, which were employed in this chapter. At first, the variable of “position” included all the possibilities (“abs” for words in isolation; “in” for words in a carrier sentence; “pin”; and “inp”). See section 6.3.
phenomenon). Durations other than zero were treated as “yes” (= presence of the phenomenon). So, as long as the phenomenon in question had duration longer than 0ms, the instance was taken as a realisation of the phenomenon. The rest of this section outlines how the potential correlates were identified.

Pre-aspiration

The description of how pre-aspiration was identified and measured was presented in Chapter 3. However, for the purposes of this chapter, pre-aspiration was analysed for its frequency of occurrence not only word-medially and word-finally, but also word-initially. Because pre-aspiration is never found in the lenis series, it was not analysed for durational differences across the two series.

Voicing

Voicing was likewise analysed for the frequency of occurrence and duration. In addition, it was analysed for what proportion of the overall closure (i.e. voiced and voiceless portions of the closure) the voicing occupies. Voicing was identified on the basis of the waveform. If preceded by silence, the onset of voicing was identified as the onset of periodicity seen in the waveform (Figure 6.1.).
In the vast majority of cases, the presence of the voicing bar in the spectrogram was also used to identify the onset of voicing, but this could not be done if the recording was not of high enough quality. This affected ABE37, but the waveform provided reliable enough information.\textsuperscript{109}

In other positions (word-medially, word-finally, word-initially in a carrier sentence), the onset of voicing was identified by a change in the amplitude of the waveform and by the simplification of the waveform: the amplitude is lower for purely glottal voicing than for a vowel and the waveform is also simpler for glottal voicing than for a vowel. This is illustrated in Figure 6.2.

\textsuperscript{109} See Lisker & Abramson (1967: 3) for the identification of voicing from spectrograms alone.
Figure 6.2. Identification of the onset of voicing (“voice”) in a voiced environment

Illustrated on the word codder, produced by a female speaker of 72 years (ABE31). ‘Unpost’ stands for unaspirated release and ‘pr’ for vowel-initial breathiness

Most of the speakers produced voicing waveforms of the pseudo-sinusoidal shape (modally voiced plosives), but a more complex waveform (creaky voiced plosives; Ladefoged & Maddieson 1996: 54) was found consistently in ABE37, the monosyllabic glottaliser, and infrequently in ABE12 (in 2 tokens), ABE14 (6 tokens), and ABE18 (7 tokens). This is illustrated in Figure 6.3.110

110 Such cases however do not fit in the description according to which creaky voiced plosives show an increase in the amplitude towards the burst (Ladefoged & Maddieson 1996: 54).
Illustrated on the word bop, produced by a female speaker of 28 years (ABE37). 'Clo' stands for voiceless closure, 'unpost' for unaspirated release, and 'CRperWH' for glottalisation ('periodic creak' affecting the whole vowel).

The end point of voicing was identified in the same way as the onset of voicing (See Figures 6.1.-6.3.). Lack of voicing during the closure of the plosives could be seen mainly in the waveform (silence = quasi-flat wave) and, reliably for nine of the speakers, also in the spectrogram (silence = no voicing bar). Occasionally, voicing lasted throughout the closure up to the beginning of the burst (Figure 6.4.) and sometimes the voicing continued throughout the release (Figure 6.2. above). In such cases, voicing duration was considered to end at the beginning of the burst.
Two aspects of the release of the plosive were annotated: duration and voicing.

Release duration was measured on the basis of the waveform. The start of the release was identical to the start of the burst, as illustrated in Figures 6.1.-6.5. The end of the release was similarly determined on the basis of the waveform when followed by a voiced sound, as illustrated in Figures 6.1.-6.4. A different criterion had to be used for word-final plosives in words which were produced in isolation (in a carrier sentence, a voiced segment followed.). The end point was based on a sudden decrease in energy across frequencies, which is illustrated in Figure 6.5.\textsuperscript{111}

\textsuperscript{111} This is in line with Ringen & van Dommelen, who say that “[i]n utterance-final position, the end of a stop’s aspiration is much harder to define. For all practical purposes the onset of normal expiration was used as a criterion. As a rule, this segmentation point was determined by a relatively abrupt decrease in spectral energy. It can be expected that, due to both measurement uncertainty and differences in speaker behavior, aspiration duration for final stops will vary more than for non-final stops.” (2013: 481) The beginning and the end of normal expiration can be seen at the end and the beginning of Figure 6.5., respectively.
Occasionally, the plosives were subject to partial spirantisation (Figure 6.6.), the latter resulting in semi-fricatives (Stevens & Hajek 2005).
In cases of semi-spirantisation, the release could still be identified based on the amount of friction, and these instances were analysed for duration together with canonical plosive-like releases. In cases of complete spirantisation, this was not possible and such tokens had to be discarded from the analyses entirely (ABE31: 4x in disyllables, 6x in monosyllables).

The data revealed a number of other aspects of plosive release that could have been analysed. Because including these is beyond the scope of this chapter, the reader is referred to Appendix E.3. for more details on which these aspects are.

**Breathiness**

Identification of breathiness and the criteria used to measure its duration were discussed in full detail in Chapter 3. Breathiness duration was measured before and after the target plosives, as illustrated in Figures 6.1.-6.2., 6.5.-6.6. In the post-plosive context, this phenomenon was involved in the analyses because it was not unusual for the transitions of post-aspiration and a vowel to contain a period of breathiness (Figure 6.7.; for a more representative example see Figure 6.8.).

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112 Although two terms are sometimes used to refer to two glottal states involving abduction gestures, breathy voice and slack voice, there is a continuum between modal voice, slack voice, and breathy voice, and it is challenging, if not impossible, to distinguish slack voice from the two ends of the continuum (Ladefoged & Maddieson 1996: 63). Although the two terms refer to two somewhat different states of the glottis, in what follows the term breathiness is used to cover both because of the problems with reliably distinguishing the two.
Figure 6.7. Long breathy post-aspiration

Illustrated on the word cabbie, produced by a female speaker of 24 years (ABE45). ‘Post’ stands for voiceless post-aspiration and ‘pr’ for vowel-initial breathiness induced by the post-aspiration.

Figure 6.8. Breathy post-aspiration

Illustrated on the word cab, produced by a female speaker of 54 years (ABE12). ‘Post’ stands for voiceless post-aspiration and ‘pr’ for vowel-initial breathiness induced by the post-aspiration.
Glottalisation

The methodology behind the identification of glottalisation was discussed in detail in Chapter 5. In this chapter, the frequency of occurrence and the duration of glottalisation are analysed. For the word-initial position, analyses include instances of glottalisation found vowel-initially (pat vs bat), vowel-medially, or spread throughout the following vowel. For the word-medial or word-final positions (catty vs caddie; cat vs cad), analyses involve glottalisation occurring vowel-finally in the stressed vowel, vowel-medially in the stressed vowel, or spread throughout the stressed vowel.\textsuperscript{113}

Fundamental frequency

Fundamental frequency, $f_0$, was measured at 10\% and 90\% of the vocalic interval, depending on whether the consonant of interest preceded (10\%) or followed (90\%) the vowel.\textsuperscript{114} 0\% and 100\% were not selected as the measurements points because vowel segmentation was done from the start to the end of the onset of periodicity as indicated by the waveform, not as indicated by the Praat pitch tracker, which means that working with 0\% and 100\% would have resulted in a higher number of undefined values. Since all the speakers are females, the $f_0$ range was set to 100-500Hz, as recommended in the Praat manual (“pitch” > “pitch settings” > “help”).

Voiceless closure

The duration of voiceless closure was measured on the waveform and the spectrogram as illustrated in Figures 6.1-, 6.3.-6.4., and 6.6. above. For tokens uttered in isolation with word-initial target plosives, closure duration could not be measured unless the token was voiced. This also applied to target items produced in

\textsuperscript{113} Even if all instances of glottalisation are taken into account by the three prosodic conditions, this does not change the results. Although including all the instances in the analyses of the same prosodic condition would be consistent with Chapter 5, this was done to shed light on whether it is correct to associate all the instances of glottalisation with the word-medial or the word-final plosives. The two different approaches do not enable to answer this question.

\textsuperscript{114} The Praat script extracting these measurements was kindly provided by Patrycja Strycharczuk.
carrier sentences with pauses. Cases where voiceless closure duration could not be measured were not included in the analyses.

Vowel duration

Vowel duration was identified on the basis of the waveform from the onset to the offset of the periodic sound wave, as illustrated in Figure 6.9.

Illustrated on the word backer, produced by a female speaker of 48 years (ABE24). ‘Post’ stands for post-aspiration, ‘br’ for breathiness, ‘pre’ for voiceless pre-aspiration, ‘clo’ for voiceless closure, ‘pr’ for vowel-initial breathiness, and ‘V’ for vowel

As visible in Figure 6.9., vowel duration included breathiness. The reason this approach was chosen is a procedural one: the measurements of $f_0$ at two points within the vowel were obtained based on the segmentation that included breathiness (see Chapter 3 for more details). Defining vowel duration differently for the $f_0$ measurements and the vowel duration measurements would not be consistent within this chapter. For the analyses of vowel duration as a potential correlate of the fortis-lenis contrast, this is not a problem because even when breathiness is included, it is consistently shorter with fortis plosives, which means that it would be even shorter without the breathy interval, and thus even more reliable as a potential correlate.

What may be problematic at first sight is whether pre-aspiration or even post-aspiration should be considered part of the vowel, which would most likely influence whether vowel duration is a correlate of the fortis-lenis contrast. Even if this was so,
however, the fact that the end and the beginning of the vowel is not modal or voiced could in itself still be a very important difference between the fortis and the lenis categories.

6.2.3. Normalisation

The durational measurements were normalised using the following formula, in which X stands for a potential correlate (e.g. pre-aspiration, post-aspiration, etc.):

\[
X \text{ duration} / (\text{Word duration}/100)
\]

As in the other chapters involving durational measurements, the interval in question was quantified as a percentage of the duration of the word in which it was measured, unless otherwise specified.

6.3. Results

Pre-aspiration indeed distinguishes the fortis-lenis plosive contrast in the Aberystwyth data, occurring only in the fortis plosives. As illustrated in Figure 6.10. below, this is the case word-medially and word-finally. Word-initially, pre-aspiration is not frequent enough in either utterance context (in words in isolation, where the initial plosive is preceded by a pause, as opposed to words in a carrier sentence, where the initial plosive is preceded by a voiced segment) to significantly distinguish the fortis and the lenis categories, as summarised in Table 6.2.

\[115\] Unless specified otherwise, Fit Bayesian Models are used throughout this chapter because of frequent cases of quasi-complete separation, with word and subject as random effects. The dependent variables are the individual potential cues. Amongst the independent variables are the type of the consonant (with two levels: fortis vs lenis) and its interaction with the utterance type (with two levels: isolation vs carrier sentence). Treatment coding is used because all the variables have only two levels, which makes the interpretation of the results uncomplicated. The tests were done separately for the three different positions within the word (i.e. foot): word-initial, word-medial, and word-final. Discriminant analysis cannot be used because it requires that within-group variance be not singular for any group (quasi-complete separation).
Figure 6.10. Pre-aspiration occurrence (%) and plosive series (fortis vs lenis) by position within word and utterance

Within the tokens uttered in isolation (on the left) and those in a carrier sentence (on the right) across three positions within the word – word-initial (top), word-medial (central row), and word-final (bottom)

Word-medially and word-finally, pre-aspiration is maximally reliable, as it never occurs in the lenis series. This is also the case word-initially when preceded by a voiced segment. In the word-initial position preceded by a pause, pre-aspiration does not apply, which leads to minimum cue availability (and vacuously also reliability) in this context.¹¹⁶

Word-finally and word-medially, pre-aspiration has very strong cue availability as well, occurring in 80-91% of the tokens analysed for the word-medial and the word-final contexts. Preceded by a voiced segment word-initially, its cue availability is much weaker because it is found only in 32% of the cases in which it could apply.

¹¹⁶ The oldest speaker (ABE14) is the only one who does not pre-aspirate word-initially at all. The remaining speakers pre-aspirate between 1-20 out of the 90-91 tokens in the post-pausal position.
If the prosodic conditions are compared, pre-aspiration is found more frequently word-finally than word-medially, and indeed the estimates (Table 6.2.) are higher word-finally than word-medially.

|               | ESTIMATE | STD. ERROR | Z VALUE | PR (>|Z|)   |
|---------------|----------|------------|---------|-----------|
| INITIAL       |          |            |         |           |
| isolation vs  | -4.4036  | 0.7812     | -5.637  | < 0.0001 *** |
| carrier sentence |        |            |         |           |
| MEDIAL        |          |            |         |           |
| fortis vs lenis | 6.6895  | 1.3847     | 4.831   | < 0.0001 *** |
| isolation vs  | -1.0764  | 0.4425     | -2.433  | < 0.05 *  |
| carrier sentence |        |            |         |           |
| FINAL (without ABE37) |         |            |         |           |
| fortis vs lenis | 7.2203  | 1.4397     | 5.015   | < 0.0001 *** |
| isolation vs  | -1.9424  | 0.6580     | -2.952  | < 0.01 ** |
| carrier sentence |        |            |         |           |

Table 6.2. Statistical results for pre-aspiration as a correlate of the fortis-lenis contrast

In the rest of this section, it is shown that although pre-aspiration exhibits maximum cue reliability word-medially and word-medially (and also word-initially when preceded by a voiced segment) and although its cue availability is similarly very strong word-medially and word-finally, this does not render pre-aspiration the most important correlate of the contrast in these positions, at least when production data is considered.

6.3.1. Other correlates of the fortis-lenis contrast

Pre-aspiration is not the only phonetic feature that distinguishes the fortis-lenis contrast. Presence of voicing, presence of breathiness, release duration, and the duration of the preceding and the following vowel are also important acoustic correlates of the contrast. This is also true for glottalisation in the case of ABE37. The other phonetic features mentioned in 6.2. do not distinguish the contrast. The
phonetic features and their role in distinguishing the fortis-lenis contrast are discussed in more detail in what follows.

**Voicing**

Voicing distinguishes the fortis-lenis plosive contrast, occurring primarily in the lenis plosives, as illustrated in Figure 6.11. This is the case in all three positions within the word, as summarised in Table 6.3.

![Figure 6.11](image)

**Figure 6.11. Presence of voicing (%) and plosive series (fortis vs lenis) by position within word and utterance**

*Within the tokens uttered in isolation (on the left) and those in a carrier sentence (on the right) across three positions within the word – word-initial (top), word-medial (central row), and word-final (bottom)*

Voicing is a little less reliable than pre-aspiration because it does occur in the fortis plosives as well. However, this is fairly infrequent (5% of the word-initial plosives in the carrier sentence and 1% of the word-medial plosives in isolation).
It has been suggested to me that the instances of voicing in the lenis series may disappear if a minimum threshold of voicing duration is set because it could be that, perceptually, voicing does not count as a correlate of lenisness unless it exceeds a certain duration threshold.\(^{117}\) The implications of this could be that voicing may actually have 100% reliability. It is indeed the case that the instances of voicing duration in the fortis series fall below 20% of the overall word duration. If these instances were considered to be durationally too low for the listener to perceive reliably, this would also have to be said of 20% of the instances of voiced plosives in the lenis category, which would significantly lower the cue strength of voicing by lowering cue availability.

It is stronger regarding cue availability than pre-aspiration is word-initially because it occurs in the word-initial position preceded by a voiced segment as well as by a pause. However, within the post-pausal context, its cue availability is weak. Otherwise, voicing has very strong cue availability, occurring in 88% of the word-final position and 91% of the medial position. Hence, if cue availability is compared across the three prosodic conditions, voicing is found more frequently word-medially than word-finally or word-initially, and this is confirmed by the size of the estimates (Table 6.3.).

\(^{117}\) I am grateful to Ricardo Bermúdez-Otero for this suggestion.
|                | ESTIMATE | STD. ERROR | Z VALUE | PR (>|Z|) |
|----------------|----------|------------|---------|----------|
| INITIAL        |          |            |         |          |
| fortis vs lenis| -2.6152  | 1.0947     | -2.389  | < 0.05 * |
| isolation vs carrier sentence | -2.0196  | 0.9431     | -2.141  | < 0.05 * |
| within fortis: isolation vs carrier sentence | -4.1224  | 1.0695     | -3.855  | < 0.001 *** |
| MEDIAL         |          |            |         |          |
| fortis vs lenis| -6.981   | 1.115      | -6.259  | < 0.0001 *** |
| FINAL          |          |            |         |          |
| fortis vs lenis| -6.302   | 1.031      | -6.110  | < 0.0001 *** |

Table 6.3. Statistical results for presence of voicing as a correlate of the fortis-lenis contrast

For voicing to significantly distinguish the fortis and the lenis categories, it is not necessary to form 100% of the overall closure duration where voicing applies, as shown in Figure 6.12. The duration of voicing is highly variable. It can reach 88-100% of the overall closure duration, 88% being the maximum word-initially in a carrier sentence, otherwise the maxima are consistently 100%. Voicing duration can however take up as little as 5-13% of the overall closure. The mean proportions across the positions form the range of 27-46%. The fact that voicing is the longest in the lenis plosives in the word-initial position preceded by pause could be explained by the prevalence of bilabial plosives in this position.
Figure 6.12. Voicing duration (%) of the overall closure duration by position

Within the tokens uttered in isolation (top) and those in a carrier sentence (bottom) across three positions within the word – word-initial (on the left), word-medial (central column), and word-final (on the right)

As shown in Figure 6.13., two individuals are responsible for the instances of voicing taking up the whole closure.
The comparison of Figures 6.11 and 6.10 reveals that the presence of pre-aspiration and the presence of voicing are complementary across the two categories word-medially and word-finally, and they both contribute to distinguish the contrast acoustically even word-initially, although voicing more so than pre-aspiration.

