The Development of the Aspiration Contrast in Germanic

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1. Introduction

1.1 Purpose

Previous literature distinguishes between two types of languages with regard to the laryngeal specification of obstruents. In some languages, voiced obstruents contrast with voiceless ones. For this reason, these languages are sometimes called voice languages. The voice contrast is particularly characteristic of the Romance and Slavic language families. French and Polish, for example, have an obstruent system where obstruents are either voiced or voiceless (Iverson & Salmons 1995: 373). In other languages, fortis obstruents contrast with lenis obstruents. Fortis obstruents are voiceless and aspirated, whereas lenis obstruents are plain voiceless (or, more precisely, partially devoiced). These languages are called aspiration languages[1]. In other words, whereas voice is the contrastive feature for obstruents in voice languages, aspiration is distinctive in aspiration languages. The aspiration contrast is especially common in the Germanic language group. English, Swedish, and German, for example, distinguish between fortis and lenis obstruents, but do not have the voiceless–voiced distinction in plosives and fricatives (Iverson & Salmons 1995: 377).

The nature of the contrast between aspiration languages and voice languages has been researched quite extensively. Several studies argue that the distinction is purely phonetic and that, underlyingly, all languages are voice languages. The aspiration contrast, then, is implemented phonetically, so that this distinction only appears on the surface. Examples of this view are Jansen (2004, 2007). Others claim that we are dealing with two different types of languages, in that the aspiration contrast and the voice contrast can both be phonemically specified. Examples of the latter approach are Iverson & Salmons (1995), Vaux (2002), and Spaargaren (2009). Since the phonology and phonetics of laryngeal specification have been discussed elaborately, this thesis will not be concerned with the issue of whether the aspiration distinction found in Germanic obstruent systems is a phonological or phonetic phenomenon. Of more importance here are the factors giving rise to the emergence of aspiration languages. To my knowledge, the problem of which contrast (if any) is older and, hence, what triggered the emergence of the other laryngeal system has not been discussed extensively before. Previous literature seems to agree that the voice distinction was already present in Proto-Indo-European and that there is not enough evidence to suggest that voice and aspiration systems cooccurred from the beginning onwards. Beekes (1995: 24) reconstructs plain voiceless, plain voiced, and aspirated voiced plosives for Indo-European, for example, and Iverson & Salmons (1995: 387, 2003a: 54) argue that the aspiration contrast is a Germanic innovation which separated Germanic from Indo-European. These claims suggest that voice languages existed before aspiration languages and that, hence, some kind of change in a voice language must have resulted in the emergence of the aspiration distinction. The nature of such a change is unclear, however, and only a few sound changes have been proposed. Firstly, Iverson & Salmons (2003a) argue for phonetic enhancement of an Indo-European voice contrast, whereby aspiration emerged in order to increase the voice distinction. Secondly, Kortlandt (1996, 1997, 2000) has argued for a glottalic set of plosives turning into aspirated stops in Germanic by positing that preaspirated stops in Germanic languages such as Swedish and High German descend from glottalic plosives.

[1] Spaargaren (2009: 17) states that the term "aspiration language' and 'voice language' should be used to indicate that aspiration or voice are phonologically specified. This thesis makes no claims about the phonological or phonetic nature of aspiration and voice, however. Here, the two terms are simply used to refer to languages which at least have an aspiration contrast or a voice distinction on the surface. Applying these terms makes it easier to refer to different types of languages clearly and briefly.

This thesis will contribute to the current literature on aspiration languages by examining the origin of the aspiration contrast and by analysing what factors triggered the emergence of the aspiration distinction. Ultimately, the analysis will result in the proposal of a method with which experimental, phonetic evidence for certain sound changes may be found. This goal will be achieved by studying various theories on the nature of the sound change involved and by developing an experimental method whereby the nature of the process can be uncovered through the examination of phonetic data, based on typological and phonetic considerations. A pilot study will be done to test the method and to provide some preliminary results.

1.2 Theoretical background

1.2.1 Laryngeal systems

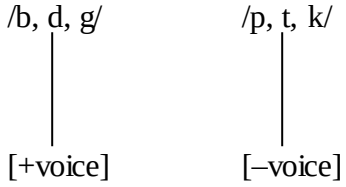
With regard to the laryngeal specification of obstruents, there are two main approaches: broad interpretation of the feature [voice] and narrow interpretation of the feature [voice] (Hall 2001: 32). Although the distinction is not directly relevant for the goal of this paper, a brief explanation of both views will be provided in order to explain the difference between voice languages and aspiration languages in as much detail as possible.

Broad interpretation of the feature [voice]

Hall (2001: 32) calls the broad approach is called such because it argues that all languages have a single, universal laryngeal system based on a voice contrast. Phonologically, obstruents can either be specified as voiced or voiceless. This is assumed to hold for any language, even languages like English, which contrast plain voiceless obstruents with aspirated voiceless obstruents phonetically (Spaargaren 2009: 16). Naturally, the precise specification of obstruents in a phonological voiced–voiceless model depends on the chosen approach to feature specification. Keating (1984: 288) proposes a model based on binary features, so that, underlyingly, obstruents are specified as either [+voice] or [–voice]. Lombardi (1995: 365–372), on the other hand, argues for privative specification. In such a model, segments are solely specified for a feature if it is present. For laryngeal specification, this means that voiced obstruents are specified as [voiced], whereas voiceless ones are left unspecified, because voice is not present in these segments. (1) illustrates the broad interpretation of the feature [voice] with binary as well as privative features[2].

(1) Broad interpretation of the feature [voice]

a. Binary feature specification



[2] In the rest of this thesis, I will use privative specification. For a thorough discussion on privative and binary features in relation to laryngeal specification, I refer to Jansen (2004: 198-200).

b. Privative feature specification

The broad approach does acknowledge that obstruents may have other characteristics than voice on the surface, since the specification [voice] cannot sufficiently describe the realisations of all obstruents on its own. The feature cannot explain why aspiration occurs on all fortis obstruents in some languages, for example, and why they contrast with voiceless aspirated obstruents rather than with voiced ones (Spaargaren 2007: 116). Hence, another feature that denotes aspiration must be present phonetically. The broad approach therefore does distinguish between two superficial types of languages: languages which contrast voiced and voiceless obstruents on the surface and languages which distinguish between aspirated voiceless and plain voiceless obstruents phonetically (Iverson & Salmons 2003a: 49). The phonetic system of type one is illustrated in (2):

(2) The surface obstruent system of languages with the contrast voiceless–voiced

p	:	b
t	:	d
k	:	g

Keating (1984: 288) argues that, in languages which do not have a surface voice contrast, the phonemic feature [voice] is phonetically implemented as one of three laryngeal categories: 1) [voiced] when obstruents are fully voiced, 2) [voiceless unaspirated] when segments are plain voiceless, and 3) [voiceless aspirated] when obstruents are voiceless and aspirated. In other words, [voice] describes all of the world's languages' obstruents phonemically, but in languages which do not have a surface voice contrast, [voice] surfaces phonetically as voiceless aspirated or voiceless unaspirated. Aspiration is only relevant on the phonetic level in aspiration languages (Spaargaren 2007: 115). Languages of type two, then, underlyingly have the contrast illustrated in (2) but display the surface contrast shown in (3):

(3) The surface obstruent system of languages with the contrast aspirated–unaspirated

p^h	:	p
t^h	:	t
k^h	:	k

Narrow interpretation of the feature [voice]

The narrow interpretation, also known as Laryngeal Realism, proposes that there is no single underlying laryngeal specification for obstruents across the world's languages. Instead, proponents believe that the systems in (2) and (3) are both phonemic (Hall 2001: 32; Spaargaren 2007: 116). In some languages, the obstruents /b, d, g/ do carry [voice] and /p, t, k/ are unspecified (assuming that features are privative). This laryngeal specification is maintained on the surface. Some languages, however, provide evidence against the phonemic specification of /b, d, g/. It is argued that, in English and German, for example, /p, t, k/ are specified instead. Proponents of Laryngeal Realism provide several arguments against the view that the aspiration contrast is merely phonetic. Firstly, obstruents in these languages are

never truly voiced unless they are placed between sonorants, which are inherently voiced (Iverson & Salmons 1995: 369, 384). /b, d, g/ are partly devoiced inherently and only acquire voice through assimilation to sonorants. Secondly, observations on assimilation in these languages do not correlate with what should occur in true voice languages. As will be explained in Chapter 2, only specified features should spread, since absent features cannot play an active part in linguistic processes. However, in Germanic it is often voicelessness and not voice that spreads to neighbouring segments. This should not be possible if obstruents are specified as voiced.

