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Dissimilation can be gradient: Evidence from Aberystwyth English

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Abstract

Dissimilation is classically considered as a phonetically categorical sound change. In contrast to this assumption, this paper presents evidence for a phonetically gradient pattern of aspiration dissimilation found in Aberystwyth English (Wales): an aspiration feature is consistently *reduced* in the vicinity of another aspiration feature. Two other patterns of gradient aspiration dissimilation have been reported, in Halh Mongolian and in Georgian, which suggests that it may actually be a more general phenomenon. The Aberystwyth data are however better controlled for phonological contexts and lexical regularity than the Mongolian and the Georgian data. The results can then be discussed in light of the two available theories of dissimilation, Ohala's (1981) hypercorrection theory, and the traditional link with speech errors. Importantly, a number of arguments support Garrett's (2015) hypothesis that gradient dissimilation might be a(nother) precursor to complete dissimilation. The pattern thus shows how the use of careful phonetic inspection can lead to a reanalysis of our understanding of well-established diachronic processes.

1 Introduction

Dissimilation is classically considered as a phonetically categorical sound change: a feature is deleted when the same feature is present within a given domain. Hock (1991) notices that laryngeal feature dissimilation is also usually lexically regular: it affects all words presenting the relevant configuration. This is the case, for example, of the famous Grassmann's Law of Sanskrit and Ancient Greek, or of the Quechua progressive dissimilation of ejective and aspiration features. In the typology of sound changes proposed by Bermúdez-Otero (2007), dissimilation would then fall in the category of sound changes which are both phonetically and lexically abrupt.[1]

In contrast to this perspective, Svantesson et al. (2005) and Svantesson & Karlsson (2012) report a case of gradient dissimilation in Halh Mongolian.[2] In C^hVC sequences, the first aspiration feature is consistently shorter when C_2 is an aspirate than when C_2 is another type of consonant. This pattern has at least four interesting theoretical implications. It first shows the importance of careful instrumental analysis for the investigation of sound patterns. Gradient dissimilation can only be seen through phonetic measurement, and shows that the previous assumption that dissimilation is a phonetically categorical phenomenon is at best incomplete. Secondly, it seems to contradict Ohala's (1981, *inter alia*) and Blevins & Garrett's (1998) analysis of aspiration as a feature with 'stretched-out' cues, that is, a feature whose perceptual cues are relatively long. Such features should be prone to coarticulation, and the specific behaviour of aspiration, such as its tendency to undergo dissimilation, has been linked by these authors to the ambiguous location of the aspiration feature within the signal. On the contrary, the aspiration feature in Halh is specifically reduced where coarticulation would be most expected, that is, in C^hVC^h sequences. It is all the more surprising in Mongolian, where stops are pre-aspirated. Such sequences are realised as $[C^hV^hC]$, with both aspiration features surrounding the same nucleus: we would expect the vowel to be pervaded with aspiration.

This unexpected reduction then raises the question of its phonetic motivation. Garrett & Johnson (2013) recall that explanations of dissimilation can be broadly classified in two types. In Ohala's (1981; 1992; 1993, *inter alia*) hypercorrection theory, dissimilation happens when the

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[1] Bermúdez-Otero (2007) defines four theoretically possible types of change: phonetically gradual and lexically abrupt (Neogrammarian sound change), phonetically abrupt and lexically gradual (classical lexical diffusion), phonetically abrupt and lexically abrupt, and phonetically gradual and lexically gradual. In this paper, we use the terms *categorical*/*gradient* for the phonetic implementation, and *regular*/*irregular* for the spread of a phenomenon within the lexicon: a process is regular if all words with similar phonological contexts are affected at the same time.

[2] These authors do not use the expression *gradient dissimilation*. With Garrett (2015), we analyse the aspiration reduction as a type of dissimilation, and call it *gradient* to express the difference with *categorical* dissimilation, that is, deletion of the feature as a whole, discrete unit. The expression *complete dissimilation* refers to reconstructed deaspirations such as Ancient Greek or Quechua, whose precise mechanism (gradient or categorical) is unknown.

listener overapplies her perceptual filters, and mistakenly analyses a given feature as a coarticulatory effect of the same feature nearby in the same word. Traditionally, however, dissimilation has been analysed as an effect of articulatory difficulty or motor planning, in connection with speech errors. In tongue-twisters involving sequences of similar features, for example, motor planning inhibition may result in altering one of the two features.[3] Given that Ohala's theory explicitly predicts phonetically categorical dissimilation, Garrett (2015) proposes to see gradient dissimilation as an argument for the second theory of dissimilation. Finally, a related, but distinct question is whether gradient dissimilation is a possible precursor to complete dissimilation. Garrett (2015) notices that a number of Mongolian dialects other than Halh present a complete deaspiration of C_1 in C^hVC^h sequences. Halh might then instantiate the incipient stage of a process which was completed in other dialects.

This paper steps into these debates by bringing forward a new case of gradient dissimilation of the aspiration feature. In the variety of English spoken in Aberystwyth (Wales), the second aspiration feature of a C^hVC^h sequence is consistently reduced in comparison to its realization in CVC^h contexts, where C_1 is not an aspirate. Since our presentation of the topic at the Second Edinburgh Symposium of Historical Phonology in December 2015, Begus (2016) has found another related pattern in Georgian: the aspiration feature of C_2 in CVC^h sequences is consistently shorter when C_1 is an aspirate than when it is another type of consonant. Although the specific parameters of each of these patterns are diverse, they all share one common point: an aspiration feature is significantly reduced in the vicinity of another aspiration feature. This suggests that gradient dissimilation might actually be a typologically frequent process hitherto overlooked.

The analysis of Aberystwyth English (AE) we present sheds light on the phenomenon of gradient dissimilation by being more precise than the data available so far for Halh and Georgian. It is better controlled for phonological contexts, for the different parameters quantifying the effect of aspiration, and for the effects of lexical frequency (relevant for lexical regularity). AE thus attests the existence of a pattern of dissimilation which is not only phonetically gradient, but also lexically regular. As will be made clear below however, our investigation is still in its infancy at this stage. In this paper, we focus on the aspiration feature of C_2 in

[3] For example, the sequence *Unique New York* contains the pattern [j...n...n...j]. When repeated, this pattern tends to alternate: [j...n...j...n] (Garrett & Johnson 2013).

C^hVC^h sequences, as well as on the properties of the intervening vowel. These analyses present the first step in a bigger project, outlined further in section 5.

The AE data allow for a comparison with the other patterns, and help us unfold three general research questions:

- what are the common points and differences between the three patterns?
- what is the phonetic motivation of these synchronic processes of reduction?
- do they represent another diachronic path to complete aspiration dissimilation? That is, could the synchronic reduction be a precursor to the deletion of one of the aspiration features?

Although we are not able to answer these questions now, the discussion frames the importance of our data within these general theoretical questions and outlines directions for future research.

The rest of the paper is organized as follows. We first present the patterns found in Mongolian and Georgian in more detail, in order to allow for a precise comparison with AE (section 2). We then present the evidence for gradient dissimilation in AE (section 3). The theoretical implications of these findings are discussed (section 4), and the conclusion outlines directions for future research (section 5).