**Breathiness**

The presence of vowel-final breathiness shows a very similar pattern to that of pre-aspiration (Figure 6.14.) and serves as one of the acoustic correlates of the fortis-lenis contrast word-medially and word-finally, as also summarised in Table 6.4.\textsuperscript{118}

\textsuperscript{118} Vowel-final breathiness was not analysed for the word-initial position, and it might be the case that they are complementary even word-initially when preceded by a sonorant.
However, it is found in the lenis plosives as well, and so it is has weaker cue reliability than pre-aspiration.

![Figure 6.14. Presence of breathiness (%) and plosive series (fortis vs lenis) by position within word and utterance](image)

Within the tokens uttered in isolation (on the left) and those in a carrier sentence (on the right) across two positions within the word – word-medial (top), and word-final (bottom)

Breathiness has strong cue availability in the fortis series, stronger than pre-aspiration, occurring in 93% of the tokens word-medially and 92% word-finally. In the lenis series, the breathiness is found in 8% and 7%.
|               | ESTIMATE | STD. ERROR | Z VALUE | PR (>|Z|) |
|---------------|----------|------------|---------|----------|
| MEDIAL        |          |            |         |          |
| fortis vs lenis | 5.7637   | 0.7973     | 7.229   | < 0.0001 *** |
| FINAL (without ABE37) |          |            |         |          |
| fortis vs lenis | 4.8818   | 0.6683     | 7.305   | < 0.0001 *** |
| isolation vs carrier sentence | -1.4399 | 0.5356     | -2.689  | < 0.01 **   |
| within fortis: isolation vs carrier sentence | 2.5918   | 0.7730     | 3.533   | < 0.001 ***  |

Table 6.4. Statistical results for presence of voicing as a correlate of the fortis-lenis contrast

Like the presence of pre-aspiration, the presence of breathiness and the presence of voicing are complementary across the two categories word-medially and word-finally. Like pre-aspiration, breathiness enhances the contrast in the same direction, but with less cue strength.

**Vowel duration**

Vowel duration is longer not only before lenis plosives word-medially and word-finally but also after word-initial lenis plosives, as shown in Figure 6.15. and Table 6.5.\(^{119}\) It has high cue reliability across the three prosodic contexts.

---

\(^{119}\) Fixed Effects Models are used for the gradient potential correlates. The dependent variables are the individual potential correlates, always normalised. Amongst the independent variables are the type of the consonant (with two levels: fortis vs lenis) and its interaction with the utterance type (with two levels: isolation vs carrier sentence). Treatment coding is used because all the variables have only two levels, which makes the interpretation of the results uncomplicated.
Figure 6.15. Vowel duration (normalised) and plosive series (fortis and lenis) by position within word and utterance

Within the tokens uttered in isolation (top) and those in a carrier sentence (bottom) across three positions within the word – word-initial (on the left), word-medial (central column), and word-final (on the right)

|             | ESTIMATE | STD. ERROR | DF      | T VALUE | PR (>|T|) |
|-------------|----------|------------|---------|---------|--------|
| INITIAL     |          |            |         |         |        |
| fortis vs lenis | 3.1292   | 1.2155     | 26.9000 | 2.574   | < 0.05* |
| isolation vs carrier sentence | -4.9757 | 0.3037     | 862.8000 | -16.386 | < 0.0001 *** |
| MEDIAL      |          |            |         |         |        |
| fortis vs lenis | 5.7998   | 1.2209     | 17.1000 | 4.750   | < 0.001 *** |
| isolation vs carrier sentence | -2.3101 | 0.3017     | 506.5000 | -7.657  | < 0.0001 *** |
Looking at the size of the estimates, vowel duration differentiates the series most word-finally, then word-medially, and then word-initially.

The effect of the word-initial consonant may seem surprising, but it has been reported before for example for the fortis-lenis contrast in American English (Allen & Miller 1999: 2031) and for the fricative contrast between the fortis and non-fortis /s/ in Seoul Korean, with the fortis /s/ being associated with longer vowel duration (Chang 2013: 19, 23-4). In the Aberystwyth English data, the difference in the duration of the following vowel cannot be attributed to the type of the post-tonic consonant in the analyses since all these plosives were fortis plosives, i.e. only one of the two types (fortis as opposed to lenis).\(^{120}\)

**Release duration**

Release duration also consistently differentiates the fortis and the lenis series and its strength decreases from the word-initial to the word-medial and from the word-medial to the word-final positions, as shown in Figure 6.16. and summarised in Table 6.6. The duration of the release thus shows higher cue reliability/availability than the presence of pre-aspiration in the word-initial position.

\(^{120}\) Raw measurements show the same pattern. None of the tokens analysed in the word-initial context were included in the analyses of the word-medial or word-final contexts, so this seems to be a genuine effect of the word-initial plosive type.
Figure 6.16. Release duration (normalised) and plosive series (fortis vs lenis) by position within word and utterance

Within the tokens uttered in isolation (top) and those in a carrier sentence (bottom) across three positions within the word – word-initial (on the left), word-medial (central column), and word-final (on the right)

<p>|                  | ESTIMATE | STD. ERROR | DF     | T VALUE | PR (&gt;|T|) |
|------------------|----------|------------|--------|---------|----------|
| <strong>INITIAL</strong>      |          |            |        |         |          |
| fortis vs lenis  | -9.7334  | 0.4678     | 47.4000| -20.809 | &lt; 0.0001 *** |
| within fortis:   |          |            |        |         |          |
| isolation vs     | -0.7297  | 0.3388     | 868.5000| -2.154  | &lt; 0.0001 *** |
| carrier sentence |          |            |        |         |          |
| <strong>MEDIAL</strong>       |          |            |        |         |          |
| fortis vs lenis  | -6.0102  | 0.9477     | 21.8000| -6.342  | &lt; 0.001 *** |
| isolation vs     | -1.0917  | 0.3995     | 504.1000| -2.732  | &lt; 0.01 **  |</p>
<table>
<thead>
<tr>
<th>carrier sentence</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>within fortis: isolation vs carrier sentence</td>
<td>1.2744</td>
<td>0.5564</td>
<td>503.9000</td>
<td>2.290</td>
</tr>
<tr>
<td>FINAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fortis vs lenis</td>
<td>-5.8029</td>
<td>0.8520</td>
<td>16.1000</td>
<td>-6.811</td>
</tr>
<tr>
<td>isolation vs carrier sentence</td>
<td>-7.5994</td>
<td>0.5593</td>
<td>514.2000</td>
<td>-13.587</td>
</tr>
</tbody>
</table>

Table 6.6. Statistical results for release duration as a correlate of the fortis-lenis contrast

**Voiceless closure duration and glottalisation**

Out of the remaining variables (vowel-initial breathiness, vowel-initial and vowel-final $f_0$, voiceless closure duration, and the frequency and the duration glottalisation), for nine of the speakers only voiceless closure duration and the frequency of glottalisation contribute to distinguishing the fortis-lenis contrast and this is the case only word-finally (Figure 6.17.).\(^{121,122}\) For ABE37, the monosyllabic glottaliser, the frequency of glottalisation distinguishes the fortis-lenis contrast word-finally (Figure 6.17.),\(^{123}\) but the duration of voiceless closure is not significantly different across the two series.

\(^{121}\) Logistic mixed effects were used with the series as the dependent variable (with two levels: fortis and lenis) and word and speakers as random effects. The dependent variables were vowel-initial $f_0$, vowel-final $f_0$, the presence of glottalisation, the duration of glottalisation, the duration of vowel-initial breathiness, and the duration of voiceless closure. This was done for each word-position separately in a step-up manner.

\(^{122}\) Individual variation is found. For two speakers, the amount of glottalisation is the same across the two categories (ABE12, ABE52). For one speaker, the fortis series presents a higher amount of glottalisation (ABE31). For the remaining speakers, the lenis series is associated with a higher frequency of glottalisation, and for one speaker glottalisation is found only in the lenis series (ABE18).

\(^{123}\) It is found in 100% of time in the fortis series and in 32% of the time in the lenis series in the word-final position. The maximal application prevents statistical analyses.
Figure 6.17. Voiceless closure duration (normalised) and the frequency of occurrence of glottalisation (%) across the series (fortis vs lenis) in the word-final position.

Nine of the respondents show glottalisation which is more frequent with the lenis rather than the fortis series (central column) whereas ABE37 shows obligatory presence of glottalisation in the fortis series a lower frequency of glottalisation in the lenis series (although it is still relatively high).

|                     | ESTIMATE | STD. ERROR | Z VALUE | PR(>|Z|)   |
|---------------------|----------|------------|---------|-----------|
| **NINE SPEAKERS**   |          |            |         |           |
| (word-finally)      |          |            |         |           |
| glottalisation:     |          |            |         |           |
| yes                 | -0.582919| 0.002259   | -258    | < 0.0001 *** |
| voiceless           | -0.048794| 0.002261   | -22     | < 0.0001 *** |
| closure duration    |          |            |         |           |

Table 6.7. Statistical results for the presence of glottalisation and voiceless closure duration across the fortis-lenis series.
Voiceless closure duration and the presence of glottalisation are thus much weaker in cue strength than pre-aspiration. Voiceless closure duration systematically distinguishes the contrast only word-finally. Glottalisation has rather weak cue reliability as well as cue availability in the nine speakers. In ABE37, glottalisation does not have maximum cue reliability, being found in the lenis series in 35% of the tokens. However, it has maximum cue availability in the fortis series in ABE37.

The reason why $f_0$ has not been found to be a correlate of the contrast at any prosodic context may be due to the fact that the $f_0$ measurements were not normalised. This needs to be addressed in future research.

This section revealed that a number of the phonetic features considered consistently distinguish the fortis-lenis contrast and that they do so with high cue strength. Although they differ in cue reliability and also differ in cue availability, considering a higher number of prosodic conditions influences their cue strength.

6.3.2. Bundles of correlates

The previous section showed that each of the two phonological categories of interest, fortis and lenis, has a number of acoustic correlates. On one hand, the fortis category is associated with pre-aspiration, breathiness, and post-aspiration.\textsuperscript{124} These therefore distinguish the fortis-lenis contrast in the same direction and form one group, or a bundle, of correlates. On the other hand, the lenis category is associated with voicing and longer vowel duration. These also distinguish the contrast in the same direction as one another and form another group, or a bundle, of correlates of the lenis category. Since pre-aspiration and breathiness are more frequent with the fortis series and the release is longer with the fortis series, these three correlates are complementary with the correlates of the lenis series: voicing, which is more frequent with the lenis series, and vowel duration, which is longer if preceding or following the lenis series. This complementarity is illustrated in Figure 6.18.

\textsuperscript{124} Although very frequently longer release is due to the presence of post-aspiration, it is not always the case that the lenis plosives are unaspirated and the fortis ones aspirated, which is why the term
Correlations between potential correlates (potential cues)

Figure 6.18. Correlations between multiple correlates (potential cues)

Positive correlations (red) – enhancing the contrast in the same direction; negative correlations (blue) – enhancing the contrast in a complementary direction.

The figure shows the relationships between the correlates of the fortis-lenis contrast outlined above. However, since the phonetic features distinguishing the fortis-lenis contrast represent a mixture of categorical and gradient variables in the statistical/mathematical sense, they were converted into gradient variables to show the correlations between the individual correlates.

For example, the presence of pre-aspiration is categorical as opposed to vowel duration, which is numeric. However, the categorical variables can be expressed as continuous variables as well because we can assign them a real number between 0ms and, in theory, infinity ms. Because the categorical variables show very high cue reliability (e.g. pre-aspiration is restricted to the fortis series; voicing is not found in the fortis series very frequently and, similarly, breathiness is not found in the lenis series particularly frequently), these categorical variables can be transformed into numeric ones if their absence is represented with the duration of 0ms. This transformation step does not change the results of how these phonetic features correlate with the fortis-lenis contrast. Figure 6.18. thus shows that the longer the

‘release’ is used in this chapter. In some cases, it is not straightforward to identify the presence of post-aspiration from the acoustic signal alone.
breathiness, the longer the release duration, and the longer the pre-aspiration, but crucially across the two series (i.e. both zero values from the lenis series and the non-zero and zero values from the fortis series are pooled.). Since they are all correlates of the contrast in the same direction, they are positively correlated with one another. Vowel duration and voicing are also positively correlated across the two series: the longer the voicing across both the fortis and the lenis series, the longer the vowel duration. However, voicing and vowel duration increase in the lenis series, unlike pre-aspiration, breathiness, and release duration, and this leads to the negative correlations between these two groups, or bundles, of correlates.

The complementarity of these bundles is represented with blue lines (negative correlations) whereas the affiliation with the same bundle is represented with red lines (positive correlations). These correlations and their strength are also summarised in Table 6.8.
<table>
<thead>
<tr>
<th>POTENTIAL CUES</th>
<th>CORRELATION DIRECTION</th>
<th>CORRELATION STRENGTH</th>
<th>NUMBER OF SPEAKERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>pre-aspiration &amp; voicing duration</td>
<td>negative</td>
<td>r = -51-87</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(moderate-very strong)</td>
<td></td>
</tr>
<tr>
<td>pre-aspiration &amp; release duration</td>
<td>positive</td>
<td>r = 45-73</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(moderate-strong)</td>
<td></td>
</tr>
<tr>
<td>pre-aspiration &amp; vowel duration</td>
<td>negative</td>
<td>r = -40-68</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(moderate-strong)</td>
<td></td>
</tr>
<tr>
<td>pre-aspiration &amp; breathiness duration</td>
<td>positive</td>
<td>r = 41-87</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(moderate-very strong)</td>
<td></td>
</tr>
<tr>
<td>breathiness &amp; release duration</td>
<td>positive</td>
<td>r = 40-64</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(moderate-strong)</td>
<td></td>
</tr>
<tr>
<td>voicing &amp; release duration</td>
<td>negative</td>
<td>r = -42-81</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(moderate-very strong)</td>
<td></td>
</tr>
<tr>
<td>voicing &amp; breathiness duration</td>
<td>negative</td>
<td>r = -43-88</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(moderate-very strong)</td>
<td></td>
</tr>
<tr>
<td>vowel &amp; release duration</td>
<td>negative</td>
<td>r = -42-47</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(moderate)</td>
<td></td>
</tr>
<tr>
<td>vowel &amp; voicing duration</td>
<td>positive</td>
<td>r = 49-73</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(moderate-strong)</td>
<td></td>
</tr>
<tr>
<td>voicing &amp; voiceless closure duration</td>
<td>negative</td>
<td>r = -48-74</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(moderate-strong)</td>
<td></td>
</tr>
<tr>
<td>vowel &amp; breathiness duration</td>
<td>negative</td>
<td>r = -43-57</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(moderate)</td>
<td></td>
</tr>
</tbody>
</table>

*Table 6.8. Correlations between potential cues*
The table confirms that not only are there more correlations between two correlates to be found, and strong correlations as well, but that there are multiple correlations in the sense that they do not affect two, but more correlates. The table summarises those correlations that were found for at least five speakers from the most to the least frequently found across the speakers. Only significant results, only those found for at least five speakers, and only those exhibiting at least moderate correlations are reported. Pooling the data across the ten speakers thus suggests that the presence of voicing, the presence of pre-aspiration, voiceless closure duration, and release duration are correlated and therefore pattern together.

The relationship between the potential cues is in fact even more complex. Figure 4.16 only shows moderate, strong, and very strong relationships and only those that were found at least in five speakers. Furthermore, once correlations are looked for within the individual prosodic conditions within the individuals, more correlations are revealed as strong or very strong, and even more correlations emerge.

6.3.3. Trade-offs

Within the fortis series, none of the individual speakers shows a negative correlation between the duration of pre-aspiration and that of closure duration in any of the positions within the word ($r = 0.11-0.13; p < 0.01$). This does not suggest a degemination pathway leading to the development of pre-aspiration. It would be useful to look into generational differences between the duration of pre-aspiration and voiceless closure duration.

However, the pathway proposed for the development of pre-aspiration in fortis plosives through a loss of voicing in the lenis plosives (Ní Chasaide & Ó Dochartaigh 1004: 151-2) is not confirmed either. No trade-offs between pre-aspiration and voicing emerge when the individual speakers are looked into. On the contrary, there is a tendency for the speakers who use a high amount of pre-aspiration to also use a high amount voicing word-medially and word-finally. Word-initially, most speakers also follow the path of the higher amount of voicing, the higher amount of pre-aspiration. See Figure 6.19. for the frequency of voicing and

125 The result was not significant for the correlations in the word-initial position.
pre-aspiration by speaker and position within the word. However, many more speakers need to be analysed for conclusive results.

![voicing and pre-aspiration](image)

**Figure 6.19.** Frequency of occurrence of pre-aspiration found in the fortis series correlated with the frequency of voicing in the lenis series (%) by position within the word.

*Every dot represents the frequency of occurrence of pre-aspiration in the fortis series and the frequency of occurrence of voicing in the lenis series as produced by a single individual.*

It is also not the case that the longer the pre-aspiration is in the fortis series, the shorter the voicing is in the lenis series \((r = 0.16; p < 0.0001)\).

### 6.4. Discussion

This chapter aimed to answer whether pre-aspiration can be seen as contrastive through establishing a. whether it systematically distinguishes the fortis-lenis plosive contrast and b. what cue strength it has. It adopted the Competition Model to establish its cue strength.

Although pre-aspiration is found in all three main prosodic conditions looked into: word-initially (*pat* vs *bat*), word-medially (*copper* vs *cobber*), and word-finally (*cop*...
vs *cob*); it systematically distinguishes the contrast only word-medially and word-finally. Considered in the absence of the other correlates of the fortis-lenis contrast, it may seem to be a very strong and in fact the strongest cue – it has a maximally strong cue reliability, never occurring in the lenis series. However, its cue availability reaches only 32% word-initially when preceded by a voiced segment, and 80-91% in the word-medial and the word-final positions.