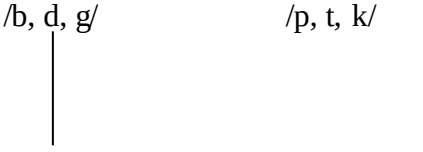
The main claim of the narrow approach is that the state of the glottis, rather than the vibration of the vocal folds, is relevant in the "laryngeal phonology of obstruents" in languages which contrast plain voiceless obstruents with voiceless aspirated ones (Sweet 1877: 77; Spaargaren 2009: 38). Sweet (1877: 77) states that obstruents in several languages can be distinguished based on the force of air release and that their perceptibility mainly depends on "the force of [air] compression". Winteler (1867: 21) and Sievers (1901: 69-73, 140) argue that the state of the glottis and air pressure are more relevant in languages such as German and English than vocal fold vibration. Crucially, both factors are relevant for an aspiration contrast, as a more open glottis and relatively high air pressure result in some degree of aspiration (Spaargaren 2009: 38; see Chapter 2). Winteler (1976: 21) distinguishes between weak voiceless sounds and strong voiceless segments (based on air pressure) in Zurich German, for example. He observes that /p, t, k, f, s/ involve more air pressure than /b, d, g, v, z/. Hence, he defines the first set as fortis and the latter set as lenis. Sievers (1901: 69–71, 140) makes the same observation and, in addition, argues that the two sets of plosives can be distinguished from one another based on the state of the glottis involved in their articulation, rather than based on the presence or lack of vocal fold vibration. The lower air pressure in /b, d, g/ etc. is the result of an obstruction of the air stream, caused by the fact that the vocal folds are closer together than for /p, t, k/. Consequently, the glottis is less open for fortis sounds. Vocal fold vibration, which causes voicing is not involved in both /p, t, k/ and /b, d, g/.

Based on the above observations, the narrow approach argues that there must be a second type of language: one in which /p, t, k/ are specified for aspiration and where there is no specification for voice, as there is no reason to assume that voice is phonemically more relevant than air pressure or the state of the glottis. The narrow approach, in short, acknowledges that the systems in (2) and (3) are both phonemic.

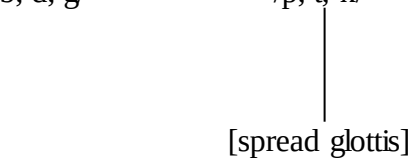
The literature has proposed several features to describe the phonemic system of aspiration languages. Many studies base their feature specification on a property that is crucial for aspiration to take place: high air pressure or a spread glottis. Browman & Goldstein (1989: 226) choose [wide] and [narrow] to indicate the width of the glottal opening, for example, and Harris (1994: 134) indicates aspiration with H (high air pressure). Furthermore, Avery & Idsardi (2001: 42) opt for Glottal Width and Iverson and Salmons (2003a) describe aspiration as [spread glottis] Similarly, Honeybone (2005: 326) uses |spread|. In keeping with most recent literature (e.g. Iverson & Salmons 1995, 2003a), I will use the specification [spread glottis] in this thesis. (4) shows the phonemic specifications acknowledged by the narrow approach:

(4) The narrow approach: two phonemic systems

a. Voice languages



b. Aspiration languages



1.2.2 Framework: Evolutionary Phonology

Evolutionary Phonology was introduced as a framework by Blevins (2004), although earlier work by Ohala (1981, 1993) defends the same arguments. The main idea behind Evolutionary Phonology is that sound changes which are common or which occur crosslinguistically are likely to have a natural cause, triggered by perceptual or articulatory characteristics that human beings have in common. This section will describe Evolutionary Phonology. First, however, I will discuss why Evolutionary Phonology is preferred above other approaches, such as 'formalism' (Jansen 2004: 18) and the comparative method.

Limitations of formalist models and the comparative method

Jansen (2004: 18–24) contrasts Evolutionary Phonology with 'formalism' (which includes approaches such as Optimality Theory). Formalist approaches argue that humans possess inherent knowledge on optial language structure and that, therefore, they can instinctively deduce what output (e.g. surface realisation of a phonemic input) is the most optimal (Saville-Troike 2006: 190). In other words, "phonological processes [...] are motivated by a small number of grammar-internal principles that are essentially arbitrary with regard to the use of speech as a communication tool" (Jansen 2004: 18). In contrast with formalist approaches, Evolutionary Phonology argues that "speakers' grammars have no direct access to functional or 'ecological' principles such as articulatory effort minimisation or perceptual optimisation" (Jansen 2004: 242). In other words, the framework does not assume the existence of speakers' internal knowledge of linguistic constraints or any conscious adaptation on the part of the speaker at all. Rather, as Jansen (2004: 242) states, such constraints are merely the result of auditory and articulatory factors which cause language change. As long as there is no concrete evidence for language-internal triggers such as an internal rule set (Optimality Theory), we should not simply assume that change is caused by constraints (Blevins 2006: 118).

The main arguments against formalism are as follows. Firstly, formalist models pay insufficient attention to what constitutes a natural sound change and what does not. There are no clear limits "on what constitutes a possible phonological constraint" (Jansen 2004: 196). Hence, formalist models cannot explain what kind of changes are most likely to occur and which changes are least likely to happen. Consequently, any change could be posited within this framework, even though the human vocal tract and the human ear are subject to limitations (Jansen 2004: 196) (see Chapter 4). Secondly, formalist models generally simply observe that a certain change occurs, but they do not explain why (Jansen 2004: 196; Blevins 2006: 117). As Jansen (2004: 196) observes, sound changes are frequently claimed to be the effect of certain syllable structures, higher-order prosodic domains, or morpheme boundaries.

For example, he states that regressive voice assimilation is often seen when two obstruents occur on opposing sides of a morpheme boundary, but that morpheme structure does not explain this phenomenon independently (Jansen 2004: 196).

The second argument against formalism is also an argument against the comparative method. Blevins (2006: 130) argues that comparative linguistics is often purely hypothetical, as certain patterns are observed but not explained. In other words, the comparative method suggests that a change may have occurred based on certain patterns in language change, but it does not go further than merely describing the pattern. Crucially, Evolutionary Phonology does not reject the comparative method — it is merely given a smaller role in the reconstruction of sound change. As Blevins (2006: 130) states, the method is useful for observing changes which might have taken place, as it does reveal linguistic patterns. However, comparative analyses must be followed by an actual explanation.

The next section will discuss how Evolutionary Phonology attempts to provide evidence for certain sound changes.

Evolutionary Phonology

The framework of Evolutionary Phonology focuses on providing actual evidence for historical processes, rather than reconstructions and assumptions only. This is argued to be possible because phonetics often plays a role in sound change (Blevins 2006: 119, 125). The influence of phonetic factors can only be denied if we find concrete proof for extraphonological causes. This hypothesis entails that reconstructions may be improved by analysing the phonetic factors which are involved in sound change. In other words, sound change should be explained by providing reconstructions as well as phonetic explanations (Blevins 2006: 117, 119). Reconstruction, then, is only the first stage of analyses of sound change, and should be followed by phonetic analyses (the second stage of analyses). Evolutionary Phonology draws its inspiration from two Neogrammarian principles:

(5) The Neogrammarian principles of sound change (Blevins 2006: 119, 156)
   a. Recurrent synchronic sound patterns are a direct reflection of their diachronic origins.
   b. Regular phonetically-based sound change is the common source of recurrent sound patterns.

Evolutionary Phonology examines these hypotheses and studies their implications for models of sound change. But how can historical sound change be examined phonetically if we do not have recordings from the past? Ohala (1993: 156) argues that we need to look for evidence from similar, synchronic processes. He claims that there are parallels between phonetic variation and sound change, since some synchronic variation resembles proposed sound changes (see Chapter 4). Ohala (1993: 156) adds that the Neogrammarian hypotheses are especially promising with regard to crosslinguistic processes. This is especially relevant when languages in which the same phenomenon is observed are unrelated, but the hypotheses also apply to languages which stem from a single ancestor, as similarities between related languages enable us to see what change might have occurred in this earlier language (Ohala 1993: 156, 160). Ohala (1993: 156) and Blevins (2006: 119) argue that crosslinguistic changes are likely to have a phonetic trigger, since phonetic factors are frequently universal due to their naturalness. In other words, phonetics may work the same way across languages, since all humans are born with approximately the same articulatory and perceptual design.