2 Mongolian and Georgian

To the best of our knowledge, only two other patterns of gradient aspiration dissimilation have been reported in the literature so far: in Halh Mongolian and Georgian.

In Mongolian, aspirated stops are pre-aspirated when post-sonorant, and post-aspirated when word-initial; other aspirates are the laryngeal fricative /h/ and the sibilant /s/, which both participate in the different aspiration dissimilation patterns.[4] In the Halh dialect, Svantesson and his colleagues found that the first aspiration feature in a C^hVC^h sequence is significantly shorter when C_2 is an aspirate than when it is another type of consonant (Svantesson et al. 2005; Svantesson & Karlsson 2012).

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[4] According to (Svantesson et al. 2005:18), /s/ is pronounced with post-aspiration in word-initial and medial position. In this paper we use the transcriptions given in Svantesson et al. (2005); Svantesson & Karlsson (2012).

(1)	[tʰaɮ]	'steppe'	72ms on average
	[tʰaʰtəx]	'to pull'	50ms
	[tʰɔs]	'fat'	49ms

There is thus a gradient, regressive pattern of aspiration dissimilation: the aspiration feature is not deleted as a discrete unit, but gradiently reduced when closely followed by another aspiration feature. Since the context involves both pre- and post-aspiration, so that the same vowel is surrounded by two aspiration features, it is remarkable that the reduction of aspiration takes place precisely where the greatest degree of coarticulation would be expected. It must be borne in mind, however, that the data at hand are incomplete: the measurements were obtained from only one speaker, reading each of the three words four times. No measurements are available for C_2, or for other words, although Svantesson estimates that the pattern is generalisable to other words with the same phonological structure (p.c.). Another point of concern is that the context in which C_2 is a pre-aspirated stop is found in a disyllabic word rather than a monosyllabic word, which may explain, at least to some extent, the durational difference considering that words with an increasing number of syllables are associated with segments of increasingly shorter durational properties (Klatt 1974).[5]

Interestingly, this gradient dissimilation differs from the patterns of aspiration found in other varieties of Mongolian: most dialects have undergone a complete dissimilation of aspiration. This dissimilation is generally regressive and regular, as exemplified below by the Chahar dialect, but is progressive and regular in Monguor, and progressive and irregular in a few other dialects (Santa, Bonan, among others).

(2)

Proto-Mongolian	Chahar	Monguor	Halh	
*CʰVCʰ-	CVCʰ-	CʰVC-	CʰVCʰ-	
*tʰatʰa	tatʰ-	tʰita-	tʰatʰ-	'to pull'

The complete deaspiration is conditioned by the material separating the two stops: dissimilation does not happen if the aspirated consonants are separated by more than a short vowel. [x] is the expected reflex of **kʰ*,

[5] Nevertheless, this is not an issue for the durational difference between the resonant context and the /s/ context, which were both analysed using a monosyllabic word.

while deaspirated *$*k^h$* is reflected in Chahar by [k] (as in *$*k^hit^hat$*, Chahar [kɪt^hɑt] 'China').[6]

(3)

Proto-Mongolian	Chahar	Halh	
*k^hauč^hin	xʊʊč^hən	xʊʊč^hən	'old'
**k^hamt^hu	xamt^h	xamt^h	'together'

This sensitivity to the intervening material contrasts with long-distance dissimilations such as Ancient Greek *hálok^hos* > *álok^hos* ('wife'). Unfortunately, we do not know whether the gradient dissimilation pattern in Halh is sensitive to the same parameter. If, as Garrett (2015) proposes, Halh shows the incipient stage of a dissimilation that was completed in Chahar, we would expect no effect of C_2 on the aspiration feature of C_1 in $C^hV{:}C^h$ sequences.

The second pattern of gradient aspiration dissimilation has been reported in Georgian very recently by Begus (2016). In this language, aspirated stops are post-aspirated. Begus found that, in the speech of twelve speakers, the aspiration feature of the second stop in C^hVC^h sequences was consistently reduced compared with contexts where C_1 is not an aspirate. This is then a case of gradient, progressive dissimilation. In this case however, the types of contexts measured so far are limited to *vot*VC*i* and *rub*VC*i* sequences, where V = [ɑ], [ɛ] or [ɔ] and C = [p^h, t^h, k^h].[7] The post-aspiration of C_1 was not measured.

These two patterns, Halh and Georgian, show that dissimilation can be gradient. The Mongolian data in particular illustrate that coarticulation of two aspiration features across a nucleus is not necessary, and may be avoided. These data are however problematic for two reasons. First, it is not clear that the two patterns proceed from the same mechanism: Halh has both pre- and post-aspiration, while Georgian has only post-aspiration; the aspiration feature that was measured in Halh is the one of C_1, while in Georgian it is the feature of C_2. Second, the evidence in both cases is scanty: data are available for only one speaker in Halh, and for three words; in Georgian, only one phonological context has been tested.

[6] All the examples provided by Svantesson et al. (2005) involve the velar.

[7] The transcription without aspiration diacritic is reproduced from Begus' poster, and is presumably due to the fact that there is no voiceless plain/voiceless aspirated contrast in Georgian stops.

Our study therefore contributes to the debates related to how the aspiration dissimilation takes place as follows. The AE data first enlarge the empirical basis by adding a third related pattern. It also provides a more detailed picture: we control for variables that were not controlled in the other relevant studies, namely foot-position, position within utterance, place of articulation of the obstruent, and lexical frequency. The methodology is also explicit regarding how pre-aspiration is defined and quantified exactly, which is the first time this has been done for the subject matter at hand. In particular, we distinguish pre-aspiration and local breathiness, which both show presence of glottal friction, but differ in absence and presence of voicing, respectively.[8] These results, in turn, help us progress in the understanding of these newly reported patterns of gradient dissimilation.

3 Aberystwyth English aspiration dissimilation

Aberystwyth English has two series of stops: lenis and fortis. The fortis series is realised as strongly post-aspirated in a number of environments (e.g. *can*, *lacquer*, *lack*). Aberystwyth English also shows pre-aspiration, which is nearly obligatory foot-medially and foot-finally (*lacquer*, *lack*) (Hejná 2016).

(4)	*lack*	[$\text{la}^{\text{h}}\text{k}^{\text{h}}$]
	lacquer	[$\text{la}^{\text{h}}\text{k}^{\text{h}}$ə]
	cap	[$\text{k}^{\text{h}}\text{a}^{\text{h}}\text{p}^{\text{h}}$]

Because of the highly frequent, near-obligatory, application of both post- and pre-aspiration, Aberystwyth English presents a situation which should be prone to display aspiration coarticulation across $\text{C}^{\text{h}}\text{VC}^{\text{h}}$ sequences.[9] In other terms, we would expect the vowel to be pervaded with one the cues of the aspiration features, voicelessness or breathiness. This is nevertheless not borne out by the results presented here. The parameters of AE gradient dissimilation are investigated through the following research questions:

- how is the pre-aspiration feature of C_2 in CVC^{h} sequences affected by an aspirated C_1?