Nonetheless, its cue strength is comparable to that of breathiness. The cue reliability of breathiness is weaker than that of pre-aspiration because we find it both in the fortis and the lenis series. On the other hand, its cue availability is somewhat higher than that of pre-aspiration, as breathiness is found in 92-93% of time. Compared to voicing, pre-aspiration again shows higher cue reliability. Yet, its cue availability is lower and especially word-initially. Voicing thus shows higher cue availability (88-91%) and is also consistently found across the prosodic environments considered. Finally, release duration distinguishes the fortis-lenis contrast in all prosodic conditions and so does the duration of the following (*pat* vs *bat*) as well as the preceding vowel (*copper* vs *cobber*, *cap* vs *cob*) and so in this sense these two phonetic features are better correlates to the contrast than pre-aspiration.

The presence of pre-aspiration has higher cue strength than the duration of voiceless closure and the presence of glottalisation. Shorter voiceless closure is associated with the lenis plosives, but only in the word-final position. For nine of the ten speakers, the lenis series is associated with more frequent glottalisation, but again only word-finally, and neither its cue reliability nor its cue availability is particularly strong. It is fairly unusual, at least in English accents, for the lenis series to be associated with more frequent glottalisation than the fortis series. This is in contrast with ABE37, for whom pre-aspiration does not distinguish the fortis-lenis contrast word-finally, where it is blocked by glottalisation, and glottalisation is more frequent with the fortis series. Although for this speaker glottalisation shows maximum cue availability in the fortis series, its cue reliability is not maximal.

The contrast between the fortis and the lenis series is realised in a gradient manner because it is phonetically implemented by multiple phonetic correlates. The question arises why multiple phonetic correlates are needed and why precisely number X or number Y, and whether the number of acoustic correlates can be established
considering a wide range of laryngeal, oral, and nasal phonetic features are at
speakers’ disposal. The presence of a number of cues with variable cue strength
reflects the complex phonetics of the fortis-lenis contrast. We could hypothesise that
this arises historically from successive rounds of phonologisation. We could further
hypothesise that because the contrast is ideally maintained across a number of
different segmental and prosodic conditions, speaking rates, styles, and conditions
with a variable degree of noise and because not all the conditions may be favourable
for some phonetic phenomena in the same way (e.g. Warner & Tucker 2011),
changes in speaking conditions may lead to changes in cue distribution. It remains to
be seen in future research a. whether pre-aspiration distinguishes the fortis-lenis
contrast across more segmental and prosodic conditions, various speaking rates,
conditions with a variable degree of noise, and other social situations; and b. if it
behaves differently in its cue strength across these positions, whether the differences
are abrupt or gradient.

The analyses presented in this chapter also offer information relevant for the
degemination scenario behind the innovation of pre-aspiration, information on the
relationship between pre-aspiration and post-aspiration, breathiness, and
glottalisation.

6.4.1. Pre-aspiration and degemination

The results presented in this chapter do not suggest that pre-aspiration is a step in a
degemination process because no correlations are found between the duration of pre-
aspiration and that of the closure. This agrees with the findings reported for the
production data from Italian looked into by Stevens & Reubold, who hypothesise
that pre-aspiration associated with concomitant closure shortening may lead to
degemination (2014: 455). However, although no such concomitant shortening of the
closure is found in their production data, the authors found that perceptually pre-
aspirated plosives were still perceived as shorter than plosives without pre-
aspiration, and thus pre-aspiration may be a perceptual step in a degemination
process after all.
In connection with the degemination hypothesis, it has also been suggested that the loss of phonetic voicing in one category may lead to the enhancement of pre-aspiration in a contrasting category (Ó Murchú 1985: 197). Ní Chasaide has suggested a connection between pre-aspiration and voicing as well, but in a different direction: “[o]nce the preaspiration is very long and perceptible, voicing in the other stop series should become redundant, and this in turn would permit of further voicing loss” (1985: 298). Ní Chasaide & Ó Dochartaigh (1984: 148-52) present data from several varieties of Scottish Gaelic, Irish, and Icelandic, where they show that the varieties/languages with longer pre-aspiration in the fortis series have shorter voicing in the lenis series. This is nevertheless not found in this chapter, because the more frequent pre-aspiration is in the fortis series, the more frequent the voicing seems in the lenis series.\footnote{126} This is true in particular of the word-medial and the word-final contexts, but the same tendency is observed for the word-initial context, even if less strong. It is furthermore not the case that the shorter the pre-aspiration is in the fortis series, the longer the voicing is in the lenis series.

It may be the case that geminates and lengthened consonants are realised either with oral closure during which the glottis is not abducted or oral closure during which the glottis is abducted. Since pre-aspiration is found in languages that also show post-aspiration (in the same context: Bangor English, Kent English, Manchester English – Bramley, Maher & Paterson 2015; Italian – Stevens & Hajek 2010; Welsh – Morris & Hejná 2014; allophonically: Faroese, Icelandic, Mongolian, Sámi, see 6.4.2. for the references), geminates, lengthened consonants, and singletons may be associated with pre-aspiration as a result of the anticipated glottal abduction gesture associated with the release. This proposal nevertheless seems plausible only for languages in which pre-aspiration and post-aspiration are not complementary, which applies to English, Italian, and Welsh, at least in the current state of our knowledge.

6.4.2. Pre-aspiration and post-aspiration

Word-medially and word-finally, both pre-aspiration and release duration distinguish the contrast in the same direction: the fortis series are associated with the presence of

\footnote{126 The word-list data most likely prompt careful speech and the correlates are likely to be enhanced or exaggerated.}
pre-aspiration as well as post-aspiration. This is in contrast to Faroese, Icelandic, Mongolian, and Skolt Sámi, where pre-aspiration is reported as complementary with post-aspiration, with the latter found word-initially, where pre-aspiration does not occur, and the former found word-medially and word-finally (e.g. Ladefoged & Maddieson 1996; Svantesson & Karlsson 2012). The analyses of this chapter agree with the general descriptions of pre-aspiration and post-aspiration insofar that whilst release duration distinguishes the fortis-lenis contrast in the Aberystwyth data word-initially, pre-aspiration does not.

Yet, Svantesson & Karlsson also report some degree of word-initial pre-aspiration for Mongolian (2012: 457) as does Steriade for Huautla Mazateco (Steriade 1998: 216), and Silverman has a question mark for word-initial pre-aspiration in Icelandic (2003). Although word-initial pre-aspiration would seem rare, it is more likely that this is to at least some extent the result of analyses focusing on the word-medial and the word-final positions. Not all studies of pre-aspiration focus on word-initial position and not all such studies therefore analyse tokens preceded by a sonorant required for word-initial pre-aspiration to occur.

6.4.3. Pre-aspiration and prosody

Pre-aspiration is usually described as a feature associated with stressed vowels and with positions other than word-initial (Steriade 1998). Steriade aims to explain these observations and suggests that “[…] in languages like Toreva Hopi and Bernera Gaelic distinctive bT occurs only after a stressed vowel. This is perhaps due to the fact that vowels, particularly stressed vowels, are sufficiently long to preserve a portion of themselves unaffected by aspiration” (Steriade 1998: 214).

Pre-aspiration in unstressed syllables has been reported for Manchester English (Hejná & Scanlon 2015) and Italian (Stevens & Hajek 2004b: 59). It is also found in unstressed syllables in the Bethesda Welsh data analysed by Morris & Hejná (2014 & in prep). Further research needs to be done to see whether a shorter duration of the unstressed vowels also results in shorter pre-aspiration and if the suggestion

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127 The authors do not mention this, however, because they focus on the post-tonic position.
proposed by Steriade holds even for Manchester English, Italian, and Bethesda Welsh.

But vowel duration is conditioned both by the segmental and the prosodic aspects of the languages of the world (e.g. Gordon & Munro 2007 and the references provided in 6.1.4.). Thus, we can hypothesise that pre-aspiration may be primarily governed either by prosody or segments as follows:

Pre-aspiration either becomes phonologised primarily as a cue to prosody, and its secondary function is cuing segmental contrasts. In this case, pre-aspiration could get lost entirely in the unstressed position or be consistently shorter in utterance positions where unstressed vowel does not undergo final lengthening.

Pre-aspiration becomes phonologised primarily as a cue to the fortis-lenis contrast, and its secondary function can be cuing prosodic contrasts. In this case, it will not disappear in the unstressed position, but durational differences conditioned by prosody can still be active.

The finding that pre-aspiration can occur word-initially, reported for Mongolian, Huautla Mazateco, and now also English spoken in Aberystwyth means that pre-aspiration can apply beyond word boundaries. For the Aberystwyth data, the rate of occurrence is less frequent in the word-initial position than in the other positions (word-medial and word-final), and this difference is not negligible. This could mean that pre-aspiration develops within words first or within stressed syllables first – we need to bear in mind that all the tokens analysed in this thesis (and many pre-aspiration studies) in which pre-aspiration is word-medial or word-final the phenomenon is also within a stressed syllable. Word-initial pre-aspiration in the words analysed in this chapter is therefore always found not only at a boundary of two lexical items and a foot boundary, but also at a boundary of two syllables, the first of which carries less stress.

Further research remains to confirm whether word-initial pre-aspiration is also the shortest across the three conditions and whether its frequency of occurrence and duration are comparable to pre-aspiration found at a boundary of unstressed and stressed syllables which are both foot-internal. These prosodic factors may point to whether it is the segmental conditioning or the prosodic one that is more important.
6.4.4. Pre-aspiration and breathiness

Apart from addressing the question of whether pre-aspiration is contrastive, this chapter also follows up on the questions discussed in Chapters 3 – whether pre-aspiration and breathiness should be considered two components of the same phenomenon.

Pre-aspiration and breathiness cue the fortis-lenis contrast in the same direction: they are more frequent in the fortis than the lenis series, which is in agreement with Nance & Stuart-Smith (2013), Gobl & Ní Chasaide (1992: 486), and Ní Chasaide (1985: 356, 365-7, 373). Nonetheless, pre-aspiration has higher cue reliability because it is only found in the fortis series. Breathiness also occurs in the lenis series. The fact that pre-aspiration can be found in the lenis series in some languages and that breathiness is more frequent than pre-aspiration in the lenis series than pre-aspiration where both are found (discussed in 6.1.2. and also in Appendix E.2.) points again to the suggestion that breathiness is a precursor to pre-aspiration and that it is not adequate to treat the two merely as two components of the same laryngeal phenomenon.

6.4.5. Pre-aspiration and glottalisation

This chapter, like Chapter 5, shows that the form of the relationship between pre-aspiration and glottalisation is not predictable in Aberystwyth English at least partially because glottalisation is an incomparably weaker acoustic correlate of the fortis-lenis contrast. It does not cue the contrast systematically word-initially and word-medially, and word-finally it is slightly more frequent in the lenis plosives than the fortis ones in most of the speakers.

For ABE37, word-final glottalisation is complementary to word-medial pre-aspiration as both show very high cue availability. Glottalisation has in fact maximum cue availability in the fortis series in the word-final position. Nonetheless, glottalisation has much weaker cue reliability.

One of the reasons why it is difficult to predict what relationships pre-aspiration and glottalisation will enter is likely due to the fact that pre-aspiration is more likely to function as a correlate of the fortis-lenis contrast, whereas glottalisation is primarily
a prosodic phenomenon occurring utterance or domain-finally, irrespective of segmental contrasts.

The next chapter looks into the last question this thesis raises: whether Aberystwyth English pre-aspiration exhibits social conditioning apart from phonetic and phonological conditioning.
Chapter 7 – Social aspects of pre-aspiration

7.1. Introduction

The previous chapters looked into questions focusing on language-internal phenomena such as the nature of the segmental and the prosodic conditioning of pre-aspiration and the relationship of pre-aspiration with other laryngeal phenomena. This chapter addresses whether pre-aspiration is also affected by social conditioning in Aberystwyth English because our understanding of the phenomenon would otherwise be limited to the domains of phonetics and phonology. This chapter shows that there is a gender difference in the frequency of occurrence of pre-aspiration, which disappears in the youngest speakers. These findings partially correspond to the commonly reported effect of gender, which is that women pre-aspirate more frequently and with longer durations, as also discussed further below.

Pre-aspiration is furthermore undergoing a sound change in apparent time, increasing in its frequency and duration. For most of the speakers, breathiness is more frequent than pre-aspiration in apparent time, which supports the suggestion raised in Chapter 3 that breathiness is a precursor to pre-aspiration. Regarding apparent time, only three studies are available for a comparison and each represents a very different social situation.

These two social aspects that affect pre-aspiration are discussed in what follows from the perceptive of how they affect pre-aspiration in other languages.

7.1.2. Pre-aspiration and gender/sex

The results of this chapter partially agree with the studies that report that it is females/women who are more prone to pre-aspiration because a gender effect is found but it disappears in the youngest speakers. More specifically, it has been reported that females/women pre-aspirate more frequently than males/men\textsuperscript{128} (Newcastle English – Foulkes & Docherty 1999: 66, Foulkes, Docherty & Watt

Because of the high number of reports of women’s being more prone to pre-aspirate, it has been put forward that (females/)women may be more likely to pre-aspirate for physiological reasons (Helgason 2002: 231; van Dommelen, Holm & Koreman 2011: 602), possibly because they “may actually spread their vocal fold processes in order to de-emphasise the fact that they radiate at higher frequencies than men do” (Helgason 2002: 230; quoting Titze 1989), or because of “differences in vocal fold size” (Helgason 2002: 229).130

Discussing physiological effects of sex on pre-aspiration, Helgason makes a connection between local breathiness, which is often mentioned in pre-aspiration studies, with global breathiness. He touches upon a gender/sex tendency for women/females to have a higher spectral tilt than men/males (2002: 229-30). It has been shown that females/women are breathier than males/men (RP and a northern accent of BrE – Henton & Bladon 1985; Dutch – Borsel, Janssens, De Bodt 2007; for English speakers originating in Chicago, St Louis, New Jersey, and California – Price 1989), which is caused by – mainly posterior – glottal gaps (Hanson & Chuang 1999; Chen, Kreiman, Shue, Alwan 2011; for Swedish – Södersten, Hertegård, Hammarberg 1995).

128 When discussing the effects of gender/sex, pre-aspiration studies use either the terms women and men or females and males. The former pair tends to be used to refer to social gender and the latter to biological sex (e.g. Stuart-Smith, Timmins & Wrench 2003). This is discussed in more detail in 7.4.1.

129 Gender motivations behind pre-aspiration are mentioned at least in one paper dealing with the historical aspects of the phenomenon. McKenna (2013) offers discussions of the areal distribution of pre-aspiration in Northern Europe and draws our attention, again since Ni Chasaide’s work (1985: 281-3), to the presence of Celtic female slaves and/or wives in Germanic speaking countries of the North of Europe.

130 Other laryngeal phenomena conditioned by gender/sex have been proposed to be possibly due to physiological differences, such as voicing in plosives (Helgason & Ringen 2008: 622) or post-aspiration duration in plosives (criticised by Oh 2011: 66).
Although it seems reasonable enough to assume that speakers who are globally breathier will also produce more or longer local breathiness, it has been shown that such connections are not necessarily present and the studies used for such assumptions are not directly comparable. Gordeeva & Scobbie have carried out a study looking into a similar question, whether speakers with more global glottalisation are also more prone to ejectives their plosives, and they find that the two are “not necessarily bound together” (2013: 249). Furthermore, the studies reported above that focus on global breathiness use ways that are different than durational or frequency of occurrence measures to analyse the amount of breathiness which are used in pre-aspiration studies. Secondly, although they are assumed to focus on global breathiness, they usually focus on breathiness found within an interval of a vowel, which is relatively more global than how breathiness is defined in this thesis, but still limited to a segment (Hanson & Chuang 1999; Henton & Bladon 1985; Price 1989; Södersten, Hertegård & Hammarberg 1995). Moreover, the studies related to breathiness quoted here used English and Dutch for the analyses, and a wider range of languages would be appreciated to confirm whether it is females that are breathier than males or women that are breathier than men in some cultural contexts, i.e. whether the breathiness is physiological or social in its origin.

In addition, the present chapter shows that although the frequency of pre-aspiration is sensitive to gender, breathiness is not. This can only be compared to the study by van Dommelen, who did not find any gender/sex difference in pre-aspiration duration in his Norwegian data (1999: 2039), but he did in breathiness duration: female speakers show longer durations of breathiness than male speakers (1999: 2039 & 2040). The Aberystwyth data therefore agrees with those of van Dommelen’s in that pre-aspiration duration is not sensitive to gender, but they disagree in that breathiness duration is not either. Both the Aberystwyth and the Norwegian data nevertheless demonstrates that pre-aspiration and breathiness are not necessarily subject to gender in the same way and they should be distinguished in sociolinguistic analyses.

However, even the reports and suggestions surrounding pre-aspiration, which often subsumes local breathiness, and gender/sex need to be approached with a degree of caution because not all studies have found the same gender (and therefore sex)
pattern for pre-aspiration. Stevens (2010) has observed that there is little variation in various standard varieties of Italian accounted for by gender. Similarly, no gender/sex difference was found in Trøndelag Norwegian (Ringen & van Dommelen 2013: 482, 485, 488).131 In one of their studies into Sienese Italian, Stevens & Hajek (2004b: 58) have even observed that the male speakers had a higher frequency of pre-aspiration than the female speakers, although the authors have attributed this to the variable number of tokens for the three places of articulation of the post-tonic plosive. Watson, on the other hand, has argued that pre-aspiration cannot be explained physiologically since, if it were, all English speaking women/females should pre-aspirate (2007: 203). The finding reported by Morris should also be considered with caution as the females in his study were more regular users of Welsh, and the pre-aspiration differences may thus be attributable to language contact rather than gender, as Morris himself admits.

Gender affects pre-aspiration in Aberystwyth English only when considered in the context of age. What follows presents an overview of pre-aspiration studies that have found an effect of this social variable. Where possible, these are compared to the Aberystwyth English pre-aspiration.

### 7.1.2. Pre-aspiration and apparent time

Aberystwyth English pre-aspiration is affected by the age of the speakers, becoming more frequent and longer in duration with the decreasing of age. A question arises whether this is found because the phenomenon is indeed undergoing an advancing sound change and/or shows age grading, or because older speakers are less likely to pre-aspirate due to the aging of the laryngeal structures. Since five pre-aspiration studies provide variable results regarding the effects of age, rather than being affected primarily by physiological age, pre-aspiration is more sensitive to social age. The strength of the social factors may be accent-specific.