The observation that phonetics is universal due to a shared articulatory and perceptual system brings us to the discussion of what kind of phonetic factors can trigger crosslinguistic

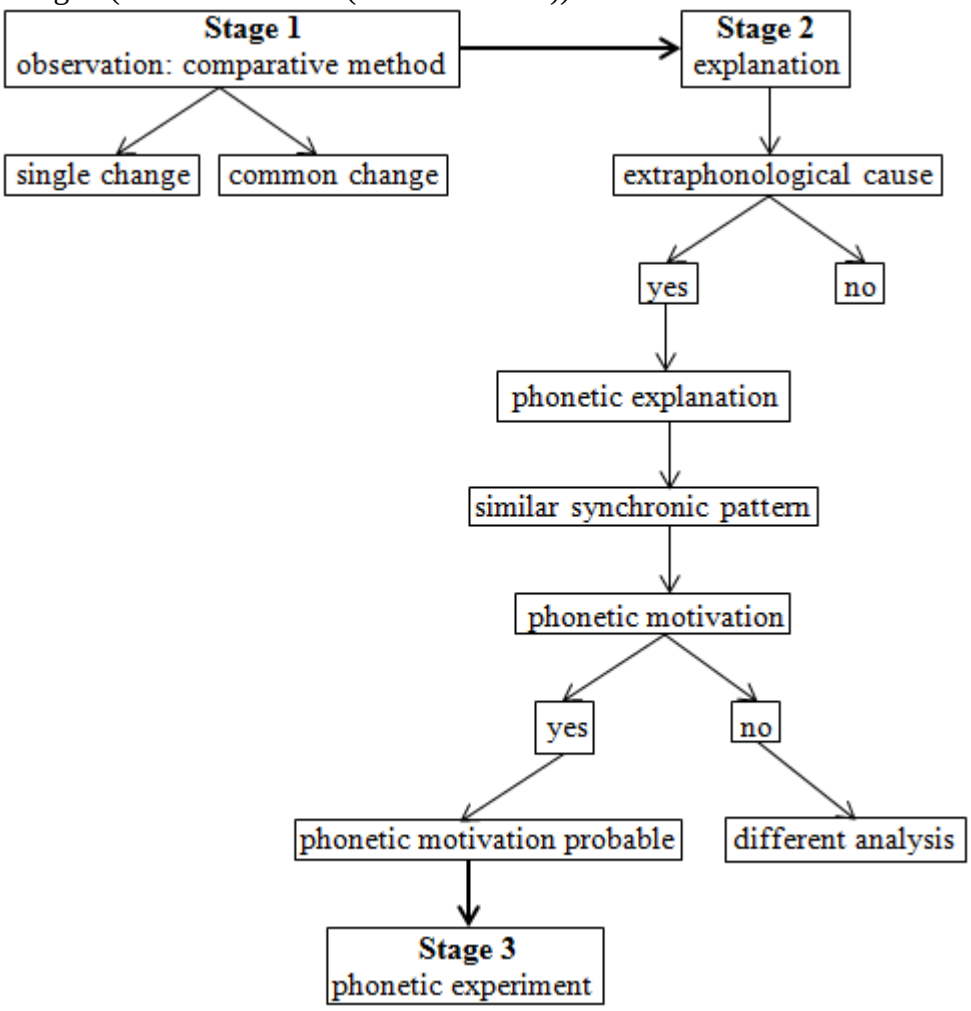
sound changes. The traditional view is that speakers initiate sound change (Ohala 1981: 178). If so, articulatory factors may be dominant. Ohala (1981: 178) mentions three major triggers that have been proposed in earlier literature:

(6) Possible roles of the speaker in the initiation of sound change
   a. Speakers adapt their pronunciation to something that takes less effort.
   b. Speakers modify their pronunciation to make their speech clearer for listeners.
   c. Speakers change their pronunciation to simplify the grammar — to make their speech easier to process cognitively.

The proposed causes of sound change in (6) imply that, although in all cases speakers initiate sound change, pronunciation may be adapted for articulatory as well as for perceptual reasons. Evolutionary Phonology emphasises the role of listeners. Jansen (2004: 242), for example, proposes that the following factors are involved in sound change: rote learning (when language learners attempt to imitate the language produced by older generations as closely as possible), transmission noise that confuses the listener, and positive feedback to the change which was initiated due to this confusion. 'Positive feedback' means that listeners accept the changed pronunciation as the pronunciation norm. Recall the example of regressive voice assimilation provided above: an obstruent tends to assimilate to a following one in terms of voice if the two obstruents are separated by a morpheme boundary. Steriade (1997: 2) and Jansen (2004: 195) state that fortis–lenis assimilation should be attributed to the perceptibility of fortis and lenis in certain contexts. In the abovementioned context, coarticulation in terms of voice often takes place, so that the left segment becomes more similar to the one on the right side of the morpheme boundary. Consequently, listeners may no longer perceive that a segment is voiced as opposed to an adjacent voiceless one, and vice versa. If so, they reanalyse the segment as having the same specification as the one on its right. This results in actual language change, in the form of voice assimilation (Jansen 2004: 195).

Ultimately, the claim that sound change has a phonetic trigger enables Evolutionary Phonology to claim that potential triggers of sound change can be researched by analysing similar, synchronic processes in the laboratory and determining their causes (Ohala 1981: 186; Blevins 2006: 155; Kirby 2010: 149–151). Laboratory research is the third stage of analyses based on Evolutionary Phonology. This is, of course, possible because phonetic analysis can be done experimentally. The idea is that, if a synchronic process has a certain phonetic motivation and the parallel sound change is found across various languages, the historical sound change may have the same cause. For clarity, Evolutionary Phonology is summarised in (7):

(7) Evolutionary Phonology: explaining common and crosslinguistic sound changes (based on Blevins (2006: 117–158)).



In short, Evolutionary Phonology suggests that analyses of sound change should have three components: reconstruction, consideration of phonetic probability to determine what kind of change may have taken place, and phonetic experiments.

1.3 Research questions

Previous literature reveals several gaps in relation to the analysis of aspiration languages and their development. Firstly, few studies have focused on the age of the aspiration contrast. Quite a few analyses of the contrast in many modern languages, such as English, Dutch and Turkish have been proposed (e.g. Iverson & Salmons 1995, 2003a; Avery 1997). Studies on the reconstruction of the aspiration contrast in older forms of modern aspiration languages are sparse, however. Some work has been done by Iverson & Salmons (1995, 2003a) on the possibility that Germanic was an aspiration language. Although their analyses are elaborate and include considerations on the naturalness of certain changes, they cannot provide actual, experimental evidence. Since phonetic observations are not made based on actual speech. Furthermore, Spaargaren (2009: 69) has argued that Old English already was an aspiration language. Her analysis focuses solely on plosives, however, rather than on the entire obstruent system. I hope to contribute to these studies by providing additional experimental data on aspiration in Germanic, focusing on stops as well as on fricatives. By doing so, I will show

that the aspiration contrast appears to have been present in earlier Germanic plosives and fricatives.

Secondly, although several theories on the development of the aspiration contrast exist, previous literature has mostly focused on finding support for certain sound changes rather than on comparing the likelihood of these changes. Work on the emergence of aspiration languages from a historical perspective has mostly been done with the traditional reconstruction of Indo-European stops in mind. Iverson & Salmons (1995; 2003a) discuss Laryngeal Realism in Germanic, for example. Although they argue that phonetic enhancement may have resulted in the aspiration contrast, they do not provide experimental data in support of this process. Another theory that has been put forward is the glottalic theory. Explaining aspiration with the glottalic theory in mind has been proven effective across various Indo-European language families. Kortlandt (1988a: 356) suggests that Icelandic preaspiration may have developed from voiceless glottalised stops, for instance, while Kroonen (forthcoming) argues that the glottalic theory explains the existence of preaspiration in Germanic languages in general and in Celtic. Furthermore, Kortlandt (1988a: 356) claims that the Modern English glottal stop is a descendent of Indo-European voiceless glottalic plosives. This thesis will compare the two approaches in terms of typological and phonetic probability. Furthermore, a research method will be proposed with which the likelihood of Germanic enhancement and aspiration coming from glottalisation can be analysed. By designing this method, I hope to show how the development of aspiration languages can be examined with actual, phonetic data rather than with reconstruction and assumptions alone.

As stated above, this thesis aims to provide a thorough analysis of the origin and development of the aspiration contrast in obstruent systems: how it developed from Indo-European, the timeframe in which certain changes relevant to the distinction between voice languages and aspiration languages must have occurred, and how to analyse historical changes like this in the present. Hence, the research question is as follows: how old is the aspiration contrast and how did it develop? Considering the abovementioned gaps in the literature on aspiration languages, I posit the following sub questions:

1. Is the development of the aspiration contrast a historical process and, if so, how far back can it be placed?
2. From a phonetic and typological perspective, what sound changes could have resulted in the emergence of the aspiration contrast?
3. Can we provide experimental evidence for these historical changes with modern research techniques and, if so, what do the results of such experiments imply?

1.4 Overview

As stated above, the research question will be discussed in three stages. Chapter 2 will provide an explanation of the nature of Germanic aspiration. In addition, it will argue that the development of the aspiration contrast is a historical change, which must at least have occurred before the emergence of the earliest Germanic languages. Chapter 3 will then discuss various possible sound changes leading to the development of the aspiration contrast and compare these with respect to naturalness and typology. Chapter 4 will build on Chapter 3 by incorporating the findings in a methodology proposed for generating actual evidence for how aspiration languages developed. This methodology will be tested in Chapter 5. Chapter 6 will discuss the findings from the previous chapters in a single conclusion on the development of aspiration languages and how to find evidence for certain sound changes involved in this process.