[8] More concrete definitions and illustrations are provided in section 3.1.
[9] The expression '$\text{C}^{\text{h}}\text{VC}^{\text{h}}$ sequence' includes both monosyllabic $\text{C}^{\text{h}}\text{VC}^{\text{h}}$ words and disyllabic $\text{C}^{\text{h}}\text{VC}^{\text{h}}\text{V}$ words. As we shall see in section 3.2, we found the same effect in the two contexts.

- do we observe coarticulation between the two aspiration features in C^hVC^h sequences?
- does the reduction happen also across long vowels, in $C^hV{:}C^h$ sequences?

The next section outlines the methodology, and defines in particular the effects of pre-aspiration proper vs. breathiness (3.1). Section 3.2 details the results we obtained. We report firstly the gradient dissimilatory aspiration pattern demonstrated with pre-aspiration in AE, and the local breathiness that serves as a transition to this pre-aspiration (3.2.1). Subsequently, it is shown in more detail that it is not the case that a longer stretch of the vowel would be breathy in the context which is predicted to exhibit most breathiness (3.2.2). Finally, preliminary results suggest that there is no dissimilation effect when the intervening vowel is long (3.2.3).

3.1 Methodology

3.1.1 Identifying and quantifying pre-aspiration

We define pre-aspiration in line with Nance & Stuart-Smith (2013) and Hejná (2015), i.e. as a period of voiceless, primarily glottal friction, occurring in the sequences of sonorants and phonetically voiceless obstruents, e.g. *lass* [la^hs], *lack* [la^hk^h]. The left boundary of pre-aspiration is determined on the basis of the lack of voicing in the interval of glottal friction. The right boundary is determined by the complete absence of the friction, visible both in the soundwave and the spectrogram, as shown in Figure 1.

3.1.2 Identifying and quantifying breathiness

Pre-aspiration is often accompanied by a period of breathiness, which precedes it (Nance & Stuart-Smith 2013; Hejná 2015). Breathiness can be identified as follows: the sound wave becomes more sinusoidal as the vocal folds spread further apart and more friction is generated, which is observable also as the presence of friction in the spectrogram. Breathiness as defined here therefore differs from pre-aspiration by the presence of voicing (vocal fold vibration) in the former. This is illustrated in Figure 2.[10]

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[10] This type of breathiness is not the same type which is discussed in studies such as Borsel et al. (2009), where more global breathiness associated with the general voice quality is of interest. In our present study of Aberystwyth English, breathiness refers

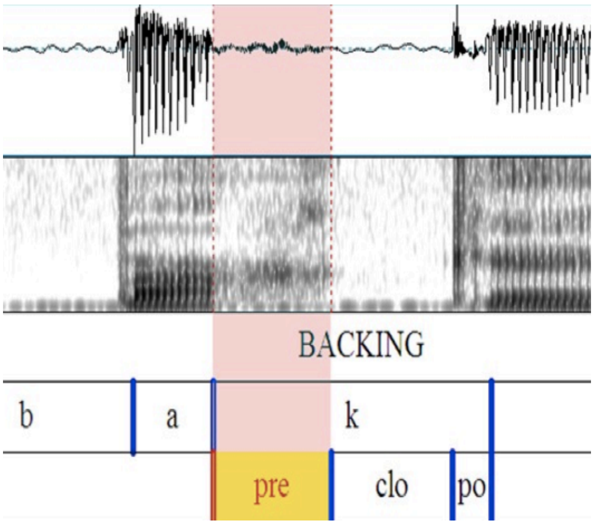

Figure 1: Identification of pre-aspiration.

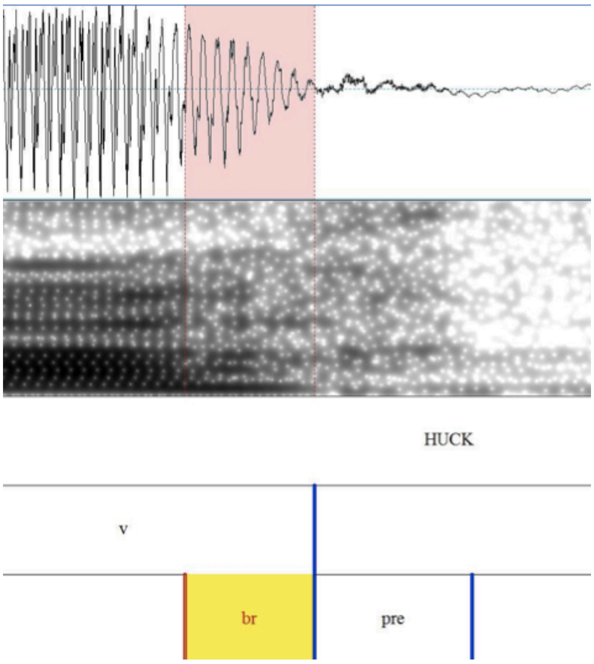

Figure 2: Identification of breathiness.

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to the transition from 'modal' vowel to the voiceless pre-aspiration. The breathiness of primary interest to us is therefore a more local, most likely subsegmental, type of breathiness.

3.1.3 Dependent variables

The questions raised at the beginning of this section are addressed by looking into the phonetic and phonological behaviour of (a) categorical presence of pre-aspiration, (b) categorical presence of breathiness, (c) duration of pre-aspiration, and (d) duration of breathiness of the second stop in C^hVC^h and C^hVC^hV.[11]

Any pre-aspiration and (local) breathiness identified in the data were treated as positive cases of pre-aspiration and local breathiness. This means that as long as their duration was not 0ms, they were treated as occurring in the data.[12]

For the durational aspects, only tokens in which pre-aspiration or breathiness occurred were included in the analyses, respectively. Pre-aspiration duration and breathiness duration were normalised as a percentage of the overall word duration.[13] All the figures (and tables in the Appendix) presented below show the normalised values.

3.1.4 Data

Our participants were recorded reading words with $'C_1VC_2$ and $'C_1VC_2V$ structures: *bap*, *bat*, *back*; *lapper*, *latter*, *lacquer*. The post-tonic consonant (C_2) includes the three places of articulation of fortis plosives available: /p/, /t/, and /k/.

C_1 subsumes three categories: (1) fortis consonants (/p/, /t/, /k/, and /h/); (2) lenis consonants (/b/, /d/, /g/); and (3) sonorants (/m/, /n/, /l/, /ɹ/). Regarding the category of fortis consonants, it has been shown that /h/ patterns with aspirated stops in many languages including English, Korean, Mongolian, and Ancient Greek (see for example Davis & Cho 2003; Kang 2014; Jatteau 2016). Our analyses furthermore showed that there was no difference in how these potential subgroups affect pre-aspiration or breathiness, thus providing further evidence for the claim that /h/ and the aspirated stops pattern together as a class.

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[11] This means that post-aspiration of C_2 is not analysed in this study, although further analyses will include it as well.

[12] This is not in line with Helgason (2002), who treats only pre-aspiration reaching at least 30ms as positive cases of pre-aspiration. We do not adopt Helgason's approach because there is no available evidence relevant for the data at hand that would suggest this procedure should be adopted.