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131 This does not agree with other studies of pre-aspiration in Norwegian (Stavanger and Trondheim Norwegian – van Dommelen, Holm & Koreman 1999; Trøndelag Norwegian – van Dommelen & Ringen 2007).
The Aberystwyth results resemble most those of Foulkes & Docherty (1999: 66), who have shown that younger females pre-aspirate most frequently in Newcastle English, which the authors interpret as a change in progress led by females. Foulkes, Docherty & Watt (1999) have confirmed pre-aspiration to be a feature of working class female speech in Newcastle English. Although they have analysed pre-aspiration in children, the fact that the data comes from spontaneous speech did not allow for any conclusions as to whether there are any gender differences in the children data: for example, one of the boys pre-aspirates in approximately 72 tokens out of 104, whilst one of the girls pre-aspirates in 6 out of 8 tokens (1999: 13).

In contrast to the studies of Newcastle English pre-aspiration, for Arjeplog Swedish, Helgason, Stölten & Engstrand (2003) have found that it is the older generations who exhibit longer durations of pre-aspiration for one of the two words examined. In Lewis Gaelic, pre-aspiration is of shorter duration and of less noisiness for the younger generation, which is interpreted again as a regressive sound change (Nance & Stuart-Smith 2013, 147). In the case of Lewis Gaelic, pre-aspiration seen as undergoing a regressing sound change fits with the socio-cultural situation of Scottish Gaelic in general.

In Norwegian spoken in Senja, pre-aspiration has been reported to occur especially in the speech of children (Iversen 1913, cited in Helgason (2002: 72, 95)). Whether this could be interpreted as an advancing sound change or due to child specific phonology or physiology is an open question.

Finally, the Aberystwyth results agree with those of Scottish Gaelic in that pre-aspiration and breathiness are not necessarily subject to the same social constraints. The authors find a sound change in progress for pre-aspiration, but not for breathiness (Nance & Stuart-Smith 2013: 16).

In the rest of this chapter, the terms “females” and “males”, or “female and male speakers”, are used, bearing in mind that it is not clear whether any of the variation found in the Aberystwyth data is connected to gender or sex. This is further discussed in Discussion (7.4.).
7.2. Methodology

7.2.1. Speakers

This chapter analyses seventeen speakers described in Chapter 2. The basic social background of the speakers is provided in Chapter 2, as is the recording procedure and the information on the further processing of the data. Additionally, this chapter provides more information on the age of the speakers and their education.

The age of the respondents by gender is summarised in Table 7.1. below. Within each gender/sex, the Aberystwythians are ordered from the youngest to the oldest.

<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>AGE</th>
<th>GENDER</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABE52</td>
<td>22</td>
<td>female</td>
</tr>
<tr>
<td>ABE45</td>
<td>24</td>
<td>female</td>
</tr>
<tr>
<td>ABE50</td>
<td>26</td>
<td>female</td>
</tr>
<tr>
<td>ABE33</td>
<td>32</td>
<td>female</td>
</tr>
<tr>
<td>ABE24</td>
<td>48</td>
<td>female</td>
</tr>
<tr>
<td>ABE12</td>
<td>54</td>
<td>female</td>
</tr>
<tr>
<td>ABE46</td>
<td>58</td>
<td>female</td>
</tr>
<tr>
<td>ABE17</td>
<td>60</td>
<td>female</td>
</tr>
<tr>
<td>ABE18</td>
<td>70</td>
<td>female</td>
</tr>
<tr>
<td>ABE31</td>
<td>72</td>
<td>female</td>
</tr>
<tr>
<td>ABE14</td>
<td>90</td>
<td>female</td>
</tr>
<tr>
<td>ABE28</td>
<td>26</td>
<td>male</td>
</tr>
<tr>
<td>ABE41</td>
<td>28</td>
<td>male</td>
</tr>
<tr>
<td>ABE25</td>
<td>31</td>
<td>male</td>
</tr>
<tr>
<td>ABE29</td>
<td>62</td>
<td>male</td>
</tr>
<tr>
<td>ABE15</td>
<td>72</td>
<td>male</td>
</tr>
<tr>
<td>ABE11</td>
<td>79</td>
<td>male</td>
</tr>
</tbody>
</table>

Table 7.1. Age and gender/sex of the speakers analysed

The vast majority of the Aberystwythians have obtained a higher education degree (such as BA or teacher’s training) or are studying towards such a degree, and if not retired they are currently also working in jobs requiring a higher education degree. For the younger and the middle aged speakers, often both parents have or had obtained a comparable degree. However, most of the older generation come from a farming background and so higher education was not easily accessible for their parents. They are also comparable regarding class.
7.2.2. Data

Wordlist A.1. was used for the analyses of this chapter (See Appendix A.), but the analyses were limited to two vocalic contexts: /a/ and /ɪ/. This resulted in words such as cap, cat, cack, kip, kit, kick; capper, catty, cacky, kipper, kitty, kicker. For each respondent, 244-250 tokens were obtained. The two vowels were deliberately selected as the former tends to be associated with the longest durations and most frequent occurrences of pre-aspiration, whilst the opposite is the case for the latter vowel. See Chapter 3 for more details on this.

7.2.3. Other factors considered

Several potential confounds and nuisance variables were identified before the study was carried out.

Firstly, we have seen on multiple occasions that one respondent, ABE37 (28 years), glottalises categorically in a way blocking pre-aspiration word-finally (bat), and this speaker was therefore excluded from the analyses because, for her, sociolinguistic variation in pre-aspiration is limited only to the word-medial position. In the word-final position, there is simply no pre-aspiration to analyse, and since most of the tokens recorded are those with a plosive in the word-final position, including this speaker in the dataset could skew the results.

Next, due to possible differences in speaking rate, the durations of pre-aspiration and breathiness were normalised as follows:

\[
\text{Pre-aspiration duration} / (\text{Word duration}/100) \\
\text{Breathiness duration} / (\text{Word duration}/100)
\]

This is consistent with the previous chapters.

Finally, although pre-aspiration studies differ in how age affects pre-aspiration, we cannot exclude a mixture of social and biological effects, with the strength of the first being possibly accent-specific. There seems to be a test that enables us to tell whether biological age is a confound. Arguably, if there is a physiological effect of aging affecting the duration of pre-aspiration, the same age-related pattern should be
found for the duration of post-aspiration. Pre- and post-aspiration nevertheless did not show the same – or a reverse – pattern in this regard, and it is therefore concluded that physiological aging of the vocal folds does not interfere with the patterns produced by a possible sound change in progress. Nevertheless, this is based on the assumption that post-aspiration and pre-aspiration should be subject to the same biological conditioning, but we do not know if this is indeed the case.¹³²

7.3. Results

This section first discusses the effects of gender and then those of age because the first are emphasised more in pre-aspiration literature.¹³³

7.3.1. Gender

Only the frequency of pre-aspiration is affected by gender. However, the effect of gender is apparent only in apparent time: the gender difference decreases with the decreasing of age, as shown in Figure 7.1 and summarised in Table 7.2.

¹³² Nothing is known about the effects of biological aging on pre-aspiration frequency or duration, but relevant research has been carried out for post-aspiration. The results are on the whole diverse (Torre III & Barlow 2009: 326, 330, and references therein). Importantly, however, it is not clear how previous research into the effects of the aging of the laryngeal structures on VOT distinguishes between sociophonetic or socio-phonological sound change in progress and genuine physiological age-related effects. Similarly, sociophonetic and socio-phonological studies often assume that the effects are necessarily social rather than biological.

¹³³ Logistic Mixed Effects Models are used to analyse the frequency of occurrence of pre-aspiration and breathiness, and Linear Mixed Effects Models for the duration of pre-aspiration and breathiness, with the random effects of “speaker” and “word”. In the logistic models, presence of pre-aspiration and breathiness were the dependent variables, respectively (with two levels: “present” and “absent”). In the linear models, normalised pre-aspiration and breathiness durations were the dependent variables, respectively. The models shared the independent variables: “age” (continuous variable), “gender” (with two levels: “female” and “male”), “vowel type” (with two levels: /a/ and /ɪ/), “place of articulation of the plosive” (with three levels: /p/, /t/, /k/), “word position” (with two levels: “word-medial” and “word-final”), and “frequency”. Forward difference coding was applied to the place of articulation, which means that /p/ was contrasted with /t/, and /t/ with /k/. For each dependent variable, we were looking for the optimal model, i.e. a model that predicts the variation in the dataset best. At first, the linguistic variables were entered in a step-up manner and, where this improved the model, their interactions were added and kept. Next, the social variables were added, again in a step-up manner, and kept a. only if this improved the model or b. if an interaction of social variables improved the model although on their own they did not contribute significantly. Finally, the variable of lexical frequency was added, but since it is never significant, it is not commented on. The individual models were compared through ANOVA.
Figure 7.1. Pre-aspiration occurrence (raw frequency count) by gender and (biological) age

|                  | ESTIMATE | STD. ERROR | Z VALUE | PR(>|Z|) |
|------------------|----------|------------|---------|---------|
| (Intercept)      | -4.77952 | 0.60974    | -7.839  | < 0.0001 *** |
| /a/ vs /ɪ/       | 1.62981  | 0.18720    | 8.706   | < 0.0001 *** |
| /p/ vs /t/       | 2.48586  | 0.16981    | 14.639  | < 0.0001 *** |
| /t/ vs /k/       | 0.79395  | 0.18127    | 4.380   | < 0.0001 *** |
| age              | 0.03085  | 0.01064    | 2.900   | < 0.01 ** |
| /ɪ/: “word-final” vs “word-medial” | 1.29428 | 0.28119 | 4.603   | < 0.0001 *** |
| “male”: age      | 0.03799  | 0.01750    | 2.170   | < 0.05 *  |

Table 7.2. Statistical results for pre-aspiration occurrence

The language-internal factors affect the frequency of occurrence of pre-aspiration as expected. /a/ is associated with a higher frequency of pre-aspiration than /ɪ/. The position within the word also affects pre-aspiration occurrence, but only regarding /ɪ/, which is less often pre-aspirated when the plosive is word-medial. The place of
articulation of the post-tonic plosive shows that the more posterior the place, the lower the frequency of occurrence of pre-aspiration, which is rather surprising. The difference between /p/ and /t/ is nevertheless much bigger than that between /t/ and /k/.

7.3.2. Age

Age conditions the frequency of the occurrence of pre-aspiration: the younger the individual, the more frequent the pre-aspiration, and this interacts with the effects of gender (Figure 7.1., Table 7.2.). Age also affects the frequency of the occurrence of breathiness and in the same direction: the younger the individual, the more frequent the breathiness is overall, as illustrated in Figure 7.2. and Table 7.3. below.

![Age, gender, and breathiness occurrence](image)

*Figure 7.2. Breathiness occurrence (raw frequency count) by gender and (biological) age*
|                        | ESTIMATE | STD. ERROR | Z VALUE | PR(>|Z|)   |
|------------------------|----------|------------|---------|-----------|
| (Intercept)            | -5.069245| 0.944567   | -5.367  | < 0.0001 *** |
| “word-final” vs “word-medial” | -0.939671| 0.208313   | -4.511  | < 0.0001 *** |
| /p/ vs /t/             | -1.267849| 0.160735   | -7.888  | < 0.0001 *** |
| /t/ vs /k/             | -1.588742| 0.168286   | -9.441  | < 0.0001 *** |
| age                    | 0.073819 | 0.014603   | 5.055   | < 0.0001 *** |
| /ɪ/: “word-final” vs “word-medial” | 1.682427| 0.278461   | 6.042   | < 0.0001 *** |

Table 7.3. Statistical results for breathiness occurrence

Breathiness occurrence is sensitive to language-internal factors as expected. The type of the vowel affects it insofar as /ɪ/ with a word-final plosive is associated with more pre-aspirated tokens than /ɪ/ with word-medial plosives and this is not the case for /a/. It is sensitive to the place of articulation of the post-tonic plosive in that the more posterior the place, the more frequent the breathiness is. Additionally, breathiness is more frequent word-medially than word-finally.

Pre-aspiration duration is affected by age as well: the younger the speakers, the longer the pre-aspiration (Figure 7.3., Table 7.4.). However, there is a great deal of individual variation, especially among the females.
Figure 7.3. Pre-aspiration duration (normalised) by gender and (biological) age

Table 7.4. Statistical results for pre-aspiration duration
The effect of age on the duration of pre-aspiration is furthermore marginal in comparison to the linguistic factors.

The direction of the effects of the language-internal factor is expected: pre-aspiration is longer with /a/, and the place of articulation predicts its duration in an expected manner as well: /p/ < /t/, /k/. There is also a significant effect of the position within the word: pre-aspiration is longer with a word-final plosive than with a word-medial plosive.

Age also predicts the duration of breathiness in the same way as the duration of pre-aspiration (Figure 7.4., Table 7.5.).

![Age, gender, and breathiness duration](image)

*Figure 7.4. Breathiness duration (normalised) by gender and (biological) age*
|                          | ESTIMATE | STD. ERROR | DF       | T VALUE | PR(>|T|)  |
|--------------------------|----------|------------|----------|---------|----------|
| (Intercept)              | 7.61842  | 0.88823    | 23.68000 | 8.577   | < 0.0001 *** |
| /p/ vs /t/               | 1.10808  | 0.21423    | 77.06000 | 5.172   | < 0.0001 *** |
| /p/ vs /k/               | 1.09840  | 0.21719    | 79.59000 | 5.057   | < 0.0001 *** |
| /ɪ/: “word-final” vs “word-medial” | -0.85386 | 0.35520    | 82.02000 | -2.404  | < 0.05 *   |
| age                      | -0.05223 | 0.01500    | 16.00000 | -3.481  | < 0.01 **  |

*Table 7.5. Statistical results for breathiness duration*

### 7.3.3. Pre-aspiration and breathiness

The results for the duration of pre-aspiration are nearly identical to those of breathiness, with breathiness duration being less sensitive to the segmental conditioning. As shown in Figure 7.5., there are nevertheless considerable differences in the duration of pre-aspiration and breathiness for some individuals, but these are cancelled out because where pre-aspiration is longer in duration in apparent-time, breathiness is shorter in duration, and vice versa. This would actually point out to a trade-off between the two phenomena in the time dimension for at least some members of the population.
Looking at the frequency of the occurrence of pre-aspiration and breathiness in apparent time reveals very little variability between the two (Figure 7.6.).
Irrespective of gender or age, there is a strong tendency for the two to co-occur, although for most speakers breathiness is more frequent than pre-aspiration, especially in the oldest generation. This supports the suggestion that breathiness is a precursor to pre-aspiration, but data from more speakers need to be analysed.

Bigger differences between pre-aspiration and breathiness are found in how their frequency of occurrence is conditioned segmentally and prosodically. They are both more frequent in /ɪ/ followed by a word-final rather than a word-medial plosive. This prosodic conditioning is however significant on its own for breathiness, whilst it is not for pre-aspiration. For pre-aspiration, on the other hand, the conditioning by the vowel type is on the whole significant, which is not the case for breathiness. The two therefore overlap in terms of their linguistic conditioning, but whilst breathiness is more sensitive to prosodic factors, pre-aspiration is more strongly affected by the segmental factors. The two show a trading pattern regarding the place of articulation of the post-tonic plosive: breathiness becomes more frequent the more posterior the plosive is, and the opposite is true for pre-aspiration.
7.4. Discussion

This chapter has demonstrated that pre-aspiration is not sensitive only to language-internal but also to language-external factors.

7.4.1. Gender

Recent studies of pre-aspiration have observed a tendency for females to be more likely to pre-aspirate than males and this chapter partially confirms this. Female speakers pre-aspirate more frequently than the male speakers, but this difference disappears in the youngest generation. Furthermore, no gender/sex difference is found for the frequency of occurrence of breathiness and no durational differences conditioned by gender are discovered either.

Aberystwyth pre-aspiration illustrates Labov’s Principle II, according to which age and gender are closely related in sound changes involving phenomena below the level of awareness (e.g. Labov 1990: 215; to appear: 12). Labov has observed that “[i]n linguistic change from below, women use higher frequencies of innovative forms than men do” (Labov 2001: 292). The principle has been confirmed by a number of studies, e.g. /uː/ and /ou/ fronting before non-liquids in Flagstaff English (Lauren Hall-Lew 2004: 18, 19), /ɪ/, /ɛ/, and /æ/ centralisation and raising in New Zealand English (Maclagan, Gordon & Lewis 1999: 31), VOT mergers trading off with \( f_0 \) differentiations in Seoul Korean (Kang 2014: 84) and many more mentioned in Labov (1990: 215-8) in a detailed literature overview of studies supporting Principle II.

The fact that pre-aspiration supports Labov’s Principle II corresponds to the phenomenon being most likely below the level of awareness. Based on the author’s observations, Aberystwythians are not aware of pre-aspirating and never comment on anything identifiable as pre-aspiration either during the recording sessions or in natural, daily situations. Furthermore, even if told they pre-aspirate in lay terms, they find it difficult to realise what it is that they do.

Labov furthermore suggests an explanation for why so many sound changes below the level of awareness are found to be led by women. He proposes that these sound changes can be explained by the asymmetry of the caregiving situation (1990: 244)
and predicts that female dominated changes will see a faster transmission than male
dominated changes because children’s caretakers tend to be females in the vast
majority of cases (2010: 254). Furthermore, he states that “[g]ender differentiation
does not continue indefinitely. On the contrary, the difference between males and
females disappears as the change continues” (2010: 255). This is also supported by
the Aberystwyth data.

Other studies have nevertheless shown that the principle does not always hold and
can be complicated by social networks and other community specificities (Eckert
1989: 248; Chicano English – Fought 1999; Cajun English – Dubois & Horvath
2000: 287, 298, 308). Labov himself offers examples which do not support the
principle (1990: 218-9) and comments on it as being “[…] less regular than Principle
I [Women lead innovations above the level of awareness.] in the sense that there is
no way to predict in any given case whether men or women lead at the beginning of
a linguistic change” (1990: 244).