2. Reconstructing the aspiration contrast

2.1 Introduction

Recall that, in order to provide a reliable analysis of sound change, Evolutionary Phonology posits three necessary stages of analysis: reconstruction, analysis of the phonetic probability of changes, and conducting phonetic experiments. This chapter focuses on the first stage. I will argue that the aspiration contrast emerged due to a diachronic change in the past, so that the emergence of aspiration languages can be regarded as a historical sound change that took place in Germanic or which was a parallel change in various old Germanic languages. Before reconstructing the contrast, however, I will provide an extensive description of aspiration and voice in 2.2. Section 2.3 will discuss the properties which distinguish aspiration languages from voice languages. In other words, these sections will reveal what phonological and/or phonetic properties to look for when reconstructing the aspiration contrast. 2.4 describes a case study on aspiration in Old English. I will argue that Old English was, indeed, an aspiration language from its early stage onwards. Consequently, the conclusion presented in 2.5 is that the aspiration distinction should be reconstructed as a historical change that must at least have taken place shortly after the split-up of the Germanic languages and, perhaps, earlier.

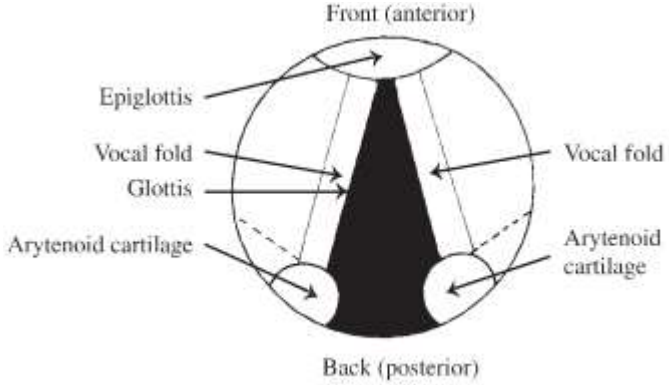
2.2 Defining voice and aspiration

2.2.1 Phonation types

The aerodynamic–myoelastic model of phonation

As stated in Chapter 1, voice and aspiration are laryngeal features. This means that the lack or presence of voice and aspiration is determined by the settings of the laryngeal muscles. The larynx contains the vocal folds and the glottis, so it is here that vocal fold vibration and glottal spreading can be measured. (1) is a simplified drawing of the larynx.

(1) The larynx (Collins & Mees 2003: 82)



There is no single strategy for pronouncing voiced sounds in all languages, however, so there are various different models to describe the production of voiced and voiceless segments (Laver 1994: 191–192). Not all of these models are relevant for a description of English obstruent voicing, so not all of them will be discussed here. I will focus on one model that is

important for analysing voice and aspiration of Germanic obstruents, namely the aerodynamic–myoelastic model of phonation (Van den Berg 1962: 93; Esling & Harris 2014: 354). Although other models may also be relevant, a description of the aerodynamic–myoelastic model should suffice for the purposes of this thesis.

The fact that the name of the model includes two elements suggests that the production of voice is based on the interaction of different laryngeal phenomena. 'Myoelastic' refers to the elasticity of the muscles in the larynx. During the production of sounds, these muscles may bring the vocal folds together and then bounce back. This process of contraction and bouncing back causes vocal cord vibration: the movement generates periodic sound waves (pulses), which are audible. The aerodynamic–myoelastic model states that both elasticity of the laryngeal muscles and vocal fold vibration are a prerequisite for voicing: the combination of vibration, air pressure, airflow, and "mechanical factors in laryngeal muscles" results in voiced sounds (Laver 1994: 192).

Laver (1994: 192) also mentions the importance of air pressure and airflow. This is what the term 'aerodynamic' denotes. Airflow from the lungs enters the larynx and interacts with the myoelastic force of the laryngeal muscles to create audible sound. Before articulation, the vocal folds are together. The air from the lungs creates a build-up of pressure behind the vocal folds, however, until the pressure is high enough to force the vocal folds apart. The gap between the vocal folds is the glottis. When air escapes through this opening, the air pressure drops and, consequently, the elasticity of the laryngeal muscles ensures that the vocal folds come back together. Voiced sounds are the result of numerous rapid repetitions of this cycle.

The aerodynamic–myoelastic model acknowledges various articulatory settings that are relevant for the distinction between voiced and voiceless sounds and for the contrast between plain and aspirated segments. These articulatory configurations of the vocal tract are called phonation types: types of sound which can be produced by the combined effort of the laryngeal elements (see (1)) and which can be identified by looking at turbulence and the vibratory patterns of the vocal folds (Laver 1994: 132). Turbulence denotes the amount of air that plays a role in the creation of sounds. Some types of segments, as we will see, require a larger amount of air than others. Vibratory patterns can be identified by observing the form of sound waves. These are periodic for voiced sounds, for example, whereas they are continuous for voiceless segments (Laver 1994: 191). The literature distinguishes between two main types of phonation, namely voiced phonation and voiceless phonation (Laver 1994: 187, 191). A definition of both phonation types is required for an accurate description of obstruent behaviour in aspiration languages and in order to see whether obstruents in aspiration languages correlate with what the aerodynamic–myoelastic model of phonation describes as voiceless and voiced. This section will focus on the characteristics of voiceless and voiced phonation which are relevant for the articulation of Germanic obstruents.

Voiceless phonation

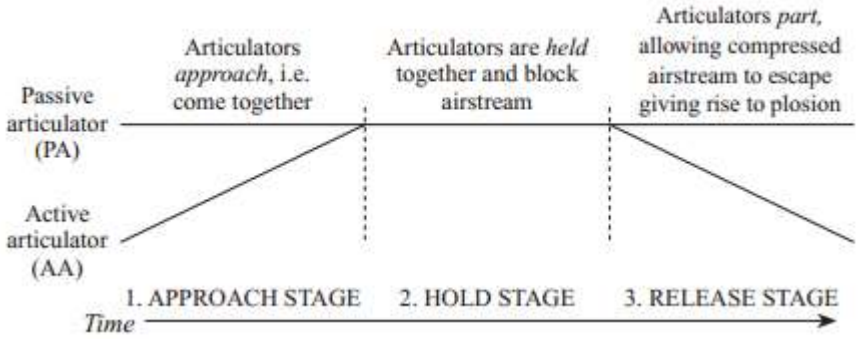
Voiceless phonation is the phonation type used for all voiceless sounds in the world's languages. Types of voiceless phonation are nil phonation, breath phonation, whisper phonation, creak phonation, prephonation, and unphonated segments (Esling & Harris 2014: 354). I will only discuss prephonation and breath phonation here, since, as we will see, these phonation states suffice to describe the articulation of Germanic voiceless obstruents.

Prephonation: plain voiceless plosives and glottalic plosives

Prephonation generates audible (though still voiceless) segments. The vocal folds are slightly apart, while the arytenoid muscles are tightly adducted (together). Crucially, there is no airflow, so the vocal folds cannot vibrate and the resulting sound is voiceless. Prephonation is

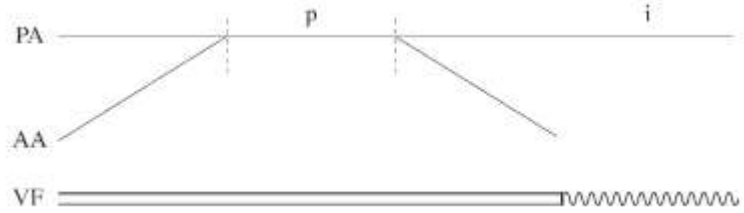
used for the articulation of voiceless unaspirated plosives, such as /p, t, k/. As (2) shows, the articulation of stops can be divided into three stages:

(2) Stages in the articulation of stops (Collins & Mees 2003: 149)



Plosives have an approach stage, a hold stage, and a release stage. During the hold stage, the phonation state is prephonation, so that no air escapes. When the closure is opened for a following voiced sound, however, the phonation state immediately shifts from prephonation to voice, as in (3). The double, straight line denotes non-vibrating vocal folds, the jagged line vibrating vocal folds.

(3) Articulation of unaspirated voiceless plosives (Collins & Mees 2003: 151).



Glottalic plosives may also include prephonation. This category of sounds includes ejectives, implosives, and glottalised plosives (Greenberg 1970: 123). Implosives are usually voiced, however (Greenberg 1970: 124). Hence, only ejectives and glottalised voiceless stops will be discussed here.

Ejectives are always voiceless, unlike implosives (Greenberg 1970: 125). They consist of two stages with regard to types of occlusion, as their articulation involves both a glottalic closure and an oral closure. Although the glottal occlusion is released after the release of the oral closure in most ejectives, various timings are observed in languages which have these sounds (Hackett 1955: 33; Greenberg 1970: 124). The two occlusions may be released simultaneously as well, in which case the result is a single segment. The glottal closure may also be released before the oral occlusion. There is one property that all ejectives have in common, however. They always involve a glottalic airstream mechanism: the glottis is closed, followed by an upwards movement of the larynx. The direction of the airstream is egressive, which means that the air is compressed in the mouth and pushed out through the mouth (Greenberg 1970: 127; Trask 2004).