[13] The formula used was as follows: pre-aspiration duration (ms) / (overall word duration (ms) / 100). For more details on whether this normalisation is appropriate, see (Hejná 2015:57-61).

The vowels in the tokens are /a/, /ɛ/, /ɪ/, /ʌ/, /ɒ/ in both structures and, in addition, /ʊ/, /ɑː/, /oː/ were also recorded in the ˈC_1VC_2 structure.

Each speaker was recorded reading 190 word types. Each type was produced twice in a carrier sentence (*Say* WORD *once.*) and once in isolation (WORD). Hence, for each speaker, 550–650 tokens were analysed. The word list can be found in Hejná (2015:Appendix A).

3.1.5 Participants

The participants consist of 12 female speakers, who were born and raised in Aberystwyth, mid-Wales. They are native speakers of Welsh, also proficient in English, and were recorded in English.

3.1.6 Recording procedure

The data were recorded with a H4 Zoom Handy Recorder and AKG C520 head-mounted microphone, and sampled at 44.1 kHz.

3.1.7 Statistical analyses

The statistical analyses were done with R Studio (R Core Team), using the packages lmer4 (Bates et al. 2014) and lmerTest (Kuznetsova 2015) for Mixed Effects Models. The optimal models were identified in a step-up fashion, through ANOVA comparisons of the individual models. The dependent variables were the presence of pre-aspiration (with two levels: 'yes' for present, 'no' for absent), the presence of breathiness (with two levels, the same as those for pre-aspiration), the duration of pre-aspiration (raw as well as normalised as a percentage of the word duration), and the duration of breathiness (again raw and normalised), respectively.

For the purposes of this study, the most important independent variable was that of the prevocalic consonant, which had three levels ('lenis' /b/, /d/, /g/; 'SG' standing for [spread glottis] /p/, /t/, /k/, /h/; and 'sonorant' /m/, /n/, /l/, /ɹ/). Forward reference coding was used for this variable, which means that comparisons were made between the lenis vs. the SG levels, and the SG vs. the sonorant levels. The other independent variables included those that have stronger effects on various properties of pre-aspiration: foot-position (with two levels: medial, as in *matter*, and final, as in *mat*), place of articulation of C_2 (with three levels: /p/, /t/, /k/; with forward reference coding applied), and vowel quality (with eight levels: /a/, /ɛ/, /ɪ/, /ɒ/, /ʊ/, /ʌ/, /aː/, and /oː/). Unless specified, the coding for the variables was the default treatment coding. The models thus involved C1type + Vowel + C2place + Foot Position. Interactions between these variables did not improve the model fit in any way concerning the frequency of occurrence.

Importantly, lexical frequency was also an independent variable originally included in the models.[14] However, it did not affect the dependent variables in any way and did not improve the fits of the models. This means that lexical frequency does not affect the duration of pre-aspiration considered on its own or in combination with other variables. We come back to this point in section 3.2.1.

3.2 Results

This section first establishes that both pre-aspiration and breathiness associated with C_2 show a dissimilatory pattern: when C_1 is a fortis plosive or /h/, pre-aspiration or breathiness associated with C_2 are less frequent and shorter (3.2.1). This is confirmed when we look specifically at the intervening vowel: the vowel does not undergo more aspiration coarticulation in C^hVC^h contexts than in CVC^h contexts (3.2.2). Finally, we examine whether the gradient dissimilation is sensitive to the length of the intervening vowel (3.2.3).

3.2.1 Evidence of a dissimilatory pattern

When we look at the presence of pre-aspiration, we find that it applies more frequently in the VC_2 sequence if C_1 is either a sonorant (*lip*) or a lenis plosive (*dip*) than when C_1 is either a fortis plosive (*tip*) or /h/ (*hip*). The same is found for breathiness, as illustrated in Figure 3 (and summarised in Tables 1–2 in the Appendix). To discuss the presence of pre-aspiration in the data, we use the expression of 'frequency of occurrence' to discuss how frequently pre-aspiration is found in the tokens, rather than just 'frequency', because the latter could be interpreted as referring to the spectral properties of the phenomenon.

As further illustrated in Figure 4 (and Tables 3–4 in the Appendix), the durational measurements follow suit: pre-aspiration and breathiness are shorter if C_1 is a fortis plosive or /h/. This effect is however slightly stronger for pre-aspiration than for breathiness.

As is visible from the figures, the difference in the duration of pre-aspiration and breathiness according to the type of C_1 is rather marginal in comparison to the difference found in Mongolian. This is the case even

[14] Lexical frequency of the words analysed was determined via SUBTLEX-UK (Van Heuven et al. 2014).

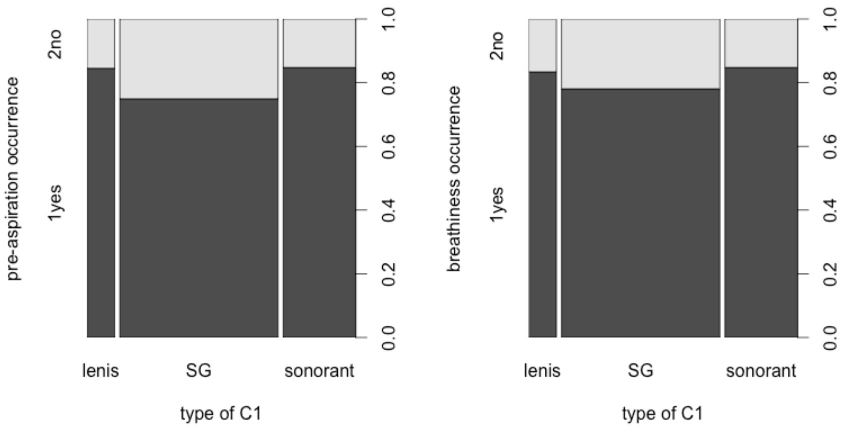

Figure 3: Frequency of occurrence, for pre-aspiration (left) and breathiness (right), depending on the type of C_1.

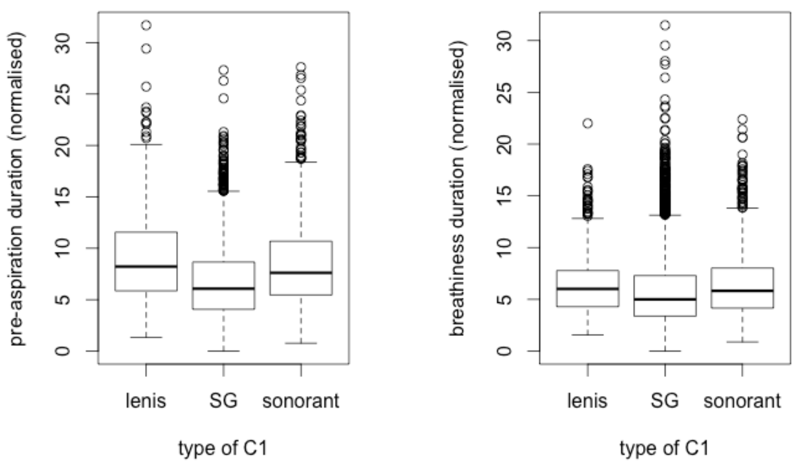

Figure 4: Normalised duration, for pre-aspiration (left) and breathiness (right), depending on the type of C_1.

when raw data are considered: the difference between the mean between the lenis and the [+spread glottis] categories is 10ms for pre-aspiration and 5ms for breathiness.