Helgason brings our attention to two studies reporting that children pre-aspirate more
frequently in Newcastle English (Foulkes, Docherty & Watt 1999) or Senja
Norwegian (Iversen 1913, cited in Helgason 2002: 72, 95). He puts forward that this
may be due to the physiological differences in the size of the vocal tract, which is
applicable not only to differences between children and adults but also to those
between female and male adults (Helgason 2002: in particular 231). However, a
sociolinguistic explanation in lines with Labov’s levelling is another possibility: that
both adult female speakers and children pre-aspirate most frequently does not mean
that children pre-aspirate necessarily solely because of the small size of their vocal
tracts. If pre-aspiration indeed innovates in females first due to physiological
reasons, these are not strong enough to avoid the pressure of social effects. This is
especially obvious in the light of the segmental conditioning, which is found
repeatedly cross-linguistically (see Chapter 3) and which points to a physiological
and/or perceptual motivation behind the segmental rather than the social factors.

As discussed in the introduction of this chapter, a number of pre-aspiration studies
have given rise to the suggestion that women are more likely to pre-aspirate due to
physiological reasons (Helgason 2002: 95, 231; van Dommelen, Holm & Koreman
2011: 602). The Aberystwyth data shows that if pre-aspiration is conditioned by
physiological sex rather than social gender at a certain point in time, this
physiological effect is not strong enough in comparison to social pressures. The relationship between biological sex and sociolinguistic gender has been described as “not clear” by Labov (2010: 370), which is in line with other studies explicitly discussing social gender as opposed to biological sex (Simpson 2009). Indeed, it is not clear to what extent studies discussing gender actually assume that the effects are social rather than biological.

7.4.2. Age

Pre-aspiration advances in the frequency of occurrence with the decreasing of age, and the same is the case for breathiness. This tendency is very similar for pre-aspiration and breathiness, and the individuals’ changes in one reflect the changes in the other.

Greater individual differences are found between the duration of pre-aspiration and breathiness, but when all speakers are considered, they follow the same pattern and increase in their duration.

Because of the gender difference in the oldest speakers, which disappears in the youngest speakers, it would seem that rather than age grading this is a case of an advancing sound change.

7.4.3. Pre-aspiration and breathiness

In line with their phonetic and phonological behaviour, pre-aspiration and breathiness again offer some similarities and some differences when their social conditioning is examined. The most notable difference is that it is only the frequency of pre-aspiration that is conditioned by gender. This does not lend support to the connections between gender and breathiness. Although the connections that have been made focus on global rather than local breathiness, if these connections are real then they should also hold between pre-aspiration and local breathiness.

Breathiness is furthermore more frequent than pre-aspiration in most of the individuals, especially in the oldest generation. This suggests that breathiness is a precursor to pre-aspiration.
Pre-aspiration and breathiness are similar regarding age when it comes to their duration in the sense that, if we look at the duration of pre-aspiration and breathiness across all seventeen speakers, there is a considerable amount of individual variation, and the cases of the highest variability in pre-aspiration are associated with the cases of the highest variability in breathiness. Pooled across the individuals, the duration of pre-aspiration shows a very similar tendency as the duration of breathiness in apparent time. This differs from the findings of Nance & Stuart-Smith, who have found an age effect with pre-aspiration but not with breathiness in their Scottish Gaelic data (2013: 16).

This chapter suffers from two limitations and should thus be considered exploratory. These are due to reasons of time. Firstly, only twelve females and six males were included in this study, which is rather few for apparent-time analyses. Secondly, other potentially important social factors were not explored, such as the effect of home language (English vs Welsh vs more complicated scenarios), proficiency in Welsh (if it is L2), how frequently Welsh is used by the speakers, class, and style.
Chapter 8 - Conclusion

The thesis has contributed to the current understanding of pre-aspiration by addressing the following questions:

1. Is the usual definition of pre-aspiration adequate?
2. Is pre-aspiration a phonetic or also a phonological linguistic feature of Aberystwyth English?
3. Are pre-aspiration and glottalisation necessarily mutually exclusive in the same environment?
4. Is pre-aspiration conditioned socially in Aberystwyth English?

8.1. Summary of the main findings

8.1.1. Is the usual definition of pre-aspiration adequate?

The first question reflects the practice of analysing pre-aspiration as having two components: a period of voiced glottal friction (breathiness) and a period of voiceless glottal friction (pre-aspiration). The question of whether breathiness and pre-aspiration should be treated as two components of the same phenomenon is at the very core of what pre-aspiration is because it asks if it is correct to assume that breathiness will show the same linguistic and social patterns as (voiceless) pre-aspiration. Chapter 3 shows that pre-aspiration and breathiness are frequently sensitive to different segmental and prosodic factors. This suggests that lumping the two together in analyses may, at least in some cases, obscure linguistic patterns. Furthermore, Chapter 3 also proposes that breathiness is a precursor to pre-aspiration.

As discussed in Chapter 1 in more detail, these findings may also be of relevance to the synchronic debates involving the segmental affiliation of pre-aspiration: is pre-
aspiration affiliated with the vowel (C|V|C: [m|a|s]), the consonant (C|V|C: [m|a|s]), both (C|V|C: [m|a|s]), or neither (C|V|C: [m|a|s])? Differentiating breathiness from pre-aspiration may lead to more exact acoustic and perceptual analyses. The results presented in Chapter 3 also confirm Kingston’s suggestions that pre-aspiration and breathiness should be differentiated (1990).

8.1.2. Is pre-aspiration a phonetic or also a phonological linguistic feature of Aberystwyth English?

Chapter 4 concludes that pre-aspiration generally forms two non-overlapping categories: it is either absent (duration of 0ms) or present (5ms and longer). Although the absence of values between 0ms and 5ms may be a result of the fact that pre-aspiration may not be detectable below 5ms (by researchers generally), the values above 5ms gradually rise towards the peak of the mode with the positive values, which suggests genuine bimodality. Whether short pre-aspiration is perceptible is a question for further research and one which may contribute to our understanding of why certain environments may be more likely than others to be associated with no pre-aspiration at all. This result and also the fact that it is phonological rather than phonetic vowel height that conditions pre-aspiration suggest that pre-aspiration may be sensitive to the phonological mechanisms of the Aberystwythians analysed.

Additionally, Chapter 6 focuses on a wide number of potential acoustic correlates of the fortis-lenis plosive contrast and finds that considered on its own pre-aspiration is a very consistent and strong correlate of the contrast. Word-medially and word-finally, based on the acoustic evidence alone it is not likely that there is one most important cue. Instead, a number of phonetic correlates to the contrast are found of very comparable strengths. However, word-initial pre-aspiration does not systematically distinguish the two plosive series and in this position it has much weaker cue strength than other phonetic features. The fortis and the lenis categories are implemented by a rich set of phonetic features, which does not support economy-driven debates surrounding the development of pre-aspiration.
8.1.3. Are pre-aspiration and glottalisation mutually exclusive in the same environment?

One pathway that has been suggested as leading towards the innovation of pre-aspiration is its development from glottalisation. However, it is not clear exactly how this happens without the assumption that they could co-occur in the same environment. Chapter 5 shows that pre-aspiration and glottalisation can indeed co-occur in the same environment. This possibility, which has so far been neglected in the discussions of whether pre-aspiration develops from glottalisation and vice versa, partially resolves the problem of such debates. The problem is only partially solved because if the two can co-occur in the same environment that means that for some reason one can win over the other in the course of time.

Chapter 5 further asks what determines the relationship between pre-aspiration and glottalisation. The analyses of the segmental and the prosodic conditioning of pre-aspiration and glottalisation demonstrate that it is determined prosodically and not segmentally. In the exclusive, allophonic pattern, pre-aspiration is favoured word-medially (patter [pʰaʔtʰa]) and glottalisation word-finally (pat [pʰaʔtʰ]) and similarly pre-aspiration is more frequent in tokens produced in a carrier sentence (Say pat once.) than in those produced in isolation (pat) and the opposite is true of glottalisation. When they co-occur (e.g. [pʰaʔhₐ]), they are both more frequent word-finally than word-medially. Finally, in the fricative context and also in one speaker in the plosive context, pre-aspiration is nearly obligatory and glottalisation is independent from pre-aspiration, determined segmentally.

8.1.4. Is pre-aspiration conditioned socially in Aberystwyth English?

Chapter 7 looks into whether the Aberystwyth data is also sensitive to social constraints, focusing primarily on sex/gender and age variation. A gender difference is found in the frequency of occurrence of pre-aspiration in the older speakers, this difference disappears with decreasing age. The frequency of occurrence of breathiness, the duration of breathiness, and the duration of pre-aspiration are not sensitive to gender/sex. Hence, if pre-aspiration innovates in languages first in females because of physiological differences in the laryngeal structures, these
physiological differences are not strong enough to avoid the pressure of social factors.

The fact that pre-aspiration is not necessarily conditioned by physiological differences related to sex seems even more solid when compared to the segmental conditioning of various aspects of pre-aspiration reported cross-linguistically. Vowel height and the place and the manner of articulation of the post-tonic plosive have on the whole a robust effect irrespective of gender/sex. Chapter 7 thus agrees with Simpson (2009), who concludes that sex and gender variation are most likely both present in speech, and it is not easy – or even always possible – to disentangle whether we are observing physiologically or socially conditioned variation.

Furthermore, most of the speakers exhibit higher rates of breathiness than pre-aspiration in apparent time, which supports the suggestion that breathiness is a precursor to pre-aspiration.

In case of Tyneside English, Clayton proposed that pre-aspiration is a recent innovation (2010: 82). This is in contrast with Aberystwyth English. This thesis repeatedly shows that pre-aspiration is a very robust feature of Aberystwyth English and, furthermore, it is also phonologically conditioned (Chapter 4). Additionally, it is a consistent acoustic correlate of the fortis-lenis contrast in plosives word-finally and word-medially (cart vs card and catty vs caddie). Chapter 6 moreover shows that pre-aspiration is also found with word-initial fortis plosives, although less frequently than in the other two positions. Such patterns are unlikely to be associated with a newly innovated linguistic feature.

8.2. Incidental findings

One of the outcomes of the thesis are also some incidental findings. These are related to sonorant devoicing, obstruent clusters and the principle of articulatory binding (Kingston 1990), post-aspirated fricatives, and certain changes possibly affecting the vowels.
8.2.1. Sonorant devoicing

Apart from the presence of pre-aspiration in the sequences of vowels and phonetically voiceless obstruents, the data suggest that sonorant devoicing is also attested in the speakers from various parts of Wales. Although sonorant devoicing and pre-aspiration are two terms, the main difference is in the type of segments they are associated with. The former is found in the sequences of sonorants other than vowels and voiceless obstruents (e.g. Milky Way). For variable approaches to whether pre-aspiration and sonorant devoicing are the same phenomenon or two phenomena, see Helgason (2002: in particular 11, 17-21).

The phenomenon requires further analyses to answer questions such as whether it is as frequent as pre-aspiration, whether it is conditioned in the same way, whether it follows the sonority hierarchy in affecting /t/ more than /l/ and /l/ more than /n/, and whether fricative or trill realisations of /r/ pattern differently than the approximant ones in this respect. If sonorant devoicing is a phenomenon conditioned by the sonority hierarchy, irrespective of the phonetic realisation of /r/, sonorant devoicing should affect the different realisations of /r/ in the same way.

8.2.2. Pre-aspiration in obstruent clusters and articulatory binding

The principle of articulatory binding was discussed in Chapter 3 in the context of singleton obstruents. The principle also predicts patterns relevant for obstruent clusters. It predicts “[…] the consolidation of all glottal gestures in a cluster into a single one, bound to the last stop in the cluster, rather than multiple openings” (1990: 428). The acoustic data from Aberystwyth English may not be supportive of this because we find pre-aspiration with obstruent clusters in Aberystwyth English. Furthermore, we find the same in Welsh English in general and also at least in Manchester English (fricative+plosive: west, left; plosive+plosive: doctor, catkin; plosive+fricative: Watson, catsup). It is always prior to the closure of the first obstruent (for plosives) or prior to the oral constriction (for fricatives) where pre-aspiration occurs and it is not obvious from the acoustic data that pre-aspiration in this instances binds itself to the second consonant in the cluster. Moreover, the
principle also rests on the assumption that the glottal gestures are timed with plosives and not fricatives.

8.2.3. Further variability in plosives and fricatives

The data also revealed instances of partial spirantisation and what seems to be obligatory affrication of /t/ in all prosodic positions looked into (word-initial: *tap* [tʰaːpʰ]; word-medial: *patter* [pʰaːtʰə]; word-final: *pat* [pʰaːtʰ]). Furthermore, affricated /t/ is frequently also post-aspirated in the word-initial position ([tʰaːpʰ]), as shown in Figure E.3.6. in Appendix E.

The data furthermore made it possible to acoustically evaluate Wells’s report that Welsh English exhibits post-aspirated /s/ (1982: 388). None of the respondents analysed in this thesis shows any post-aspiration following any fortis fricative. However, data from other respondents shows three such cases, two associated with /s/ (Figure 8.1.) and one with /f/.

![Figure 8.1. Post-aspirated /s/ in the word Sam in Aberystwyth English](image)

‘Post’ stands for post-aspiration and ‘pr’ for vowel-initial breathiness or slack voice

134 Pavel Iosad informs me that fricatives are fairly frequently post-aspirated in his Southern Welsh data. His data involves mainly /s/ and /ʃ/.
This leaves the question of why plosives seem more prone to variation than fricatives. Is this an outcome of methodological limitations, or is this a real observation, and if the latter is the case, why is this the case?

8.2.4. Variability in vowels

The formant measurements also point to some variability in the phonetic realisations of some vowel phonemes. Most notably, the data gives an impression that the DRESS and the KIT vowels are undergoing lowering and also a degree of centralisation, which corresponds to what has been reported for other varieties of English (e.g. Californian English – Eckert 2008; Canadian English – Boberg 2005; Dublin English – Hickey 2015). Some speakers furthermore reveal a partial merger in the quality of the TRAP and STRUT vowels. These two features are shown in Figures 8.2. and 8.3.
The vowels are marked as follows: /ɪ/ (KIT: orange) is represented with 'i'; /e/ (DRESS: green) is represented with 'e'; /a/ (TRAP: red) is represented with 'a'; /ʌ/ (STRUT: brown) is represented with 'ʌ'; /u/ (FOOT: light blue) is represented with 'u'; /ɑː/ (PALM: dark blue) is represented with 'ɑː'; /ɒ/ (LOT: purple) is represented with 'o'; and /oː/ (NORTH, FORCE: yellow-grey) is represented with 'o.'
The vowels are marked as follows: /ɪ/ (KIT: orange) is represented with 'i'; /e/ (DRESS: green) is represented with 'e'; /a/ (TRAP: red) is represented with 'a'; /ʌ/ (STRUT: brown) is represented with 'ʌ'; /ɒ/ (FOOT: light blue) is represented with 'o'; /aː/ (PALM: dark blue) is represented with 'aː'; /oː/ (LOT: purple) is represented with 'oː'; and /oː/ (NORTH, FORCE: yellow-grey) is represented with 'oː'.

Speakers also vary in the realisation of the FOOT vowel. For some it is central, whilst for others it is further back, and yet other speakers show differences in the individual words and whether they are affiliated with the FOOT or the STRUT vowel. Further variation is found in the phonetic realisation of the START vowel. In some Aberystwythians this vowel is central, like that of TRAP, but in most speakers it is further back.
8.3. Beyond acoustics

This thesis has addressed the individual research questions through acoustic analyses. Many of these questions would however benefit from a combination of acoustic and perceptual experiments. With respect to the third question, in the area of cues to contrasts it has been shown that cues in production and perception can be different within individuals (e.g., Aaltonen, Eerola, Hellstrom, Uusipaikka & Lang 1997, quoted in Frieda, Walley, Flege & Sloane 1999; Hazan & Rosen 1991; Helgason 2004; Stevens & Reubold 2014).

Furthermore, although the affiliation issue is not addressed in this thesis, Stevens & Reubold (2014) have reported that speakers differ in their production and perception regarding the affiliation of pre-aspiration, but what role individual variation in breathiness as opposed to pre-aspiration plays is not known. Perceptual studies into the segmental affiliation of breathiness and pre-aspiration could be beneficial for our understanding of whether non-contrastive quantity alternations between V₀P and V:P arise categorically or gradually, i.e. whether there is a sudden emergence of one variant or a gradual emergence through increasingly longer/shorter durations of the vowel. This could be done following the method used in Gussenhoven & Zhou (2013).135

Perceptual studies could also shed light on the social aspects of pre-aspiration: for example, are speakers of a certain age perceived as more feminine or masculine depending on how frequent, how long in duration, and how noisy their pre-aspiration is?

8.4. Beyond pre-aspiration in Welsh English

Further questions stem from the increasing reports of pre-aspiration in more varieties of English and in more languages.

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135 I am thankful to Carlos Gussenhoven for pointing this study out to me.
8.4.1. How old is English pre-aspiration?

The first question coming to our mind is just how widespread pre-aspiration is in English spoken in the UK and the Republic of Ireland, and how much accents found in these countries differ in its behaviour. A closely related question calling out for an answer is how old pre-aspiration is in English.

Both questions could be enlightened by carrying out acoustic analyses for a number of accents in the UK and the Republic of Ireland for multiple generations in a formal and informal style and by real-time acoustic analyses of older recordings. It would seem that there is a lack of pre-aspiration in some major dialect groups of English, e.g. Canadian, Australian, or New Zealand English. However, Clayards & Knowles have recently reported pre-aspiration in fortis fricatives in North American English as well.