Glottalised plosives differ from ejectives in that their articulation does not require a glottalic airstream mechanism. Rather, they involve a pulmonic airstream mechanism: air is generated by the lungs, which is then moved upwards through the larynx. The larynx itself does not move. Moreover, glottalised plosives differ from plain stops in that the airstream through the larynx is, at some point, stopped by closure of the glottis (Trask 2004). As in ejectives, glottal closure may occur before or after oral occlusion, which results in

preglottalisation and postglottalisation respectively. Both situations are called glottal reinforcement. The glottal and oral occlusion may also occur simultaneously. If the closure in the glottis is complete, the outcome is glottal replacement (the glottal stop replaces the oral stop). When the glottal occlusion is incomplete, however, the result is an oral plosive articulated with creaky voice (Greenberg 1970: 127).

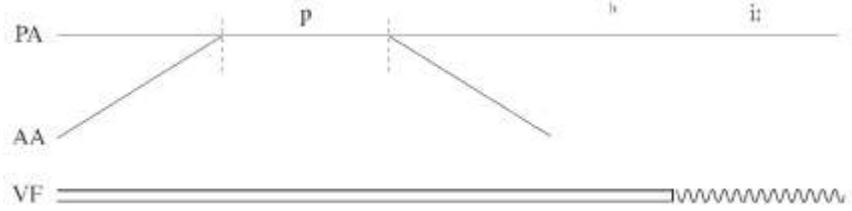
Breath phonation: fricatives and aspirated voiceless plosives

Breath phonation, in contrast to prephonation, involves a high volume of air flow and a widely abducted glottis (Laver 1994: 184). Across the world's languages, this phonation type is found in fricatives, voiceless vowels, approximants, taps, flaps, trills, and nasals (Esling & Harris 2014: 115). For this thesis, the only relevant sounds are fricatives and voiceless vowels, as fricatives are obstruents and (as we will see) voiceless vowels are relevant for the analysis of aspirated sounds.

Fricatives are articulated with abducted vocal folds, so that there is a constant stream of air. They are different from stops in that there is no complete closure. Furthermore, In contrast to nil phonation, fricatives are audible — the rate of airflow involved in their articulation is higher (Esling & Harris 2014: 115). Consequently, the energy released during their pronunciation is measurable. Recall that nil phonation is characterised by a volume lower than 200–300 cm^3/s and that higher rates result in breath phonation. In stressed position, English /h/ (a voiceless glottal fricative) has an airflow of about 1000 cm^3/s, for example (Laver 2014: 189).

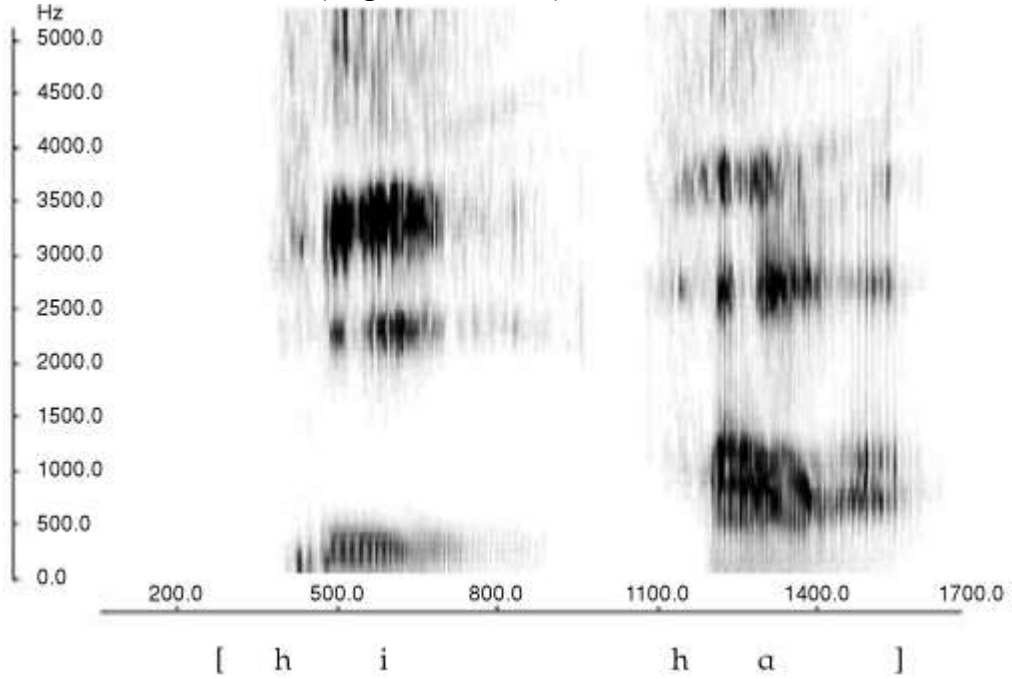
Although Esling & Harris (2014: 115) do not explicitly mention voiceless aspirated plosives in their list, I argue that these, too, involve a stage of breath phonation. The diagram in (3) showed that plain voiceless stops only have one phonation state: prephonation. (4) illustrates that this setting is also required for the articulation of aspirated voiceless plosives, but that breath also is involved:

(4) Articulation of aspirated voiceless plosives (Collins & Mees 2003: 151)



After the release of the voiceless plosive, there is a short period of voicelessness before the vowel becomes voiced: the vowel has a delayed voice onset time (VOT). Collins & Mees (2003: 151) label this voiceless period as aspirated ([^{h}]), showing that there is still some audible sound. But what, exactly, is this period of aspiration? They describe aspiration as "a delay in voicing after the release of a voiceless stop, often described as a brief 'puff of air' or an [h]-like sound" (Collins & Mees 2003: 51). If true, analysing the properties of [h] should tell us more about the exact nature of aspiration. According to measurements by Rogers (2014: 163), [h] is a weak period of energy in which the formants are the same as those of the following vowel. The only difference between [h] and a voiced vowel, therefore, is that for [h], the vocal folds do not vibrate and that the velocity of air flow is lower (resulting in breath phonation rather than voicing). Hence, we could transcribe a word such as *hat* as [ˈa̤æʔt]. This is clearly visible in Rogers' analysis of the sequences [hi] and [hɑ], reproduced in (5):

(5) [h] as a voiceless vowel (Rogers 2014: 163)



In (5), weak energy is measured for [h] at exactly the same frequencies as [i] and [ɑ]. The vowels are clearly voiced, however (as shown by the darker waves), whereas [h] is not. These observations show that [h] is pronounced with the articulators already in position for the following vowel, but that it is uttered with breath phonation rather than with voice. In other words, [h] is a voiceless vowel.

If [h] is, indeed, identical to aspiration noise, aspiration should also be a period of voicelessness where the articulators are in place for a neighbouring sound. This is exactly what is observed in the literature. Vowels and consonant sonorants following aspirated stops are always partially devoiced, whereas voicing starts immediately after plain voiceless plosives (see (3) and (4)). Ladefoged (2001: 120) shows the difference with recordings of both Spanish and English words which contain a voiceless plosive–vowel sequence. The English stop is aspirated, whereas the Spanish plosive is not:

(6) VOT of the vowel following aspirated and unaspirated voiceless plosives

a. Unaspirated plosive in Spanish *pesos* 'money'

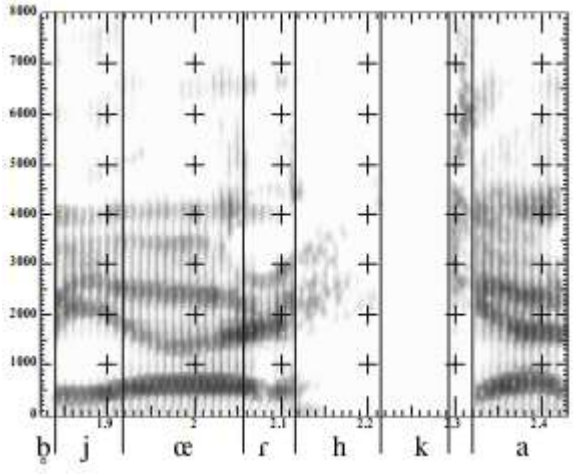
b. Aspirated plosive in English *paces*

Aspiration of plosives also tends to affect adjacent sonorants. Rather than a short 'puff of air', however, aspiration surfaces as sonorant devoicing in this context (Collins & Mees 2003: 152). Helgason (1999) provides empirical data on sonorant devoicing caused by the

preaspiration of a following stop in the Swedish Gräsö dialect. (7a) illustrates the effect of aspiration on a preceding [ɾ]:

(7) Sonorant devoicing in the Gräsö dialect of Swedish (Helgason 1999: 2)

a. Devoicing of [ɾ]



b. Fully voiced [ɾ] and devoicing of [n]

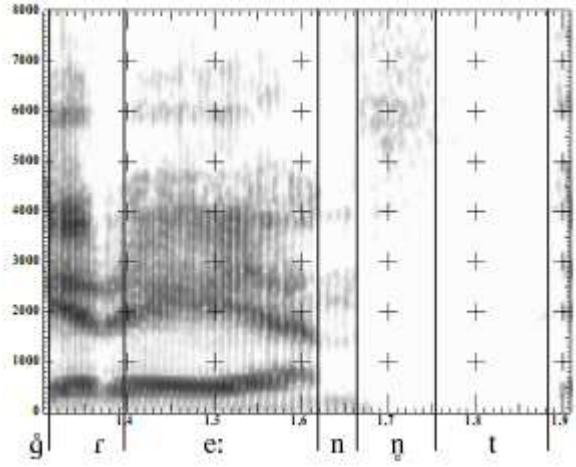


Diagram (7b) shows the usual length of [ɾ], when the sonorant is not affected by devoicing. In (7a), where [ɾ] precedes a preaspirated plosive, the sonorant has reduced to two-thirds of its original length. In total, twenty instances of [ɾ] before a preaspirated plosive were examined and all of them had undergone devoicing. The results showed that a large portion of [ɾ] was devoiced in this context (Helgason 1999: 3).