This effect is stable across segmental contexts: there is no significant interaction with place of articulation. It is also constant across prosodic conditioning (with the exception of vowel length; see below): we found no difference between the word-medial and word-final positions, nor between the words spoken in isolation and the words in a carrier sentence.[15] Importantly, the frequency of occurrence of pre-aspiration and breathiness, as well as their duration, are not sensitive to lexical frequency in the data. Together with the fact that no word-specific effect is found, in a corpus of 190 word types, these results show that gradient aspiration dissimilation in Aberystwyth English presents a lexically regular, i.e. exceptionless, phenomenon.

3.2.2 Lack of coarticulation

As mentioned in section 1, Ohala contends that the features which tend to undergo dissimilation are specifically features with 'stretched-out cues', that is, features that 'spill over onto preceding vowels' (1981:181), or whose perception requires a long time window (Ohala 1993:252): dissimilation happens when the location of the aspiration feature is ambiguous in the signal.[16] If the aspiration feature extends over a long time window, we would expect the sequences of C_1VC_2 with both consonants having an aspirate feature to show most coarticulation: a bigger proportion of the intervening vowel should be affected by the breathiness which serves as a transition from voiceless aspiration to the modal vowel. Pre-aspirating languages such as AE are the best candidates for this coarticulation, because the glottal friction associated with C_1 (in the form of post-aspiration) is closer to that associated with C_2 (in the form of pre-aspiration): $[C_1{}^hV^hC_2]$ rather than $[C_1{}^hVC^h{}_2]$.

This prediction is however not borne out by the AE data. As shown in Figure 6, there are three modes in the distribution of what percentage of the vowel is affected by breathiness induced by pre-aspiration. The first mode is centred around zero values: no breathiness is present in the vowel — this is the least coarticulatory scenario. The second mode is centred primarily around 20–30% of the vowel duration affected by breathiness. Finally, there is a peak concentrated around 95–100%, which is represented by examples like those shown in Figure 5: the vowel is (almost) completely breathy.

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[15] For more detail, see the Appendix and also (Hejná 2015:chapter 3).
[16] The list of these features is revised and updated by Blevins & Garrett (1998).

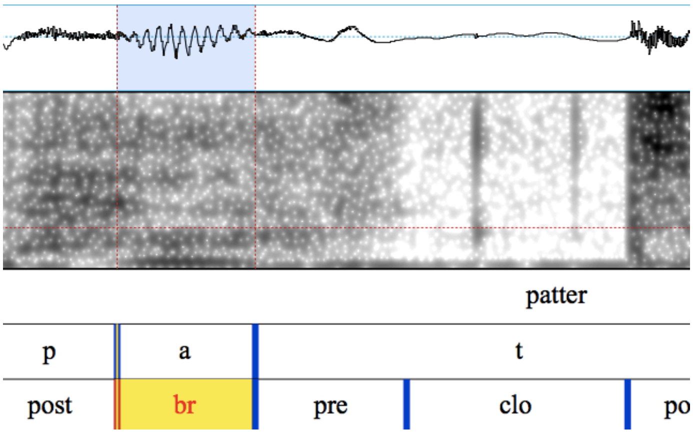

Figure 5: Fully breathy vowel.

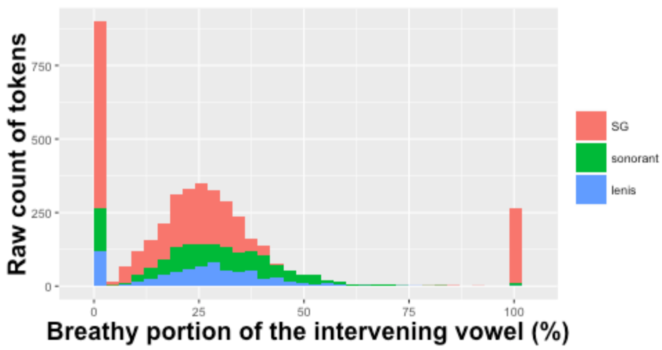

Figure 6: Breathy proportion of the intervening vowel (as a percentage of vowel duration) depending on the type of C_1.

In Figure 6, we observe that the third peak is primarily associated with [+spread glottis] C_1: as expected, full breathiness happens mostly in C^hVC^h contexts, as Ohala would predict.[17] The presence of the third peak

[17] Statistical analyses do not suggest any correlations between the percentage of the vowel being breathy and the type of C_1, most likely because of the small amount of cases from this peak. We used Linear Mixed Effects modelling as follows. The dependent variable was the proportion of the vowel affected by breathiness, expressed as a percentage of the overall vowel duration. Vocalic portion was identified by the onset and the offset of voicing. The independent variables were added in a step-up fashion, including potential interactions between these variables, and the individual models were compared via ANOVA analyses. The model which was deemed most optimal included foot position (two levels: medial and final), vowel phoneme (eight levels), place of articulation of C_2 (three levels), and C_1 type. 'Word' and 'Subject' were set as random effects. It is noteworthy to add that the type of C_1 did not show any effect on the amount of the vowel being breathy

could be accounted for by cases in which the post-aspiration of C_1 also induced local breathiness. Nevertheless, such cases are not very frequent: complete coarticulation is actually the rarest case.

The data set also contains two cases of completely voiceless vowels, which had to be excluded from the analyses because the post-aspiration of C_1 or the friction of the phoneme /h/ could not be separated from pre-aspiration of C_2. These examples comprise less than 1% of the cases in a relatively big data set. Complete coarticulation thus happens much more rarely than we could expect with a 'stretched-out feature' such as aspiration.

Interestingly, the opposite strategy is also attested: the first peak, representing the cases where the vowel is not breathy at all, includes cases of C^hVC^h contexts. Surprisingly, this mode is not associated with any of the three categories specifically. The vowel may not be breathy in *lip* as well as in *tip*. The same is the case for the second, middle mode. Although the [+spread glottis] category reaches highest peaks, this is simply because most tokens in the data set have a [+spread glottis] C_1. What matters is that the 0 peak is not correlated with any of the categories in the first and in the second peak. This means that the proportion of the vowel affected by breathiness is not bigger in [C^hV^hC] sequences than in [CV^hC] sequences where C_1 is not an aspirate.

The examination of the intervening vowel thus shows three different strategies of coarticulation between the vowel and the pre-aspiration feature of C_2 in C^hV^hC sequences. It is not clear at the moment how to interpret the presence of these three distinct categories. As we suggest in section 4, it may be the case that looking at what proportion of the vowel is breathy does not quantify coarticulation adequately: it may be the case that the degree of noisiness of this breathiness is an important dimension to consider as well. Among the three strategies however, complete coarticulation of the two aspiration features stands out as clearly dispreferred.