8.4.2. Typology of pre-aspiration

Chapter 5, which looked into the compatibility of pre-aspiration and glottalisation in the same environment, further investigated the predictability of whether the two laryngeal phenomena will enter a mutually exclusive or a co-occurring pattern in the same context. Both pre-aspiration and glottalisation ensure phonetic voicelessness of an obstruent, with the exception of periodic creak. Is innovation of one connected with the innovation of the other? Whilst this is not the case in all pre-aspirating or glottalising languages because many languages that glottalise do not pre-aspirate, this question is not farfetched in case of English.

The two phenomena are fairly widespread across the UK, but we do not know practically anything about the age of pre-aspiration, and what we know about the age of glottalisation is limited to glottalling, i.e. glottal replacement (and not glottal reinforcement), which is first reported by Jespersen (1909-49) in 1887 for dialects of Scots and Northern English (as reported in Beal 2004: 165-6, 208-9). Since pre-aspiration has been reported for English recently, there have been a rather small number of studies addressing sociolinguistic factors relevant for the phenomenon in some way or other. None of these have made any direct and often even indirect connections with glottalisation or glottalling.
Glottalisation and pre-aspiration have been both subject to sociolinguistic research in studies focusing on Newcastle and Derby English pre-pausal /t/. Social class, gender, and age have been shown to affect pre-aspiration in Newcastle – it is more frequent in working class female speech amongst the young generation of adults, and the same has been observed for glottalisation in this variety (Foulkes, Docherty & Watt 2001: 67, 76; Foulkes, Docherty & Watt 2011: 12). The social conditioning of glottalisation and pre-aspiration therefore overlaps in this variety of English, and this is all we know about the social conditioning of pre-aspiration in English. Unfortunately, no studies of stylistic variation of pre-aspiration seem to have been done. Pre-aspiration, especially when considered together with glottalisation, presents a good phenomenon to learn more about the interaction of language-external and language-internal factors in language variation and change.

More specifically, the following questions emerge:

1. What level of variability is there in the relationships between pre-aspiration and glottalisation?

2. Is this variability predicted by language-internal and language-external factors?

3. Considering some varieties may be predominantly glottalising and some predominantly pre-aspirating, do accents of English form discrete geographic areas with one or the other or is there a dialectological continuum of dialects preferring abduction or adduction of the vocal folds?

A more ambitious question is whether pre-aspiration is indeed as rare as claimed cross-linguistically. To answer this question, a considerable number of languages would have to be subject to acoustic analyses.

Cross-linguistic studies are also important to systematically assess whether females are physiologically more likely to pre-aspirate at least when the phenomenon has been recently innovated. Similarly, although it has been claimed that females are breathier than males (see Chapters 1 and 7 for the references), we do not know if it is the case cross-linguistically that females/women are breathier than males/men.
Finally, it has been proposed that the existence of /h/ as a separate phoneme may be a necessary aspect for a language to acquire pre-aspiration (Stevens & Reubold 2014: 480). Whether this is indeed the case remains to be explored.

8.4.3. Interactions of laryngeal and oral phenomena

Returning to English accents, it would be interesting to see if the history of glottalisation is connected with changes leading to the lowering of front vowels in English (for connection between glottalisation and vowel lowering, see Brunner & Žygis 2011) and if pre-aspiration is connected with vowel raising in any way (for connection between breathiness and vowel raising, see Thurgood 1999: 179).

8.5. Pre-aspiration and style

The data analysed to answer the questions asked in this thesis are laboratory data in the sense that they come from lists of words occurring either in isolation (pat) or in a carrier sentence (Say pat once.), i.e. what Lisker & Abramson refer to as “spoon-fed” data (1967: 9). With only one stylistic context at our disposal, it is impossible to assess if pre-aspiration behaves in the same way in other styles.

The nature of the research questions posed here required control over a range of linguistic factors such as vowel height, vowel backness, vowel length, place of articulation of the post-tonic consonant, manner of articulation of the post-tonic consonant, laryngeal specifications of the prevocalic consonant, and fortisness/lenisness of the post-tonic plosive within stressed syllables. On top of that, place and manner of articulation of the following consonant was controlled for in unstressed syllables as well. These variables would have been very difficult, if not impossible, to control for with a different methodological set-up.

While it is true that a less formal style could be obtained by carefully designing read passages or very inventive tasks such as those used in Watson (2007), these would have taken longer than the methodology resorted to here, which required 40-60 minutes per speaker including compulsory breaks. This is a considerable amount of time for speakers who are not rewarded for their time and energy.
Leaving these practical issues aside, we could think of lab data as one of the most formal styles we could obtain, and analyses using lab data therefore present a point of comparison for future studies of pre-aspiration in other styles and other tasks, establishing what effects on pre-aspiration should be taken into consideration.

You say I am repeating
Something I have said before. I shall say it again.
Shall I say it again? In order to arrive there,
To arrive where you are, to get from where you are not [...],
You must go by a way which is the way of ignorance [...].

So here I am, in the middle way [...].

References


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Wilhelm, S. In prep. “Segmental and suprasegmental change in North West of Yorkshire – a new case of supralocalisation?”.


Appendix A

A.1. Test items for stressed condition

The items in brackets were recorded only for some speakers (ABE50, ABE52).

Plosives – sonorant-initial:

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<td><strong>sheck</strong> - sheeky</td>
<td><strong>sick</strong> - sicker</td>
<td><strong>sock</strong></td>
</tr>
</tbody>
</table>

**Longstockings**

- tap - tapper: NA
- tip - tipper: top - topper: tup - tupper
- cap - capper: NA
- kip - kipper: cop - copper: cup - capper

<table>
<thead>
<tr>
<th>/aː/</th>
</tr>
</thead>
<tbody>
<tr>
<td>tar</td>
</tr>
<tr>
<td>car</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>/ʊ/</th>
<th>/aː/</th>
</tr>
</thead>
<tbody>
<tr>
<td>put</td>
<td>part</td>
</tr>
<tr>
<td>NA</td>
<td>tart</td>
</tr>
<tr>
<td>NA</td>
<td>cart</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>/ʌ/</th>
<th>/aː/</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA</td>
<td>park</td>
</tr>
<tr>
<td>took</td>
<td>talk</td>
</tr>
<tr>
<td>cook</td>
<td>cark</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>/ɒ/</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA</td>
</tr>
<tr>
<td>NA</td>
</tr>
<tr>
<td>NA</td>
</tr>
<tr>
<td>NA</td>
</tr>
</tbody>
</table>

309
Plosives – /h/-initial:

<table>
<thead>
<tr>
<th></th>
<th>/a/</th>
<th>/e/</th>
<th>/ɪ/</th>
<th>/ɒ/</th>
<th>/ʌ/</th>
</tr>
</thead>
<tbody>
<tr>
<td>/p/</td>
<td>hap ~ happen</td>
<td>NA</td>
<td>hip ~ hipper</td>
<td>hop ~ hopper</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>/aː/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>harp</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>/a/</th>
<th>/e/</th>
<th>/ɪ/</th>
<th>/ɒ/</th>
<th>/ʌ/</th>
</tr>
</thead>
<tbody>
<tr>
<td>/t/</td>
<td>hat ~ hatter</td>
<td>NA</td>
<td>hit ~ hitter</td>
<td>hot ~ hotter</td>
<td>hut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>/aː/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>heart</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>/a/</th>
<th>/e/</th>
<th>/ɪ/</th>
<th>/ɒ/</th>
<th>/ʌ/</th>
</tr>
</thead>
<tbody>
<tr>
<td>/k/</td>
<td>hack ~ hacker</td>
<td>NA</td>
<td>hick ~ hickey</td>
<td>hock ~ hocker</td>
<td>Huck</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>/ʊ/</th>
<th>/aː/</th>
<th>/oː/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>hook</td>
<td>hark</td>
<td>hawk</td>
</tr>
</tbody>
</table>

Plosives – lenis plosives initial:

<table>
<thead>
<tr>
<th></th>
<th>/a/</th>
<th>/e/</th>
<th>/ɪ/</th>
<th>/ɒ/</th>
<th>/ʌ/</th>
</tr>
</thead>
<tbody>
<tr>
<td>/p/</td>
<td>bap</td>
<td>NA</td>
<td>dip</td>
<td>NA</td>
<td>gupt</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>/oː/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>dorpd</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>/a/</th>
<th>/e/</th>
<th>/ɪ/</th>
<th>/ɒ/</th>
<th>/ʌ/</th>
</tr>
</thead>
<tbody>
<tr>
<td>/t/</td>
<td>bat ~ batting</td>
<td>bet</td>
<td>bit</td>
<td>dot</td>
<td>gut</td>
</tr>
</tbody>
</table>
to batter
a batter

/al/ /el/ /il/ /ɑːl/ /ʌl/

/k/ back ~ baeker beck Dick bock guck
backing

/ʊl/
book (~ booker)

Plosives – other initial:

/al/ /el/ /il/ /ɑːl/ /ʌl/
/t/ at set sit otter utter
fit

/ʊl/ /ɑː:l/
foot (~ footer) art
soot (~ sooty)

/ʊl/ /oː:l/
/k/ (crook ~ crooked) fork
brook
shook

Fricatives:

/al/ /el/ /il/ /ɑːl/ /ʌl/
/f/ NA Jeff if off puff

/θ/ /l/ /θ/ /l/ /θ/ /l/
ath death myth moth NA
<table>
<thead>
<tr>
<th>/s/</th>
<th>ass</th>
<th>mess</th>
<th>miss</th>
<th>loss</th>
<th>fuss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mass</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>/ʃ/</td>
<td>mash</td>
<td>mesh</td>
<td>fish</td>
<td>bosh</td>
<td>mush</td>
</tr>
</tbody>
</table>
A.2. Test items for the unstressed condition

<table>
<thead>
<tr>
<th>Plosives:</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>/p/</td>
<td>polyp</td>
<td>Philip</td>
<td>turnip</td>
</tr>
<tr>
<td>/t/</td>
<td>gullet</td>
<td>millet</td>
<td>spirit</td>
</tr>
<tr>
<td>/k/</td>
<td>manic</td>
<td>frolic</td>
<td>relic</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fricatives:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>/ʃ/</td>
<td>Irish</td>
<td>Polish</td>
</tr>
<tr>
<td>/ʃ/</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/s/</td>
<td>bodice</td>
<td>Wallace</td>
</tr>
<tr>
<td>/ʃ/</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### A.3. Distractor items

<table>
<thead>
<tr>
<th>Item</th>
<th>Item</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>a house</td>
<td>honour</td>
<td>pact</td>
</tr>
<tr>
<td>a louse</td>
<td>Hopkins</td>
<td>parse</td>
</tr>
<tr>
<td>Abertawe</td>
<td>is</td>
<td>pectin</td>
</tr>
<tr>
<td>Aberystwyth</td>
<td>jazz</td>
<td>pipkin</td>
</tr>
<tr>
<td>abracadabra</td>
<td>ladybird</td>
<td>potato</td>
</tr>
<tr>
<td>Ann</td>
<td>lazy</td>
<td>quiz</td>
</tr>
<tr>
<td>arm</td>
<td>lice</td>
<td>raptor</td>
</tr>
<tr>
<td>as</td>
<td>lies</td>
<td>rouse</td>
</tr>
<tr>
<td>cactus</td>
<td>Lipton</td>
<td>rice</td>
</tr>
<tr>
<td>capkin</td>
<td>literature</td>
<td>Sam</td>
</tr>
<tr>
<td>captain</td>
<td>Liz</td>
<td>tactic</td>
</tr>
<tr>
<td>catkin</td>
<td>Llanbadarn Fawr</td>
<td>to house</td>
</tr>
<tr>
<td>chapter</td>
<td>loose</td>
<td>tomato</td>
</tr>
<tr>
<td>cuckoo</td>
<td>lose</td>
<td>tree</td>
</tr>
<tr>
<td>daisy</td>
<td>Macy</td>
<td>vase</td>
</tr>
<tr>
<td>Eisteddfod</td>
<td>Mars</td>
<td>victor</td>
</tr>
<tr>
<td>eyes</td>
<td>might rain</td>
<td>Wales</td>
</tr>
<tr>
<td>fact</td>
<td>Milky Way</td>
<td>wall</td>
</tr>
<tr>
<td>factor</td>
<td>my train</td>
<td>Watkins</td>
</tr>
<tr>
<td>farse</td>
<td>napkin</td>
<td>well</td>
</tr>
<tr>
<td>hapten</td>
<td>night rate</td>
<td>whales</td>
</tr>
<tr>
<td>hedgehog</td>
<td>nitrate</td>
<td>wheel</td>
</tr>
<tr>
<td>his</td>
<td>octopus</td>
<td>will</td>
</tr>
<tr>
<td>honey</td>
<td>Oz</td>
<td>wool</td>
</tr>
</tbody>
</table>
### Appendix B

#### Table B.1. Statistical results for the manner of articulation and stress and pre-aspiration or breathiness occurrence

| VARIABLES                          | ESTIMATE | STD. ERROR | Z VALUE | PR(>|Z|)  |
|-----------------------------------|----------|------------|---------|-----------|
| **Pre-aspiration occurrence**     |          |            |         |           |
| stressed vs unstressed            | 4.9009   | 0.7508     | 6.527   | < 0.0001 *** |
| unstressed: fricatives vs plosives| -3.5034  | 0.9495     | -3.690  | < 0.001 *** |
| **Breathiness occurrence**        |          |            |         |           |
| fricative vs plosive              | 4.3699   | 0.6557     | 6.664   | < 0.0001 *** |

#### Table B.2. Statistical results for the manner of articulation and pre-aspiration or breathiness duration

| VARIABLES                          | ESTIMATE | STD. ERROR | DF       | T VALUE | PR(>|T|)  |
|-----------------------------------|----------|------------|----------|---------|-----------|
| **Pre-aspiration duration**        |          |            |          |         |           |
| stressed vs unstressed            | -6.1100  | 1.0219     | 268.1300 | -5.979  | < 0.0001 *** |
| **Breathiness duration**           |          |            |          |         |           |
| fricative vs plosive              | -2.1157  | 0.2746     | 238.7500 | -7.704  | < 0.0001 *** |
| stressed vs unstressed            | -1.2644  | 0.5071     | 260.2100 | -2.493  | < 0.05 *  |
| VARIABLES | ESTIMATE | STD. ERROR | Z VALUE | PR(>|Z|) |
|-----------|----------|------------|---------|---------|
| Pre-aspiration occurrence | | | | |
| fricative vs plosive | -3.3008 | 0.6739 | -4.898 | < 0.0001 *** |
| Breathiness occurrence | | | | |
| fricative vs plosive | 3.152 | 1.202 | 2.622 | < 0.01 ** |

*Table B.3. Statistical results for the manner of articulation and pre-aspiration or breathiness occurrence (CVCVC)*

| VARIABLES | ESTIMATE | STD. ERROR | DF | T VALUE | PR(>|T|) |
|-----------|----------|------------|----|---------|---------|
| Pre-aspiration duration | | | | | |
| fricative vs plosive | 1.5762 | 0.3840 | 15.1950 | 4.105 | < 0.001 *** |
| Breathiness duration | | | | | |
| fricative vs plosive | -1.7680 | 0.4717 | 17.4810 | -3.748 | < 0.01 ** |

*Table B.4. Statistical results for the manner of articulation and pre-aspiration or breathiness duration (CVCVC)*

| VARIABLES | ESTIMATE | STD. ERROR | Z VALUE | PR(>|Z|) |
|-----------|----------|------------|---------|---------|
| Pre-aspiration occurrence | | | | |
| /p/ vs /t/ | 2.4526 | 0.3113 | 7.877 | < 0.0001 *** |
| Breathiness occurrence | | | | |
| /p/ vs /t/ | 1.1751 | 0.2832 | 4.149 | < 0.0001 *** |

*Table B.5. Statistical results for the plosive and pre-aspiration or breathiness occurrence and /a/ and /a:/*
| VARIABLES                  | ESTIMATE | STD. ERROR | Z VALUE | PR(>|Z|)     |
|---------------------------|----------|------------|---------|--------------|
| Pre-aspiration occurrence |          |            |         |              |
| /o:/ vs /ɔ/               | -0.9465  | 0.2827     | -3.349  | < 0.001 ***  |
| /p/ vs /t/                | 2.6728   | 0.3318     | 8.055   | < 0.0001 *** |
| [+SG] vs sonorant         | 0.8056   | 0.3025     | 2.663   | < 0.01 **    |
| Breathiness occurrence    |          |            |         |              |
| /o:/ vs /ɔ/               | -1.07950 | 0.24251    | -4.451  | < 0.0001 *** |
| /p/ vs /t/                | 1.56808  | 0.27578    | 5.686   | < 0.0001 *** |

Table B.6. Statistical results for the plosive and pre-aspiration or breathiness occurrence and /ɔ/ and /o:/

| VARIABLES                  | ESTIMATE | STD. ERROR | DF     | T VALUE  | PR(>|T|) |
|---------------------------|----------|------------|--------|----------|---------|
| Pre-aspiration duration   |          |            |        |          |         |
| /a:/ vs /a/               | 3.2124   | 0.2204     | 1123.3 | 14.577   | < 0.0001 *** |
| /p/ vs /t/                | -2.5856  | 0.2474     | 1123.0 | -10.452  | < 0.0001 *** |
| /t/ vs /k/                | -1.3406  | 0.2407     | 1123.0 | -5.570   | < 0.0001 *** |
| [-SG] vs [+SG]            | 1.8718   | 0.3753     | 1123.0 | 4.987    | < 0.0001 *** |
| [+SG] vs sonorant         | -1.2523  | 0.2276     | 1123.0 | -5.503   | < 0.0001 *** |
| isolation vs carrier      | -0.9113  | 0.2114     | 1124.1 | -4.311   | < 0.0001 *** |