(7b) also indicates that [n] may undergo devoicing. When [n] is followed by a preaspirated voiceless plosive, the sonorant is largely devoiced — about two-thirds of the segment has become voiceless. Twelve instances of [m, n, ŋ] preceding a preaspirated plosive were analysed in total and ten turned out to have undergone devoicing (Helgason 1999: 3).

In short, like [h], aspiration is a voiceless period in which the articulators are already in place for the following sound (in the case of postaspiration) or still in the positions required for the preceding segment (in the case of preaspiration).

Voiced phonation

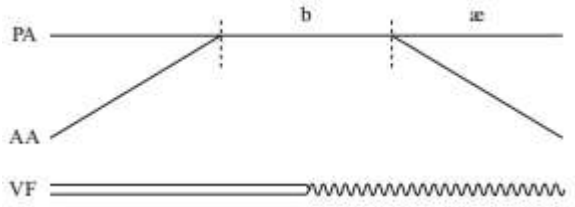
The phonation state for voiced sounds is voiced phonation. In the Germanic languages, this setting of the larynx is used for vowels and sonorant consonants. Above, it was explained that the interaction of the laryngeal muscles and airflow through the glottis are a prerequisite for

voicing: there needs to be a sufficient amount of air to let the vocal folds vibrate, and the laryngeal muscles need to be able to bounce back to their original position to create a cycle of so-called 'pulses' (see p. 15). This pulsed input of air makes voiced sounds different from voiceless ones, which have a continuous input of air (Laver 1994: 191). The process of voicing starts with a closed glottis. The vocal folds make contact during articulation. If air is released from the lungs into the larynx, the closure of the glottis results in a build-up of air pressure, since the air cannot escape as in voiceless sounds, when the glottis is spread (Laver 2014: 236). The air pressure keeps rising until it pushes the vocal folds apart, and voice is generated due to the compressed air flowing through the gap and triggering movement of the vocal folds. This vocal fold vibration generates audible utterances (Laver 2014: 236).

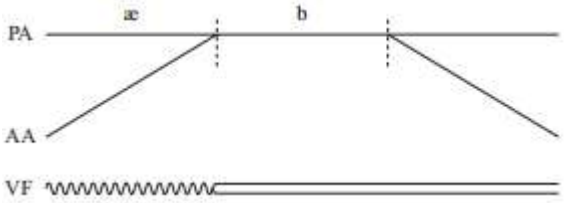
Crucially, Laver (2014: 236) does not regard obstruents as being voiced unless they are fully voiced: the hold phase of articulation must be characterised by voice completely. In other words, voiced plosives display voice from the first instant to the last instant of complete closure and voiced fricatives show voice from the first to the last occurrence of close approximation. Otherwise, the obstruents are regarded as partially devoiced (phonetically). The criterion that only fully voiced sounds are regarded as voiced is relevant, since this means that not all languages have voiced obstruents. Incomplete voicing of obstruents is often perceived as initial devoicing (when voicing starts late) or as final devoicing (when voicing ends early). Initial devoicing may occur in word-initial obstruents, whereas final devoicing may affect word-final ones. An overlapping term is partial devoicing. In languages which have partially devoiced obstruents instead of voiced ones, the articulation of obstruents can be described as in (8):

(8) Partial devoicing of obstruents (Collins and Mees 2003: 150)

a. Initial devoicing



b. Final devoicing



In (8), devoicing is indicated with the straight, double lines and voiced phonation with the jagged ones. (8a) shows onset of voicing that starts halfway through the hold stage, while (8b) illustrates lack of voicing.

2.2.2 Rule-based aspiration versus non-rule-based aspiration

Rule-based aspiration

One view of English aspiration is that it is a rule-based phenomenon: a context-sensitive and therefore nondistinctive (allophonic) feature (Vaux 2002: 1). Aspiration, in short, is claimed to be a phonetic feature that is added after obstruents in certain environments only. The perception of aspiration as an added segment entails that the laryngeal specification [spread

glottis] is not inherently present in obstruents. Consequently, the contrast between /p/ and /b/ could never be based on aspiration and there is an underlying voice distinction instead (see Chapter 1). Aspiration is claimed to be implemented phonetically in contexts which trigger it. Many theories have been put forward as to what exactly triggers aspiration in obstruents. All of these argue that prosody plays an important role. Vaux (2002: 2–3) states that there are at least four different claims in the literature. Aspiration is either triggered by word-initial position, syllable-initial placement, initial occurrence in a stressed syllable, or word-initial position in a stressed syllable of a plosive. Below, I will provide some examples of studies which have made these claims and discuss the (empirical) data that have been gathered in support of these statements.

The analysis by Clark & Yallop (1995) is an example of the assumption that aspiration only occurs when a stop is in word-initial position. They claim that /p/ in *plain* does carry aspiration, whereas /p/ in *im*ˈ*perious* does not. Since the main difference is that the first /p/ is word-initial and the second /p/ is not, Clark & Yallop argue that word-position must determine whether obstruents are aspirated or not. This is a problematic explanation, however, since we do actually find aspiration within words. Nespor & Vogel (2007: 90–91) observe word-internal aspiration in American English. They analysed the speech of American English speakers. In total, 25 words were analysed, all of which contained a potentially aspirated stop. These plosives occurred in various positions, such as stressed, unstressed, word-initial, word-medial, foot-initial, etc. Nespor & Vogel found medial aspiration in the following words:

(9) Medial aspiration in American English (Nespor & Vogel 2007: 90–91)

deˈtain	de[tʰ]ain
deˈtention	de[tʰ]ention
enˈtire	en[tʰ]ire
curˈtail	cur[tʰ]ail
ˈsatire	sa[tʰ]ire
ˈreptile	rep[tʰ]ile
ˈinfantile	infan[tʰ]ile
ˈlongitude	longi[tʰ]ude

An example of the second view is Giegerich (1992: 219), who states that plosives in stop–sonorant clusters do not appear to aspirate unless the plosives form part of the onset of a syllable. This solves the problem of word-internal aspiration mentioned above, since word boundaries are no longer a criterion for aspiration. Sonorant devoicing, which is the surface effect of aspiration if the segment following a plosive is not a vowel, only occurs if the plosive and the following sonorant form an onset cluster together, as in *pray* and *unpleasant*. In words such as *at*ˈ*las*, the stop and the sonorant are separated by a syllable boundary, so that /t/ is a syllable-final stop. The /l/ in the following onset remains fully voiced. Hence, there is no evidence to suggest that /t/ is aspirated. Unlike Clark & Yallop (1992), Giegerich (1992: 219), then, acknowledges the existence of word-internal aspiration. Vaux (2002: 4) argues that this solution is also problematic, however. He observed that the stops in words such as *happy* and *petrol* are aspirated, even though they are not merely onset consonants. The segments are ambisyllabic: they are regarded as codas as well as parts of the onset (Vaux 2002: 4). Stating that both onset obstruents and ambisyllabic consonants are aspirated is an undesirable solution, since ambisyllabic consonants are both codas and onsets, creating ambiguity.

Odden (2001) claims that only stressed syllable-initial obstruents are aspirated. The counterargument is simple: there are numerous words in English where unstressed syllable-initial segments are at least lightly aspirated (/p, t, k/ are followed by a brief period of

voiceless breath, although this is barely audible). Examples are /p/ in *po'tato* and /t/ in *ter'rain* (Vaux 2002: 6). Nespor & Vogel (2007: 91) also find aspiration of unstressed syllable-initial obstruents in the speech of American English speakers:

(10) Aspiration of unstressed syllable-initial obstruents in American English (Nespor & Vogel (2007: 91)

ter'rain	[t^h]er 'rain
ty'phoon	[t^h]y'phoon

Lastly, Cho (2001) analyses aspiration as a phenomenon limited to word-initial and stressed syllable-initial obstruents. Vaux (2002: 4) finds this claim less than ideal as well, however, since aspiration then would not be triggered by "a unified environment". Furthermore, the results of Nespor & Vogel's (2007: 90–91) experiment show that obstruents do not need to be in word-initial or stressed syllable-initial position to be aspirated (see (9) and (10)).