3.2.3 Length of the vowel

Considering that aspiration dissimilation is categorically blocked in Mongolian if the intervening vowel is phonologically long, at least in the dialects where dissimilation has been completed, the next analytical step is to see whether vowel length may block the gradient pattern found in the

in *any* of the models in a very consistent fashion, whilst all the other variables showed a consistent effect.

Aberystwyth English data. The data at hand allow for the following comparisons, limited to two types of C_1 and two places of articulation of C_2:[18]

(5)

	C_1 = sonorant	C_1 = fortis	
/-t/	*mart*	vs. *part*, *tart*, *cart*, *heart*	(174 tokens)
	[mɑːʰtˢ]	vs. [pʰɑːʰtˢ], [tˢɑːʰtˢ], [kʰɑːʰtˢ], [hɑːʰtˢ]	
/-k/	*lark*, *mark*	vs. *park*, *cark*, *hark*	(167 tokens)
	[lɑːʰkʰ], [mɑːʰkʰ]	vs. [pʰɑːʰkʰ], [kʰɑːʰkʰ], [hɑːʰkʰ]	

The results are displayed in Figures 7 and 8.

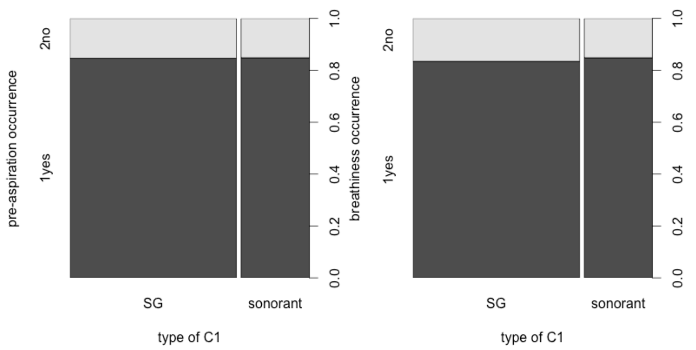

Figure 7: Frequency of occurrence, for pre-aspiration (left) and breathiness (right), depending on the type of C_1; context of long vowels.

As shown in Figures 7 and 8, visual evidence reveals that the tendency for pre-aspiration and breathiness to be shorter in the context of a

[18] Interactions between vowel length and the type of C_1 were not possible within the models presented above because of missing values for one of the levels within the type of C_1 in combination with the two phonologically long vowels; this level is that of lenis plosives. In addition, only two places of articulation of C_2 are available following the two vowels in our dataset (/t/ and /k/). Furthermore, /oː/ — one of the long vowels in our dataset — is restricted by the number of tokens per these conditions even further. Because of these issues, the additional analysis related to whether aspiration dissimilation is found in the context of long vowels as well therefore relies on selected tokens only. This necessarily limits our understanding of the overall picture. Importantly, note that the results of the models used in the previous sections do not differ if they are limited only to phonologically short vowels.

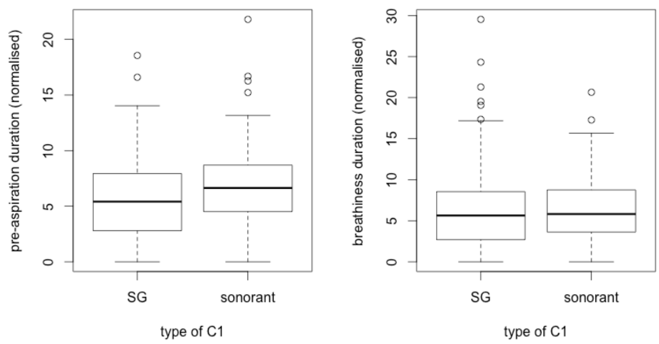

Figure 8: Normalised duration, for pre-aspiration (left) and breathiness (right), depending on the type of C_1; context of long vowels.

[+spread glottis] C_1 than a sonorant C_1 is only marginal: it amounts to 2%. Statistical analyses confirm this point: there is no gradient dissimilation in the context of the phonologically long vowel, in this case /ɑː/.[19] It therefore seems that long vowels do not participate in the same gradient dissimilatory pattern in Aberystwyth English: pre-aspiration is as long in $C^hV{:}C^h$ as it is in $CV{:}C^h$ where C_1 is not an aspirated consonant.

It should however be noted that phonologically long vowels are associated with the smallest breathy proportions of the vowel ($p < 0001$; /ɑː/ compared to /a/ and /oː/ to /a/): breathiness is shorter in the context of phonologically long rather than short vowels, irrespective of the type of C_1 (see also Hejná 2015, chapters 3 and 4). In other words, breathiness tends to be already reduced in the context of phonologically long vowels. We cannot then exclude that the pre-aspiration feature of C_2 also undergoes a degree of dissimilation in this context, but that this effect is masked by the reduction induced by the long vowel.

3.3 Summary of the findings

To summarize, we have seen that the aspiration feature of the second stop in C^hVC^h sequences in AE is consistently reduced when C_1 is an aspirate consonant (/p/, /t/, /k/ or /h/) rather than another type of consonant (namely, a lenis plosive or a sonorant). Both pre-aspiration and breathi-

[19] Chi-Square tests for the effect of C_1 on the two aspects of pre-aspiration and breathiness within the velar or the alveolar group, respectively, do not suggest any significant patterns.

ness are shorter and less frequent in the aspirate environment, and the effect is stable across segmental contexts and prosodic positions. AE therefore represents a case of phonetically gradient and lexically regular dissimilation. The intervening vowel is not permeated by breathiness, suggesting that the coarticulation is not greater in the aspirate context when compared to the other contexts. Crucially, complete coarticulation is very rare. Coarticulation therefore does not seem to be a necessary aspect of sequences of aspiration features, even when both features flank the same vowel. Finally, preliminary results suggest that the gradient dissimilation could be limited to short vowels, as is complete dissimilation in Mongolian: there is no reduction of the aspiration feature of C_2 which would be specific to $C^hV{:}C^h$ sequences.[20]

4 Discussion

These results confirm the existence of a third pattern of gradient aspiration dissimilation. We can now address the three general research questions introduced in section 1: do the patterns in AE, Halh Mongolian and Georgian reflect the same phenomenon (section 4.1)? What is the motivation for the gradient dissimilation (section 4.2)? Is gradient dissimilation another precursor to complete dissimilation (section 4.3)? As seen in section section 3, only C_2 and the intervening vowel have been examined so far. We therefore lack the rather crucial information on the aspiration feature of C_1. The aim of this section is thus to unfold the possible theoretical consequences of these first results.

4.1 Typology of aspiration dissimilation

Aberystwyth English, Halh Mongolian and Georgian all attest a type of gradient dissimilation: in C^hVC^h sequences, one of the two aspiration features is consistently reduced, but not deleted. It may then be the case that dissimilation can be either categorical or gradient. This first result confirms the importance of instrumental analysis for the study of sound patterns.