Breathiness duration

| VARIABLES                  | ESTIMATE | STD. ERROR | DF     | T VALUE  | PR(>|T|) |
|---------------------------|----------|------------|--------|----------|---------|
| /p/ vs /t/                | -0.8588  | 0.2654     | 26.700 | -3.236   | < 0.01 ** |
| VARIABLES                        | ESTIMATE | STD. ERROR | DF  | T VALUE  | PR(>|T|) |
|---------------------------------|----------|------------|-----|----------|---------|
| **Pre-aspiration duration**     |          |            |     |          |         |
| /oː/ vs /p/                     | 3.6133   | 0.3753     | 27.2000 | 9.627    | < 0.0001 *** |
| /p/ vs /t/                      | -3.4188  | 0.4248     | 26.2000 | -8.047   | < 0.0001 *** |
| /t/ vs /k/                      | -1.1019  | 0.3631     | 27.5000 | -3.034   | < 0.01 **  |
| [-SG] vs [+SG]                  | 2.0880   | 0.5076     | 26.6000 | 4.113    | < 0.001 *** |
| [+SG] vs sonorant               | -1.3173  | 0.3762     | 26.3000 | -3.501   | < 0.01 **  |
| isolation vs carrier sentence   | -0.9155  | 0.2282     | 1003.3000 | -4.012   | < 0.0001 *** |
| **Breathiness duration**        |          |            |     |          |         |
| /p/ vs /t/                      | -1.3510  | 0.3262     | 25.4000 | -4.142   | < 0.001 *** |
| /t/ vs /k/                      | 1.0348   | 0.2795     | 26.4000 | 3.703    | < 0.001 *** |
| [+SG] vs sonorant               | -0.9876  | 0.2890     | 25.5000 | -3.417   | < 0.01 **  |
| isolation vs carrier sentence   | -0.8603  | 0.1900     | 1005.2000 | -4.528   | < 0.0001 *** |

Table B.7. Statistical results for the plosive and pre-aspiration or breathiness duration and /a/ and /aː/

Table B.8. Statistical results for the plosive and pre-aspiration or breathiness duration and /ɒ/ and /oː/
### Table B.9. Statistical results for ‘CVC words with fricatives – pre-aspiration occurrence

| VARIABLES | ESTIMATE | STD. ERROR | Z VALUE | PR(>|Z|) |
|-----------|----------|------------|---------|---------|
| Females   |          |            |         |         |
| /e/ vs /i/ | 2.6771   | 0.5696     | 4.700   | < 0.0001 *** |
| /ɪ/ vs /θ/ | 2.4121   | 0.6225     | 3.875   | 0.001 *** |
| Males     |          |            |         |         |
| /a/ vs /i/ | 2.0661   | 0.5974     | 3.458   | < 0.001 *** |

### Table B.10. Statistical results for ‘CVC words with fricatives – pre-aspiration duration

| VARIABLES | ESTIMATE | STD. ERROR | DF     | T VALUE | PR(>|T|) |
|-----------|----------|------------|--------|---------|---------|
| Females   |          |            |        |         |         |
| /e/ vs /i/ | -4.4545  | 0.5669     | 13.6000| -7.858  | < 0.0001 *** |
| /ɒ/ vs /ʌ/ | -3.0434  | 0.6968     | 14.1000| -4.368  | < 0.001 *** |
| /ɪ/ vs /θ/ | -1.7526  | 0.6436     | 14.3000| -2.723  | < 0.05 * |
| /θ/ vs /s/  | 1.1847   | 0.5441     | 14.0000| 2.178   | < 0.05 * |
| isolation vs carrier sentence | -1.8516  | 0.2649     | 759.1000| -6.990  | < 0.0001 *** |
| Males     |          |            |        |         |         |
| /a/ vs /i/ | -3.09533 | 0.52023    | 6.40000| -5.950  | < 0.001 *** |
| isolation vs carrier sentence | -1.15175 | 0.50755    | 184.05000| -2.269  | < 0.05 * |
| VARIABLES | ESTIMATE | STD. ERROR | DF | T VALUE | PR(>|T|) |
|-----------|----------|------------|----|---------|---------|
| Females   |          |            |    |         |         |
| /æ/ vs /ʊ/ | -1.57220 | 0.46333    | 12.60000 | -3.393 | < 0.01 ** |
| /ʊ/ vs /ɑ/ | -1.60880 | 0.51714    | 13.00000 | -3.111 | < 0.01 ** |
| /ɑ/ vs /ʌ/ | -1.94268 | 0.57040    | 13.20000 | -3.406 | < 0.01 ** |

Table B.11. Statistical results for ‘CVC words with fricatives – breathiness duration’

| VARIABLES | ESTIMATE | STD. ERROR | Z VALUE | PR(>|Z|) |
|-----------|----------|------------|---------|---------|
| Pre-aspiration occurrence | | |
| /p/ vs /t/ | -3.0680 | 0.5824 | -4.671 | < 0.0001 *** |
| /t/ vs /k/ | -3.5969 | 0.6975 | -5.157 | < 0.0001 *** |
| Breathiness occurrence | | |
| /p/ vs /t/ | -4.1232 | 1.1173 | -3.691 | < 0.001 *** |
| /t/ vs /k/ | -2.0623 | 0.5346 | -3.857 | < 0.001 *** |

Table B.12. Statistical results for the place of articulation of the plosive and pre-aspiration or breathiness occurrence (‘CVCVC’)

| VARIABLES | ESTIMATE | STD. ERROR | DF | T VALUE | PR(>|T|) |
|-----------|----------|------------|----|---------|---------|
| Pre-aspiration duration | | |
| /p/ vs /t/ | 1.3889 | 0.5047 | 7.3300 | 2.752 | < 0.05 * |
| /t/ vs /k/ | 2.1338 | 0.5208 | 6.5780 | 4.098 | < 0.01 ** |
| Breathiness duration | | |
| /p/ vs /t/ | 1.9443 | 0.5507 | 7.3650 | 3.530 | < 0.01 ** |

Table B.13. Statistical results for the place of articulation of the plosive and pre-aspiration or breathiness duration (‘CVCVC’)
| VARIABLES               | ESTIMATE | STD. ERROR | DF  | T VALUE | PR(>|T|) |
|-------------------------|----------|------------|-----|---------|---------|
| Breathiness duration    |          |            |     |         |         |
| /f/ vs /s/              | 1.5970   | 0.5047     | 5.0570 | 3.164   | < 0.05 * |
| /s/ vs /ʃ/              | 1.8439   | 0.5793     | 4.8110 | 3.183   | < 0.05 * |

Table B.14. Statistical results for the place of articulation of the fricative and pre-aspiration or breathiness duration ('CVCVC')

| VARIABLES               | ESTIMATE | STD. ERROR | Z VALUE | PR(>|Z|) |
|-------------------------|----------|------------|---------|---------|
| Pre-aspiration occurrence|          |            |         |         |
| /e/ vs /ɪ/              | 1.60684  | 0.17663    | 9.097   | < 0.0001 *** |
| /p/ vs /t/              | 2.61947  | 0.17877    | 14.653  | < 0.0001 *** |
| [-SG] vs [+SG]          | -0.78423 | 0.31072    | -2.524  | < 0.05 * |
| [+SG] vs sonorant       | 0.91381  | 0.17205    | 5.311   | < 0.0001 *** |

| Breathiness occurrence  |          |            |         |         |
| /e/ vs /ɪ/              | 1.4898   | 0.1772     | 8.407   | < 0.0001 *** |
| /p/ vs /t/              | 1.6532   | 0.1809     | 9.140   | < 0.0001 *** |
| [+SG] vs sonorant       | 0.7030   | 0.1700     | 4.134   | < 0.0001 *** |
| word-final vs word-medial | 0.3071  | 0.1461     | 2.102   | < 0.05 * |

Table B.15. Statistical results for the plosive and pre-aspiration or breathiness occurrence and /e/ and /ɪ/
| VARIABLES | ESTIMATE | STD. ERROR | Z VALUE | PR(>|Z|) |
|-----------|----------|------------|---------|----------|
| Pre-aspiration occurrence |
| /b/ vs /o/ | 1.4087 | 0.3386 | 4.160 | < 0.0001 *** |
| /p/ vs /t/ | 2.8761 | 0.3166 | 9.084 | < 0.0001 *** |
| [-SG] vs [+SG] | -1.0391 | 0.4078 | -2.548 | < 0.05 * |
| [+SG] vs sonorant | 1.0381 | 0.2735 | 3.795 | < 0.001 *** |
| word-final vs word-medial | -0.7017 | 0.3004 | -2.336 | < 0.05 * |
| Breathiness occurrence |
| /b/ vs /o/ | 1.3466 | 0.2405 | 5.599 | < 0.0001 *** |
| /p/ vs /t/ | 1.5036 | 0.2325 | 6.467 | < 0.0001 *** |
| [-SG] vs [+SG] | -0.6243 | 0.3077 | -2.029 | < 0.05 * |
| word-final vs word-medial | -0.6020 | 0.2041 | -2.950 | < 0.01 ** |

Table B.16. Statistical results for the plosive and pre-aspiration or breathiness occurrence and /b/ and /o/
| VARIABLES | ESTIMATE | STD. ERROR | DF | T VALUE | PR(|T|) |
|-----------|----------|------------|----|---------|--------|
| Pre-aspiration duration | | | | | |
| /ɒ/ vs /ɑ/ | -3.7456 | 0.3680 | 43.9000 | -10.179 | < 0.0001 *** |
| /p/ vs /t/ | -3.2820 | 0.3284 | 38.2000 | -9.993 | < 0.0001 *** |
| /t/ vs /k/ | -0.8286 | 0.3052 | 39.4000 | -2.715 | < 0.01 ** |
| [-SG] vs [+SG] | 2.3004 | 0.4379 | 43.9000 | 5.253 | < 0.0001 *** |
| [+SG] vs sonorant | -1.7837 | 0.2708 | 39.0000 | -6.587 | < 0.0001 *** |
| word-final vs word-medial | -1.7202 | 0.2718 | 41.6000 | -6.330 | < 0.0001 |

Table B.17. Statistical results for the plosive and pre-aspiration or breathiness duration and /e/ and /ɪ/
<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>isol. vs carrier</td>
<td>-0.6827</td>
<td>0.1754</td>
<td>1491.1000</td>
<td>-3.892 &lt; 0.001 ***</td>
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<tr>
<td>sentence</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breathiness duration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>/ɒ/ vs /ʊ/</td>
<td>-0.8673</td>
<td>0.2749</td>
<td>40.7000</td>
<td>-3.155 &lt; 0.01 **</td>
</tr>
<tr>
<td>/p/ vs /t/</td>
<td>-0.9258</td>
<td>0.2438</td>
<td>36.4000</td>
<td>-3.798 &lt; 0.001 ***</td>
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<tr>
<td>/t/ vs /k/</td>
<td>0.6487</td>
<td>0.2269</td>
<td>37.1000</td>
<td>2.859 &lt; 0.01 **</td>
</tr>
<tr>
<td>[-SG] vs [+SG]</td>
<td>0.8598</td>
<td>0.3274</td>
<td>41.4000</td>
<td>2.626 &lt; 0.05 *</td>
</tr>
<tr>
<td>[+SG] vs sonorant</td>
<td>-0.6411</td>
<td>0.2012</td>
<td>37.2000</td>
<td>-3.186 &lt; 0.01 **</td>
</tr>
<tr>
<td>word-final vs word-</td>
<td>-0.5517</td>
<td>0.2026</td>
<td>39.5000</td>
<td>-2.723 &lt; 0.01 **</td>
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<tr>
<td>medial</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>isolation vs carrier</td>
<td>-0.7802</td>
<td>0.1451</td>
<td>1493.9000</td>
<td>-5.379 &lt; 0.0001 ***</td>
</tr>
</tbody>
</table>

*Table B.18. Statistical results for the plosive and pre-aspiration or breathiness duration and /ɒ/ and /ʊ/
| VARIABLES                      | ESTIMATE | STD. ERROR | Z VALUE | PR(>|Z|)   |
|-------------------------------|----------|------------|---------|-----------|
|                               |          |            |         |           |
| **Pre-aspiration occurrence** |          |            |         |           |
| /p/ vs /t/                    | 2.72717  | 0.22774    | 11.975  | < 0.0001 *** |
| /t/ vs /k/                    | 0.51394  | 0.22108    | 2.325   | < 0.05 *   |
| [-SG] vs [+SG]                | -1.12966 | 0.32797    | -3.444  | < 0.001 *** |
| [+SG] vs sonorant             | 1.07917  | 0.21497    | 5.020   | < 0.0001 *** |
| **Breathiness occurrence**    |          |            |         |           |
| /p/ vs /t/                    | 1.65501  | 0.19380    | 8.540   | < 0.0001 *** |
| [-SG] vs [+SG]                | -0.90154 | 0.26745    | -3.371  | < 0.001 *** |
| [+SG] vs sonorant             | 0.84691  | 0.26745    | -3.371  | < 0.0001 *** |

*Table B.19. Statistical results for backness in 'CVC words with plosives – pre-aspiration and breathiness occurrence*
| VARIABLES                        | ESTIMATE | STD. ERROR | DF      | T VALUE | PR(>|T|) |
|----------------------------------|----------|------------|---------|---------|---------|
|                                  |          |            |         |         |         |
| **Pre-aspiration duration**      |          |            |         |         |         |
| /p/ vs /t/                       | -2.6727  | 0.3660     | 39.6000 | -7.302  | < 0.0001 *** |
| [-SG] vs [+SG]                   | 1.9943   | 0.4495     | 48.8000 | 4.437   | < 0.0001 *** |
| [+SG] vs sonorant                | -1.6334  | 0.3155     | 40.9000 | -5.177  | < 0.0001 *** |
| **Breathiness duration**         |          |            |         |         |         |
| /p/ vs /t/                       | -1.3966  | 0.2790     | 37.9000 | -5.007  | < 0.0001 *** |
| /t/ vs /k/                       | 0.6061   | 0.2617     | 38.1000 | 2.316   | < 0.05 * |
| [-SG] vs [+SG]                   | 1.5387   | 0.3548     | 46.8000 | 4.337   | < 0.0001 *** |
| [+SG] vs sonorant                | -1.2941  | 0.2415     | 38.8000 | -5.358  | < 0.0001 *** |
| isolation vs carrier sentence    | -0.6428  | 0.1622     | 1391.1000 | -3.962  | < 0.0001 *** |

*Table B.20. Statistical results for backness in 'CVC words with plosives – pre-aspiration and breathiness duration*
## Appendix C

<table>
<thead>
<tr>
<th></th>
<th>ESTIMATE</th>
<th>STD. ERROR</th>
<th>Z VALUE</th>
<th>PR &gt;</th>
<th>Z</th>
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<td></td>
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<td></td>
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<tr>
<td>/e/ vs /ɪ/</td>
<td>2.2331</td>
<td>0.9404</td>
<td>2.374</td>
<td>&lt; 0.05 *</td>
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<td></td>
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<td>word-final vs word-medial</td>
<td>-8.0416</td>
<td>0.8712</td>
<td>-9.231</td>
<td>&lt; 0.0001 ***</td>
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<td></td>
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<tr>
<td><strong>Glottalisation</strong></td>
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<td></td>
</tr>
<tr>
<td>word-final vs word-medial</td>
<td>8.2971</td>
<td>1.0027</td>
<td>8.275</td>
<td>&lt; 0.0001 ***</td>
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</tr>
</tbody>
</table>

*Table C.1. Statistical results for the conditioning of pre-aspiration and glottalisation with plosives*

*ABE37: obligatory exclusivity.*
|                        | ESTIMATE | STD. ERROR | Z VALUE | PR(>|Z|) |
|------------------------|----------|------------|---------|---------|
| **Pre-aspiration**     |          |            |         |         |
| /a:/ vs /e/            | 1.0929   | 0.4610     | 2.371   | < 0.05  * |
| /e/ vs /i/             | 2.3952   | 0.3999     | 5.989   | < 0.0001 *** |
| /o:/ vs /ɔ/            | 2.5437   | 0.6112     | 4.162   | < 0.0001 *** |
| /ɔ/ vs /ʌ/             | 1.8989   | 0.4300     | 4.416   | < 0.0001 *** |
| /p/ vs /t/             | 3.8191   | 0.3717     | 10.273  | < 0.0001 *** |
| /p/ vs /k/             | 1.5535   | 0.3256     | 4.771   | < 0.0001 *** |
| “isolation” vs “carrier” | -0.5714 | 0.2251     | -2.539  | < 0.05 * |
| **Glottalisation**     |          |            |         |         |
| /e/ vs /i/             | 1.94812  | 0.52903    | 3.682   | < 0.001 *** |
| /ɔ/ vs /ʌ/             | 1.82043  | 0.37717    | 2.175   | < 0.05 * |
| /p/ vs /t/             | 0.82043  | 0.37717    | 2.175   | < 0.05 * |
| “isolation” vs “carrier” | 1.09920 | 0.31091    | 3.535   | < 0.001 *** |
| Word-final vs word-medial | 1.80963 | 0.49702    | 3.641   | < 0.001 *** |
| Pre-aspiration: “yes” vs “no” | -4.43302 | 0.49881 | -8.887 | < 0.0001 *** |

**Table C.2.** Statistical results for the conditioning of glottalisation with plosives

*ABE14 and ABE46: optional exclusivity*

|                        | ESTIMATE | STD. ERROR | Z VALUE | PR(>|Z|) |
|------------------------|----------|------------|---------|---------|
| **Pre-aspiration**     |          |            |         |         |
| /a/ vs /i/             | 2.1584   | 0.3416     | 6.319   | < 0.0001 *** |
| /p/ vs /t/             | -2.1409  | 0.3641     | -5.880  | < 0.0001 *** |
| /t/ vs /k/             | -2.7653  | 0.4222     | -6.550  | < 0.0001 *** |
| Word-final vs           | 1.8289   | 0.3214     | 5.690   | < 0.0001 *** |
|                      | ESTIMATE | STD. ERROR | Z VALUE | PR > |Z| |
|----------------------|----------|------------|---------|-------|---|
| Glottalisation       |          |            |         |       |   |
| /a/ vs /u/           | 2.19908  | 0.49767    | 4.419   | < 0.0001 *** |
| Word-final vs word-medial | 0.82425  | 0.39606    | 2.081   | < 0.05 * |

Table C.3. Statistical results for the conditioning of glottalisation with plosives

ABE25 and ABE28: gradient co-occurrence.

|                      | ESTIMATE | STD. ERROR | Z VALUE | PR > |Z| |
|----------------------|----------|------------|---------|-------|---|
| Pre-aspiration       |          |            |         |       |   |
| /u/ vs /o/           | 2.6655   | 1.2151     | 2.194   | < 0.05 * |
| Glottalisation: ‘1yes’ vs ‘2no’ | -3.1767   | 1.2123     | -2.620  | < 0.01 ** |

Table C.4. Statistical results for the conditioning of glottalisation with fricatives

ABE14: optional exclusivity.

|                      | ESTIMATE | STD. ERROR | Z VALUE | PR > |Z| |
|----------------------|----------|------------|---------|-------|---|
| GLOTTALISATION       |          |            |         |       |   |
| /a/ vs /o/ (ABE28)   | 3.0517   | 1.4191     | 2.151   | < 0.05 * |
| /o/ vs /a/ (ABE37)   | 3.6385   | 1.3549     | 2.685   | < 0.01 ** |
| /f/ vs /θ/ (ABE37)   | 2.4662   | 1.2213     | 2.019   | < 0.01 ** |

Table C.5. Statistical results for the conditioning of glottalisation with fricatives

ABE28 and ABE37: optional co-occurrence.
Appendix D

D.1. Types of glottal gestures and position within the vowel

Chapter 5 reports that pre-aspiration and glottalisation co-occur. However, we do not know if this is applicable to all types of glottalisation and whether this is limited to glottalisation found only in some positions with respect to the vowel. Various types of glottalisation may have different functions and glottalisations occurring at various positions with respect to the vowel may similarly have different functions. For example, vowel-initial glottalisation or periodic creaks occurring throughout the vowel may not be associated with the post-tonic obstruent at all.