In short, the above analyses, where aspiration is viewed as a context-dependent phenomenon, all appear to be incorrect. Below, I will discuss non-rule-based aspiration and argue that this approach provides a more accurate description of Germanic aspiration.

Non-rule-based aspiration

Several studies argue that aspiration is a gradual phenomenon, which is always inherently present on voiceless stops and the strength of which depends on the phonological environment in which a plosive occurs. I will call this the non-rule-based approach, since it entails that the occurrence of aspiration is independent of any phonological context.

Non-rule-based approaches argue that aspiration is found in obstruents in almost all positions. Iverson & Salmons (1995: 15), for instance, claim that there is not one realisation of aspiration, but no fewer than three, depending on the phonological environment. Aspiration is a gradual phenomenon in Germanic with no, light, or heavy realisation. Aspiration is not found in obstruents between sonorants, for example, where voiceless obstruents become voiced instead. Heavy aspiration is found stress-foot-initially, and light aspiration occurs elsewhere. The gradualness of aspiration was already discussed in O'Connor (1973: 32). Like Iverson & Salmons (1995: 15), he states that light aspiration occurs elsewhere than stress-foot initially. Another study in favour of the non-rule-based approach is Roach (1991: 32–33). He claims that initial plosives are always heavily aspirated. Aspiration is clearly audible, due to the fact that there is audible plosion after stops. Vowel-medial aspiration may occur, depending often on whether the preceding vowel and the following vowel are stressed. Stressed positions may enhance aspiration, making it more audible than in less stressed contexts. Kingston & Diehl (1994: 431) add that aspiration is gradual and often not perceived medially, because the glottal opening for the release of stops tends to be smaller between vowels and especially before unstressed vowels: "glottal opening is simply smaller intervocalically than initially and before unstressed than before stressed vowels, and this smaller opening leads to shorter voicing lags […] and thus less aspiration" (Kingston & Diehl 1994: 431). Consequently, the VOT for a following unstressed vowel is shorter and there is less aspiration. Furthermore, Roach (1991: 33) states that aspiration also occurs in final position, but because the release of the stop is very weak (light aspiration), it frequently remains unobserved.

Iverson & Salmons (1995: 377) state that gradual aspiration is not unusual. Rather, it should be expected. Unlike non-gradient (that is, rule-based) aspiration, gradual aspiration is in accordance with Vennemann's Head Law, which dictates the following rule for word structure:

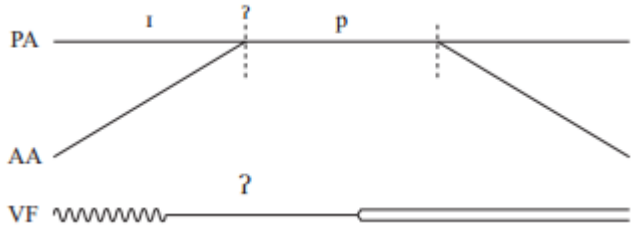
(11) Vennemann's Head Law
The optimal phonological word form [...] is one in which the initial syllable, and in addition any stressed syllable, has a very strong consonant, while all other syllables have weak consonants (Vennemann 1993: 323–332).

In English and several other Germanic languages, such as German and Danish, aspiration is frequently perceived solely in foot-initial and syllable-initial position. This is unsurprising if one considers Vennemann's Head Law, since foot-initial syllables in English are stressed and therefore of maximum prosodic strength (Iverson & Salmons 1995: 378). Aspiration is most audible and longest in this environment, because glottal spread is enhanced initially due to prosodic prominence. Iverson & Salmons summarise this observation in the following rule: "vocal fold abduction in syllable onsets is enhanced in relation to metrical prominence" Iverson & Salmons (1995: 378).

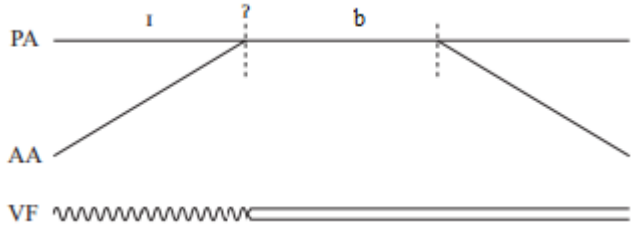
Crucially, the fact that aspiration is often not perceived finally, but speakers are able to distinguish between English words such as *rip* and *rib*, is no argument for a voiced–voiceless distinction, in contrast to what is argued by proponents of the rule-based approach. Final /p/ and /b/ cannot be distinguished from each other if no attention is paid to the preceding segments. Hence, it is not necessary to posit an audible contrasting property (e.g. voice) in final /p/ and /b/. Take, for example, the diagrams in (12):

(12) /t/ and /d/ in final position (Collins and Mees 2003: 152)

a. The pronunciation of the rhyme in *rip* (['rɪʔp])



b. The pronunciation of the rhyme in *rib* (['rɪb̚])



Rip and *rib* are distinguished due to glottalisation and vowel length, not because of the absence or presence of voice in the obstruents. Speakers are aware that a glottal stop signals a following voiceless plosive, as in 'rip'. Furthermore, a long vowel predicts a following voiced stop. Assuming that final /p/ is inaudibly aspirated whereas /b/ is not, and observing that the contrast between the words is maintained through coda-preceding phenomena, there is no clear reason to support a voice-voiceless distinction that would relegate aspiration to a rule-based, context-dependent phenomenon.

Several studies argue that it is impossible for medial and final plosives to aspirate, however, and that, therefore, the non-rule-based approach cannot be correct. A key argument of such approaches is that the VOT of vowels following obstruents is wrongly regarded as a phonologised phenomenon. Phonologisation is a diachronic change from a gradient pattern of

variation to a categorical (phonemic) alternation (Hyman 1976: 32). However, phonologising VOT as *the* phenomenon that contrasts aspirated sounds with unaspirated ones is problematic for two reasons. Firstly, VOT is not an "overriding cue to stop voicing and aspiration" (Vaux & Samuels 2005: 406). There are several other cues that help distinguish between voiced and aspirated obstruents as well, such as F1 values, formant transitions, vocal cord vibration during closure, duration, tenseness, glottal spreading, glottal constriction, intensity of the release burst, and articulatory force (Vaux & Samuels 2005: 406). Phonetic perception tests suggest that VOT is not necessarily required for listeners to distinguish between aspirated and unaspirated stops. A study by Tsui (1996), for example, shows that normal as well as hearing-impaired speakers of Chinese needed aspiration noise to perceive the difference between aspirated and unaspirated plosives. The lack or presence of VOT, in contrast, did not affect perception. Consequently, Vaux & Samuels (2005: 406) conclude that apparent lack of VOT in medial and final obstruents cannot be an argument for rule-based aspiration.

Secondly, there is no universal neutralisation of aspiration in preconsonantal and word-final position, in contrast to what phonologisation of VOT would suggest. Obstruents are expected to deaspirate preconsonantally and word-finally, since there is no onset of voicing in these contexts. Consequently, VOT cannot be delayed there, and aspiration must be limited to stress-foot-initial position. However, we have seen that aspiration contrasts can be measured without analysing VOT and studies have shown that final aspiration is quite common crosslinguistically. There is evidence that syllable-final neutralisation results in aspirated stops in several Germanic languages, for instance. In Danish dialects which lack the vestjysk stød (literally 'West Jutland shock': "a complete occlusion of the vocal cords, combined with the diaphragm's movement of inhalation, equalising the difference in pressure, and caused by an attempt to pronounce pure and unaspirated fortis plosives when medial" (Ringgaard 1960: 199)), voiceless aspirated plosives vary freely with voiceless plain stops in final position. In word-final position, the aspirated plosive is more common than the unaspirated one (Kortlandt 1997: 176). The situation in German is similar. Here, all final stops are voiceless and optionally aspirated (Alber 2001: 16). Furthermore, Swedish plosives may become aspirated in final position (Johansson et al. 2001: 78). In addition, there is evidence in English for word-final aspiration. Vaux (2002: 1) reports aspiration of the final stop in *hit*, for example. In some dialects, final stops are postaspirated rather than glottalised, so that *hit* is pronounced as [hɪtʰ]. Such variation is also found in a study by Local (2003). Seven speakers of Tyneside English were recorded while having a casual conversation. The results show that all of them aspirated final plosives in the same position. The data are repeated in (13):

(13) Final aspiration in Tyneside English (Local 2003: 325)

Utterance-final		*Word-final*	
[tʰʊʰkʰ]	took	[gɒˀt]	got
[baʱkʰ]	back	[ɣ̃ĩnəɲ̟ʔ]	Vincent
[tʰəilɨɪtʰ]	toilet	[ɲ̟əʔ]	that

Previous studies such as Davenport & Hannahs (1998: 109) have suggested that data such as those in (13) show that there is free variation between aspirated final plosives and unaspirated ones, as in Swedish and German. Once again, it is shown that aspiration is not limited to the initial plosives of stressed feet.