The next step is to understand whether the three patterns we have seen correspond to a unique mechanism. Comparison is difficult: these languages differ in whether they have pre- and/or post-aspiration,

[20] Recall that pre-aspiration features are frequently reduced after long vowels, but regardless of the quality of C_1.

whether the dissimilation is regressive or progressive, as well as in the magnitude of the effect.[21]

(6)

	AE	Halh	Georgian
Aspiration Dissimilation	pre- and post- C_2	pre- and post- C_1	post- C_2

The case of Georgian in particular seems to stand out: the dissimilated aspiration feature is not the first but the second one, and it is realised after the release of C_2. It could well be that the sequence is pronounced with only one long [spread glottis] gesture, with full coarticulation, and that the reduction of the second aspiration feature is simply due to a more general limit on the duration of this gesture (Chitoran p.c.; Begus p.c.). The post-aspiration of C_1 however has not been measured yet.

Crucially, however, an important shortcoming of all three datasets is that the data are available and/or analysed only for one of the two consonants, and not always both for pre- and post-aspiration for C_2. We therefore do not know whether reduction proceeds in both directions, affecting the aspiration features of C_1 as well as those of C_2.

In connection to this point, it should be underlined that, in cases of completed dissimilation of laryngeal features, there does not seem to be a clear correlation between the direction of aspiration and the direction of dissimilation. As shown in 7, although dissimilation is more often regressive, all four patterns are attested.[22]

(7)

	Regressive	Progressive
Pre-aspiration	Chahar Mongolian	Monguor Mongolian
Post-aspiration	Ancient Greek, Sanskrit, Basque	Quechua

[21] Because the effect is larger in Halh than in AE. We could imagine that Halh and AE stem from the same mechanism, but that Halh represents a more advanced stage of the dissimilation. The question would then be whether listeners are able to pick up on the small effect in AE to enlarge it in a second step.

[22] For Basque, cf. Egurtzegi (2015); for Quechua, cf. Longacre & Orr (1968). A more complete typology could be established if we took into account languages with synchronic co-occurrence restrictions on laryngeal features (see in particular MacEachern 1999; Gallagher 2010). It is not clear however whether all co-occurrence restriction patterns arise from a diachronic dissimilation.

The case of Mongolian is particularly fascinating: dissimilation happens in both directions, regressive and progressive, depending on the dialect, but these different patterns stem from the same proto-language. We are not aware at any attempt to explain this divergence.

4.2 Motivation of the gradient dissimilation

As summarized by Garrett & Johnson (2013), there are broadly speaking two theories of dissimilation: Ohala's hypercorrection model, which is based on the listener, and the connection with speech errors, in which the speaker is responsible for the change.

As already mentioned, Ohala's (1981; 1992; 1993) listener-oriented explanation of aspiration dissimilation cannot account for the gradient dissimilation patterns. The core mechanism is the following. Features, and in particular features with stretched-out cues, tend to alter neighboring segments. The listener is used to filter out these coarticulation effects in the signal. Dissimilation happens when the listener, having heard for example [he̤kʰɔ̤ː] for /hekʰɔː/ ('I have' in Ancient Greek), with coarticulation of the aspiration feature across the /e/, overapplies the perceptual filters and mistakenly analyses one of the two features as a coarticulatory effect of the first one. What is modified is then the underlying, lexical form of the word, reanalysed as /ekʰɔː/, and then repeated with only one aspiration feature by the 'listener-turned-speaker'. In this model, dissimilation is predicted to be categorical, contrary to what we find in AE, Halh and Georgian. Another incorrect prediction of the model is the presupposition of coarticulation. As we have seen, in AE the vowel between two aspirated stops is not more coarticulated with the aspiration feature than in the other contexts. This is all the more surprising in languages such as Halh and AE, where the aspiration features flank the vowel in the same [CʰVʰC] sequence.

The second account of dissimilation is taken over in connection with the Mongolian data by Garrett (2015): if gradient dissimilation cannot be attributed to hypercorrection, it may be linked to speech errors, that is, to motor planning or gestural organisation. Garrett & Johnson (2013) define motor planning as 'the process of constructing or retrieving motor plans that will later be executed by speaking'. Dissimilation in particular would be the result of motor planning *inhibition*, that is, the preference for alternation over repeating patterns. Garrett & Johnson (2013) and Garrett (2015) contend that the dissimilated feature should be the one in the weakest position in the word. This prediction seems to be supported by the AE data: in words like *tapper*, the reduced aspiration feature is borne by the /p/, which is not under stress; in words like *tap*, both stops belong to the stressed syllable, but the reduced one is in coda, word-final position. We cannot confirm this point, however, without knowing what happens to the first aspiration feature. A second point that seems unclear to us is whether motor planning inhibition is compatible with gradient and regular dissimilation. The speech errors mentioned in the literature represent apparently categorical dissimilations (as for example in Garrett & Johnson 2013). We have not found any specific prediction on this last point in the literature on speech errors mentioned by Garrett. In any case, speech errors are necessarily sporadic, while gradient dissimilation is regular. It should be noted, though, that motor planning may be understood in different ways, from neural activity to muscle activation. Different levels of planning might be able to trigger different types of dissimilation.

If motor planning proves not to correspond to the types of phenomena we observe in AE, other hypotheses should be explored. Among them, we could imagine that gradient dissimilation arises from an anti-coarticulation strategy: it would stem not from the difficulty of articulating two aspiration features at a short distance, but from the necessity to preserve the perceptibility of the intervening vowel. It remains to be seen what predictions such a contrastive hypothesis would make with regard to purely articulatory approaches.

4.3 Another precursor to complete dissimilation?

As mentioned in the Introduction, Garrett (2015) claims that the gradient reduction of aspiration in Halh is 'obviously the precursor to complete deaspiration'. Of course, this assumption cannot be controlled in the absence of a careful longitudinal study of the languages in question. The motivation for this statement is probably the parallel with the other dialects of Mongolian, which have undergone a complete dissimilation: Halh would attest an incipient stage of a change that was completed in its neighbour dialects. Further arguments support Garrett's idea. Within the Mongolian dialects, it should be underlined that the same set of consonants is involved in both complete and gradient dissimilations. In particular, the sibilant triggers dissimilation in both cases. Second, the gradient dissimilation pattern is lexically regular, at least in AE: it happens in all the words presenting the relevant configuration. If gradient dissimilation is a precursor to complete dissimilation, it would be consistent with the regularity of aspiration dissimilation sound changes, as observed in other dialects of Mongolian, Ancient Greek, Sanskrit or Quechua. A last point is the connection with vowel length. As we have mentioned in section 2, complete dissimilation, as in Chahar, can be sensitive to the weight of the intervening rhyme: it is blocked when the aspirated consonants are separated by more than a short vowel. We have seen in section 3.2.3 that the AE data suggest a similar sensitivity to vowel length: pre-aspiration of C_2 is not reduced in $C^hV{:}C^h$ with regard to $CV{:}C^h$ when C_1 is a sonorant. It could then be the case that the complete dissimilation patterns in Mongolian arose from a gradient reduction similar to the one in Halh or AE.

5 Conclusion and further steps

This study has looked at the effect of the aspiration of C_1 on the frequency of occurrence and the duration of pre-aspiration associated with C_2 in AE. We observe a pattern of gradient, regular dissimilation, and the avoidance of fully coarticulated C^hVC^h sequences. This pattern has counterparts in at least two other languages, Halh Mongolian and Georgian. Halh and AE contradict the prediction found in the literature that sequences of aspiration features within a short window should be prone to coarticulation. The motivation for this change could be motor planning, although it is not clear whether motor planning can generate a gradient and regular dissimilation instead of the sporadic, and apparently categorical dissimilations found in speech errors. A number of arguments support the idea that gradient dissimilation could be a precursor to complete dissimilation.