This section looks into whether only some types of glottalisation co-occur with pre-aspiration and whether glottalisations found only in certain positions with respect to the vowel co-occur with pre-aspiration. Although correlations between the types of glottalisation, vowel position, and frequency of occurrence of pre-aspiration are found, it is not the case that these correlations result in obligatory patterns, e.g. in pre-aspiration only ever co-occurring with glottalisation when the latter is vowel-initial. Hejná & Scanlon (2015) see this as crucial in determining the laryngeal allophony in Manchester English, where glottalisation is obligatory word-finally (pat) and pre-aspiration word-medially (patter). Although glottalisation is found word-medially in their analyses, crucially the glottalisation found word-finally is also vowel-final, whereas the glottalisation found word-medially is vowel-initial. The main claim of Chapter 5, that pre-aspiration and glottalisation could co-occur with the same segment, is therefore not undermined, although this remains subject to further analyses contrasting obstruents with consonantal sonorants, and multiple prosodic conditions related to position and to intonational correlations with glottalisation.

Four types of glottalisation are distinguished: periodic glottalisation (“periodic creak”), aperiodic glottalisation (“aperiodic creak” and “glottal stop”), and glottal squeaks. As discussed in Chapter 5, however, periodic and aperiodic glottalisation can be treated as various states of a single continuum as can be what is labelled here “aperiodic creak” and “glottal stop”. Hence, at times it is extremely challenging to
distinguish these types. The same data as that used for Chapter 5 is subject to analyses here (i.e. tokens produced by 10 females and 6 males for the plosive context, and 12 females and 6 males for the fricative context).

Glottalisation is discussed in the plosive context first (e.g. *pat, patter*) and then in the fricative context (e.g. *mass*).

### D.1.1. Plosives

Within the female plosive data, aperiodic creaks are most prevalent, followed by periodic creaks, glottal stops, and glottal squeaks. Table D.1.1. shows that the vast majority of glottalisations, irrespective of the type, are vowel-final or occurring throughout the vowel:

<table>
<thead>
<tr>
<th>GLOTTAL GESTURE</th>
<th>V INITIAL</th>
<th>V MEDIAL</th>
<th>V FINAL</th>
<th>EDGES</th>
<th>WHOLE V</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Periodic creak</td>
<td>10 (5%)</td>
<td>8 (4%)</td>
<td>82 (41%)</td>
<td>0</td>
<td>98 (50%)</td>
<td>198</td>
</tr>
<tr>
<td>Aperiodic creak</td>
<td>23 (5%)</td>
<td>14 (3%)</td>
<td>332 (75%)</td>
<td>2 (&lt; 1%)</td>
<td>74 (17%)</td>
<td>445</td>
</tr>
<tr>
<td>Glottal stop</td>
<td>5 (7%)</td>
<td>0</td>
<td>62 (93%)</td>
<td>0</td>
<td>0</td>
<td>67</td>
</tr>
<tr>
<td>Glottal squeaks</td>
<td>0</td>
<td>0</td>
<td>34 (100%)</td>
<td>0</td>
<td>0</td>
<td>34</td>
</tr>
</tbody>
</table>

*Table D1.1. Types of glottalisation in the female plosive tokens and their occurrence with respect to the vowel*

V = vowel; vowel-initial, vowel-medial, vowel-final, edges = at the beginning and at the end of the vowel, whole = throughout the vowel.

Glottal squeaks are the only type limited to the vowel-final position and they are the only glottalisation never co-occurring with pre-aspiration. “Glottal stop”, or minimal aperiodic creak, only occurs vowel-initially or vowel-finally.

Irrespective of the type of glottalisation, vowel-final glottalisation co-occurs with pre-aspiration less frequently than glottalisation found in the other positions within the vowel (p < 0.0001 for all level comparisons in each model). Nevertheless, in every glottalisation type it co-occurs with pre-aspiration in approximately 20% of all
the tokens with vowel-final glottalisation. Thus, although vowel-final position is the least favourable for co-occurrence with pre-aspiration, it is not the case that vowel-final glottalisation necessarily blocks pre-aspiration.\textsuperscript{136}

As Table D1.2. demonstrates, within the male plosive data, aperiodic and periodic creaks are the most frequent types, followed by glottal stops/minimal aperiodic creaks. No glottal squeaks are found in the male data. The majority of the attested glottalisations occur throughout the vowel.

<table>
<thead>
<tr>
<th>GLOTTAL GESTURE</th>
<th>V INITIAL</th>
<th>V MEDIAL</th>
<th>V FINAL</th>
<th>EDGES</th>
<th>WHOLE V</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Periodic creak</td>
<td>6</td>
<td>4</td>
<td>5</td>
<td>0</td>
<td>14</td>
<td>30</td>
</tr>
<tr>
<td>Aperiodic creak</td>
<td>3</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td>20</td>
<td>31</td>
</tr>
<tr>
<td>Glottal stop</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>9</td>
</tr>
</tbody>
</table>

\textit{Table D1.2. Types of glottalisation in the male plosive tokens and their occurrence with respect to the vowel.}

Glottalisation co-occurs with pre-aspiration in each position, although in different ways. Since there are few instances of glottalisation per type and vowel position, statistical analyses are not done.

\textbf{D.1.2. Fricatives}

Within the fricative data, periodic creaks are most prevalent, followed by aperiodic creaks, and glottal stops/minimal aperiodic creaks. Table D1.3. provides information on the position of the glottal types with respect to the vowel:

\textsuperscript{136} Three logistic Mixed Effects Models were used to answer this question. In each model, presence of pre-aspiration (with two levels: “present” and “absent”) was entered as the dependent variable. The independent variable was “position of the periodic creak”, “position of the aperiodic creak”, and “position of glottal stop”, respectively, with “subject” and “word” as the random effects in all three.
Periodic creaks co-occur with pre-aspiration most frequently when vowel-final or when occurring throughout the vowel. This does not agree with the findings from the plosive context. Vowel-medial and vowel-initial glottalisations co-occur with pre-aspiration in at least 50% of these glottalisations. Aperiodic creaks always co-occur with pre-aspiration when vowel-final, vowel-initial, or at the edges of the vowel. Vowel-medial aperiodic creaks and those occurring throughout the vowel co-occur with pre-aspiration in at least 50% of these glottalisations. Glottal stops/minimal aperiodic creaks only occur four times: three times vowel-finally and once at the edges of the vowel. They always co-occur with pre-aspiration. These are only found in ABE37 and ABE45. As noted above, glottal squeaks do not occur in the fricative context.

---

Table D1.3. Types of glottalisation in the fricative tokens and their occurrence with respect to the vowel

Vowel-initial, vowel-medial, vowel-final, throughout the vowel; no glottal squeaks occur in the fricative data.

<table>
<thead>
<tr>
<th>GLOTTAL GESTURE</th>
<th>V INITIAL</th>
<th>V MEDIAL</th>
<th>V FINAL</th>
<th>EDGES</th>
<th>WHOLE V</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Periodic creak</td>
<td>13</td>
<td>12</td>
<td>22</td>
<td>0</td>
<td>24</td>
<td>71</td>
</tr>
<tr>
<td>Aperiodic creak</td>
<td>3</td>
<td>4</td>
<td>10</td>
<td>1</td>
<td>6</td>
<td>24</td>
</tr>
<tr>
<td>Glottal stop</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

models. Treatment coding was employed, which means that every position was compared to the vowel-final position.
D.2. Whispey creaks

Whispey creaks can be identified with the same criteria as glottalisation, but a significant degree of friction has to be visible in the spectrogram. The degree of friction opens itself to subjective judgements. In this thesis, the degree of friction was determined by comparing the amount of friction in the glottalised interval to the friction generally found in the global phonation of the speaker in question and to that of pre-aspiration preceded by a breathy transition.

Apart from one respondent (ABE37), whispey creaks were very rare in the data analysed in this thesis, as summarised in Table D2.1.

<table>
<thead>
<tr>
<th>SPEAKER</th>
<th>NUMBER OF TOKENS WITH GF</th>
<th>OF WHICH GLOTTALISED</th>
<th>OF WHICH PRE-ASPIRATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABE14</td>
<td>7</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>ABE37</td>
<td>135</td>
<td>135</td>
<td>0</td>
</tr>
<tr>
<td>ABE45</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>ABE28</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

*Table D2.1. Glottal friction and glottalisation*

*The third column indicates how many of these tokens are also glottalised, and the fourth column shows how many of the tokens with ‘glottal friction’ are also pre-aspirated.*

Further examples of whispey creaks are shown in Figures D2.1.-D2.3. In D2.1., we can see that glottal friction is present not only where indicated as ‘GF’ but also during the interval marked ‘CRaper’.
Figure D2.1. Glottal friction between and following glottal pulses (‘GF’)

Illustrated on the word fit, produced by a female speaker of 28 years (ABE37). Another instance of glottal friction is visible within ‘CRaper’ (‘aperiodic creak’); ‘CRper’ stands for periodic creak and ‘clo’ for voiceless closure.

Figure D2.2. Glottal friction (‘GF’) and flatulence (highlighted)

Illustrated on the word tech, produced by a female speaker of 28 years (ABE37). The term flatulence is adopted from Skarnitzl (2004: 60). ‘CRaperFIN’ (‘aperiodic creak’) stands for vowel-final glottalisation and ‘clo’ for voiceless closure.
The glottal friction could reach considerable durations even in between glottal pulses, as illustrated in Figure D2.3.

Figure D2.3. Glottal friction (‘GF’) between two glottal pulses

Illustrated on the word keck, produced by a female speaker of 28 years (ABE37).

The spectrogram shows glottal friction between two irregular glottal pulses (‘GS’), which corresponds to a barbell glottal stop in Skarnitzl (2004)’s classification. ‘Post’ stands for post-aspiration and ‘clo’ for voiceless closure.
Appendix E

E.1. Test items for the fortis/lenis contrast

The following list shows the fortis-lenis pairs used in Chapter 6. These are grouped according to the position within word (word-initial, word-medial, word-final) and further according to the place of articulation of the plosive in question (bilabial, alveolar, velar).

Word-initial:

/pl vs /b/ /t/ vs /d/ /k/ vs /g/  
pap ~ bap  
tip ~ dip  
pat ~ bat  
tick ~ Dick  
pack ~ back  
tot ~ dot  
packer ~ backer

tet ~ bet

pit ~ bit

peck ~ beck

pock ~ bock

pop ~ bop

Word-medial:

/pl vs /b/ /t/ vs /d/ /k/ vs /g/  
capper ~ cabbie  
kitty ~ kidder  
cock ~ cogger  
copper ~ cobber  
ottar ~ oadder  
pecker ~ Peggy
<table>
<thead>
<tr>
<th>cotter ~ codder</th>
<th>tacker ~ tagger</th>
</tr>
</thead>
<tbody>
<tr>
<td>catty ~ caddie</td>
<td></td>
</tr>
</tbody>
</table>

**Word-final:**

<table>
<thead>
<tr>
<th>/p/ vs /b/</th>
<th>/t/ vs /d/</th>
<th>/k/ vs /g/</th>
</tr>
</thead>
<tbody>
<tr>
<td>cap ~ cab</td>
<td>cot ~ cod</td>
<td>cock ~ cog</td>
</tr>
<tr>
<td>cat ~ cad</td>
<td>peck ~ peg</td>
<td>tech ~ teg</td>
</tr>
<tr>
<td>at ~ add</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cart ~ card</td>
<td></td>
<td>tack ~ tag</td>
</tr>
</tbody>
</table>
E.2. Lewis Gaelic pre-aspiration and breathiness

The Lewis Gaelic data provided by Claire Nance consisted of 26 disyllabic tokens with a post-tonic word-medial plosive. The words presented minimal and near-minimal pairs contrasting in the aspirated and unaspirated series (for the specific words, see the appendix in Nance & Stuart-Smith 2013). Each word was repeated 3 times, giving 74-78 tokens by speaker. With 6 speakers, this resulted in 453 tokens. Of those, 157 represented the aspirated series and 296 the unaspirated series.

Zero durations of pre-aspiration and breathiness were labelled with “no” (absence of pre-aspiration/breathiness) and any other values were labelled with “yes” (presence of pre-aspiration/breathiness), which is in line with what has been done throughout this thesis to analyse the frequency of occurrence of pre-aspiration and breathiness categorically. Pre-aspiration and breathiness could thus be analysed as categorical dependent variables with two levels (“present” and “absent”). Using Mixed Effects Models (Bates, Maechler, Bolker & Walker 2014), each was entered in the appropriate model as the dependent variable respectively. The independent variable in each model was “Series” (with two levels: “aspirated” and “unaspirated”, i.e. fortis and lenis). “Word” and “Speaker” were set as random effects. Since, apart from “Word” and “Speaker”, only two variables were entered in the model, it did not matter whether “Series” or “Pre-aspiration” / “Breathiness” was used as the dependent variable (For the Aberystwyth analyses, the dependent variable was always the series.).

The frequency of occurrence of both pre-aspiration and breathiness distinguish the fortis-lenis contrast in the data (p < 0.0001 in both models). Pre-aspiration occurs in 79 tokens from the aspirated series (50%) and in 7 tokens from the unaspirated series (2%). Breathiness is found in 150 tokens from the aspirated series (99%) and 111 from the unaspirated series (37.5%). This is illustrated in Figure C.2. below.
Figure E2.1. Pre-aspiration (left) and breathiness (right) occurrence (%) in Lewis Gaelic fortis and lenis plosives

The labels ‘asp’ and ‘unasp’ stand for aspirated and unaspirated, respectively. The darker colour represents tokens with pre-aspiration and breathiness.
E.3. Further aspects of the release of plosives

As discussed in Chapter 6 (6.2.2.), the release of plosives presents a wide range of phonetic, and possibly also phonological, variability.

Firstly, it could be voiced. In such cases, the release onset was identified on the basis of higher energy in the waveform as well as in the spectrogram, and the end point was identified as the end of the burst (as shown in Figure E3.2.). Although these cases were annotated, they were not very frequent (ABE14: disyllables 14x; ABE31: disyllables 16x, monosyllables 12x; ABE33: disyllables 4x, monosyllables 1x).

Secondly, the data also revealed some degree of epenthetic vocoids (Figures E3.1.-E3.2.). Such epenthetic vocoids may well contribute to differentiating the fortis-lenis contrast. These vocoids either occur simultaneously with the burst (Figure E3.1.) or following the burst (Figure E3.2.).

*Figure E3.1. Epenthetic vocoid following voiced burst ('post(schwa)')*

Illustrated on the word cad, produced by a female speaker of 72 years (ABE31). ‘Voice’ stands for voicing.
Figure E3.2. Epenthetic vocoid (‘schwa’) following voiceless burst (‘post’)

Illustrated on the word card, produced by a female speaker of 70 years (ABE18). ‘Voice’ stands for voicing, ‘clo’ for voiceless closure, and ‘post’ for post-aspiration.

In one instance, the release in the data was followed by a single glottal pulse, possibly a glottal stop (Figure E3.3.).

Figure E3.3. Release followed by a single glottal pulse (‘GS’)

Illustrated on the word card, produced by a female speaker of 72 years (ABE31). ‘Voice’ stands for voicing and ‘unpo[st]’ for unaspirated release.
The release gesture could also be analysed for the presence of aspiration. However, although in many cases the spectrogram suggested a high degree of glottal friction, in some cases it was impossible to tell if there was a brief amount of glottal friction or low-frequency oral friction, especially when the release was short. EGG analyses would be needed to reliably indicate presence of aspiration in such cases, which is beyond the scope of this chapter. Furthermore, the analyses of the presence of aspiration are complicated by the presence of affrication, which is fairly common in the data especially with /t/ (Figures E3.4.-E3.5.). This affrication could be considered aspiration, although this would not be phonetically accurate. However, the affrication can be post-aspirated word-initially (Figure E3.5.), which suggests that affricated plosives should not be put on par with those that are post-aspirated but not affricated.

![Figure E3.4. Affrication](image)

*Illustrated on the word kidder, produced by a female speaker of 48 years (ABE24). 'Voice' stands for voicing, 'clo' for voiceless closure, 'post' for post-aspiration, and 'pr' for vowel-initial breathiness*
Figure E3.5. Post-aspirated affrication

Post-aspiration is highlighted. Illustrated on the word tagger, produced by a female speaker of 48 years (ABE24).