Importantly, these results need to be completed with further investigation. The first research question is whether the dissimilatory process is actually bidirectional, affecting both C_1 and C_2. Further analyses will be required to show whether the post-aspiration of C_1 in AE is affected by the type of C_2 in the same way as the pre-aspiration of C_2 is affected by the type of C_1.

Another important point to bear in mind is that a combination of the two ways to quantify aspiration dissimilation here may not be *fully* adequate to capture the phenomenon in question. We can make two observations. Firstly, what has been labelled local breathiness here can be of variable noisiness. Noisiness could be trading off with the durational properties of breathiness and pre-aspiration, and so focusing on only one of the two may not provide the full picture. The second observation is that even the modal component of the vowel can be of variable breathiness. In other words, local breathiness, which serves as a transition to the voiceless pre-aspiration, may be as important for the subject matter as the slightly more global breathiness within the vocalic interval. It remains to be seen whether incorporating these aspects into further analyses will affect the interpretation of the data. We are planning to address these two questions via Cepstral Peak Prominence analyses (for noisiness), measurement and analysis of the post-aspiration component in C_2, and a future fieldwork in Aberystwyth to obtain information relevant for C_1.

Comments invited

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Appendix

This section provides the output of the statistical analyses (for the optimal models only), relevant for the section 3.2.1 above presenting the evidence of dissimilatory patterns in Aberystwyth English. [sg] means [+spread glottis]; son. = sonorant and F = foot.

Variable	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-2.0091	0.4699	-4.276	1.90e-05 ***
/a/ vs. /ɑː/	0.6476	0.2457	2.636	0.00839 **
/a/ vs. /ɛ/	0.6246	0.2124	2.941	0.00327 **
/a/ vs. /ɪ/	2.0102	0.1691	11.889	< 2e-16 ***
/a/ vs. /ɒ/	0.3501	0.1745	2.006	0.04481 *
/a/ vs. /oː/	1.3132	0.2728	4.813	1.49e-06 ***
/a/ vs. /ʊ/	1.6576	0.2841	5.834	5.43e-09 ***
/a/ vs. /ʌ/	1.4983	0.1981	7.565	3.88e-14 ***
/p/ vs. /t/	2.4719	0.1399	17.667	< 2e-16 ***
/t/ vs. /k/	0.2085	0.1377	1.514	0.13002
lenis vs. [sg]	-0.8679	0.1922	-4.516	6.30e-06 ***
[sg] vs. son.	0.7663	0.1289	5.945	2.77e-09 ***
F-final vs. F-medial	-0.8242	0.1294	-6.367	1.92e-10 ***

Table 1: Statistical results for the frequency of occurrence of pre-aspiration

Variable	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-1.991057	0.540025	-3.687	0.000227 ***
/a/ vs. /ɑː/	0.494705	0.219807	2.251	0.024409 *
/a/ vs. /ɛ/	0.325173	0.193604	1.680	0.093039 .
/a/ vs. /ɪ/	1.791292	0.150323	11.916	< 2e-16 ***
/a/ vs. /ɒ/	0.490085	0.154515	3.172	0.001515 **
/a/ vs. /oː/	1.502425	0.236556	6.351	2.14e-10 ***
/a/ vs. /ʊ/	1.775187	0.242959	7.307	2.74e-13 ***
/a/ vs. /ʌ/	1.096350	0.179432	6.110	9.96e-10 ***
/p/ vs. /t/	1.425797	0.121769	11.709	< 2e-16 ***
/t/ vs. /k/	-0.003031	0.118926	-0.025	0.979665
lenis vs. [sg]	-0.526080	0.166150	-3.166	0.001544 **
[sg] vs. son.	0.535936	0.113144	4.737	2.17e-06 ***
F-final vs. F-medial	-0.874530	0.114515	-7.637	2.23e-14 ***

Table 2: Statistical results for the frequency of occurrence of breathiness

—

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Variable	Estimate	Std. Error	df	t-value	Pr(>|t|)
(Intercept)	11.9886	0.5612	14.0300	21.36	4.25e-12 ***
/a/ vs. /ɑː/	-3.1112	0.2206	175.4400	-14.100	< 2e-16 ***
/a/ vs. /ɛ/	-1.2419	0.1788	159.4800	-6.947	8.96e-11 ***
/a/ vs. /ɪ/	-3.4320	0.1576	191.1800	-21.774	< 2e-16 ***
/a/ vs. /ɒ/	0.1046	0.1434	155.6800	0.729	0.467
/a/ vs. /oː/	-3.0583	0.2546	179.0300	-12.011	< 2e-16 ***
/a/ vs. /ʊ/	-3.5306	0.2629	188.9800	-13.430	< 2e-16 ***
/a/ vs. /ʌ/	-2.6693	0.1815	208.4300	-14.704	< 2e-16 ***
/p/ vs. /t/	1.7724	0.1605	174.8400	11.041	< 2e-16 ***
/t/ vs. /k/	-1.2947	0.1108	166.1300	-11.690	< 2e-16 ***
lenis vs. [sg]	-1.6552	0.1321	214.5700	-12.528	< 2e-16 ***
[sg] vs. son.	-1.0381	0.1118	162.4600	-9.288	< 2e-16 ***
F-final vs. F-medial	-2.2874	0.1104	187.5700	-20.714	< 2e-16 ***

Table 3: Statistical results for pre-aspiration duration (normalised)

Variable	Estimate	Std. Error	df	t-value	Pr(>|t|)
(Intercept)	7.7722	0.5692	14.2600	13.655	1.39e-09 ***
/a/ vs. /ɑː/	0.4655	0.2358	184.6000	1.974	0.049883 *
/a/ vs. /ɛ/	0.5031	0.1907	170.7900	2.637	0.009124 **
/a/ vs. /ɪ/	-0.9655	0.1642	197.0400	-5.881	1.72e-08 ***
/a/ vs. /ɒ/	-1.0753	0.1543	168.0900	-6.970	6.87e-11 ***
/a/ vs. /oː/	-0.6828	0.2782	203.2800	-2.454	0.014966 *
/a/ vs. /ʊ/	-1.4896	0.2877	233.1100	-5.177	4.87e-07 ***
/a/ vs. /ʌ/	-0.4714	0.1890	212.1100	-2.494	0.013396 *
/p/ vs. /t/	0.5924	0.1728	193.3200	3.428	0.000742 ***
/t/ vs. /k/	-0.5594	0.1185	179.2600	-4.719	4.75e-06 ***
lenis vs. [sg]	-0.4689	0.1349	199.8400	-3.477	0.000622 ***
[sg] vs. son.	0.6090	0.1214	183.6900	5.014	1.25e-06 ***
F-final vs. F-medial	-0.7423	0.1160	198.7900	-6.398	1.11e-09 ***

Table 4: Statistical results for breathiness duration (normalised)