In addition to aspirating final stops, some Germanic languages also aspirate plosives in medial position. Icelandic, for example, neutralises all plain voiceless plosives to aspirated voiceless plosives word-medially (Vaux & Samuels 2005: 419). Some dialects of English display medial aspiration as well, despite claims to the contrary. Vaux (2002: 6) states that, in

dialects where flapping occurs, /t/ is aspirated in all positions where flapping does not apply, including finally[3]. It is flapping that is rule-based, rather than aspiration. In short, it is unnecessary to posit an aspiration rule, since aspiration can occur on stops in any position: initially, medially, and finally. Aspiration merely does not take place if another, rule-based process such as flapping overrules it (Vaux 2002: 6). Consequently, I agree with Iverson & Salmons that aspiration is inherent to English voiceless stops, because a spread glottis "forms part of their basic representation" (Iverson & Salmons 1995: 376).

To summarise, the existence of non-rule-based aspiration and therefore aspiration languages is plausible, since there is no solid evidence that aspiration is a rule-based phenomenon. Aspiration can occur in any position, but it may be inaudible due to its gradual nature.

2.2.3 Some notes on the aspiration of fricatives

The facts regarding plosives are quite straightforward, but aspiration in fricatives is a controversial topic in the literature. Halle & Stevens (1971: 55–56) claim that English fricatives lack aspiration altogether and that they therefore are underlyingly unspecified for [spread glottis]. Their argument is that English fricatives differ from those found in Burmese, for example, where plain fricatives contrast with aspirated ones. Chang (2003: 62, 67) adds that, crucially, this contrast remains clear in English loanwords. Some examples of loanwords are provided in (14):

(14) The adaptation of English loanwords in Burmese (Local 2003: 325)

English /s/ = Burmese [s]		*English /s/ > Burmese [sʰ]*	
[sɛʔtĩbà]	'September'	[kʰəjĩ sʰòùdà]	'cream soda'
[sĩgapù]	'Singapore'	[sʰaiʔ]	'size'
[màsɪti]	'Mercedes'	[sʰwɪzàlɛ̃]	'Switzerland'

The data in (14) suggest that aspiration is added to the English fricative /s/ in some contexts, but not in others. There is no clear reason for assuming that aspiration is deleted when Burmese borrows words from English, since other fricatives always appear unaspirated in all environments. It should not simply be assumed that aspiration is deleted from these fricatives everywhere, as Burmese has a very specific rule for the distribution of aspirated and unaspirated /s/: /s/ is realised as [s] before high vowels. Elsewhere, the fricative becomes aspirated (Chang 2003: 62). A rule which deletes aspiration from all other fricatives when the rule for /s/ in English loanwords targets very specific contexts seems unlikely. Secondly, if aspiration of English /s/ was taken into account, one would expect to observe it in those positions where it is most likely to be perceived in English: initially in a stressed foot. This is not suggested by the data in (14), however. /s/ in *Singapore* and *Mercedes* is positioned stress-foot-initially, as is /s/ in *size*. Yet two out of the three segments are plain. Consequently, it seems that the aspiration is a Burmese addition and not of English origin.

Jacques (2011: 2) posits a typological argument against surface aspiration of Germanic fricatives in general. Fricative aspiration is typologically uncommon. There is no evidence at all that it occurs outside Asia and the Sino-Tibetan language family, except for a few isolated cases. Consequently, there is no reason to posit fricative aspiration as a common Germanic development, unlike stop aspiration. A second typological problem with suggesting that fortis fricatives were aspirated in Germanic is that, often, only /s/ is aspirated in the Sino-Tibetan

[3] /t/ and /d/ may be pronounced as [ɾ] between a preceding sonorant (excluding /m, ŋ/) or vowel and a following vowel (Vaux 2000: 6). If so, aspiration does not occur. According to Vaux (2000: 7), flapping cannot occur in foot-initial position, but it does appear when the preceding syllable in a word carries primary or secondary stress. Elsewhere, dialects which display flapping aspirate /t/.

languages (Jacques 2011: 4). To state that Modern English fricatives have surface aspiration, however, would entail that /f, θ/ are aspirated as well. Since Old English also had /x/, we would need to argue that yet another fricative was aspirated at this stage of English. Nonstrident aspirated fricatives are extremely rare, however. Fieldwork by Xi & Li (1997) and Jacques (2011: 4) has shown that /fʰ/ is found in only three languages, namely Ofo, Yanghao, and Heqing Bai. /xʰ/ is even rarer, being attested in two languages: Heqing Bai and Cone Tibetan. /θʰ/ is completely unattested. Considering that aspirated alveolar and velar fricatives are extremely uncommon and dental ones are unattested within the one language family where surface aspirated fricatives have been attested, it is improbable that the Germanic languages had a shared surface aspiration contrast in these fricatives.

Stevens (1991: 402) provides a phonetic argument for the aspiration of fricatives, stating that voiceless fricatives are naturally aspirated. It is impossible to produce fricatives without a spread glottis, since this would not allow sufficient air through the gap to build up pressure behind the closure formed by the primary articulator. Of course, I will not argue against a voice distinction based on Stevens' observation that fricatives are always [spread glottis], since languages such as French and Italian have been shown to have both voiceless and voiced fricatives. Rather, I suggest that the fact that fricatives are articulated with a spread glottis does not automatically entail that they are audibly aspirated. The fact that fortis plosives are not audibly aspirated in all positions either shows that such a situation is possible (recall that aspiration on stops is often not perceived in unstressed, non-initial position). It would explain why neither aspiration languages nor voice languages have aspirated voiceless fricatives. A spread glottis would be the distinctive feature in aspiration languages rather than aspiration, so fortis fricatives would still be distinguishable from lenis fricatives. In voice languages, on the other hand, voiced fricatives carry the feature [voice], which is much more audible than the effect of the spread glottis on voiceless fricatives. Hence, voice plays a distinctive role there.

Considering the above observations, it is plausible that in Germanic languages, fricatives have a contrast based on [spread glottis] rather than [voice], though the spread glottis does not audibly surface as aspiration.

2.3 Contrastive properties of aspiration languages and voice languages

In order to decide whether a certain language is an aspiration language or a voice language, it is important to be aware of the differences between these language types. There are several linguistic characteristics that distinguish aspiration languages from voice languages. Firstly, as was already stated above, aspiration languages display a fortis/lenis contrast in the obstruent system, whereas voice languages have a voiced/voiceless distinction (Jansen 2004: 35). In aspiration languages, in short, voice does not play a contrastive role. Obstruents are never truly voiced unless they assimilate to surrounding sonorants. The properties of voice, which characterise fully voiced sounds, are therefore underlyingly absent: there is no pulsed input of air and no vocal fold vibration throughout the entire stop or throughout the entire fricative. Collins & Mees (2003: 51) state that English, as an aspiration language, never has fully voiced obstruents initially or finally. Voicing starts late in initial fricatives and plosives and it ends early in final ones. In voice languages like Dutch, in contrast, initial and final /b, d, g/ are fully voiced (Jansen 2004: 2). The data in (15) are examples of English and Dutch obstruents in initial and final position:

(15) Initial and final obstruents in English and Dutch

a. English (Giegerich 1992: 222)

Initial devoicing		*Final devoicing*	
[b̥aɪ]	buy	[rɪb̥]	rib
[d̥aɪ]	die	[rɪd̥]	rid
[g̊aɪ]	guy	[rɪg̊]	rig
[z̥u]	zoo	[raɪz̥]	rise
[ɣ̊iɬ]	veal	[draɪɣ̊]	drive
[ð̥eɪ]	they	[raɪð̥]	writhe

b. Dutch[4]

Lack of initial devoicing

[bɑɬ]	bal	'ball'
[di]	die	'that one'

English has partially voiced obstruents in initial and final position. Dutch, on the other hand, retains fully voiced obstruents initially. Final obstruents are devoiced, but this is not a consequence of aspiration contrasts. Rather, it is assumed to be the effect of final devoicing: obstruents are neutralised in word-final position. The underlying specification ([voice]) may not surface there (Grijzenhout & Krämer 1998: 56).

Due to the lack of a voice contrast in English, initial /b/ and /p/ are only different in that /p/ is aspirated and /b/ is not. Initially, we do not find [b] and [p] (as in voice languages), but devoiced [b̥] and voiceless aspirated [pʰ] (Jansen 2004: 35). In addition, in final position, the obstruents of aspiration languages are indistinguishable from one another if the surrounding sounds are ignored, since aspiration is hard to perceive in this position and there is no voice contrast (Jansen 2004: 54). The obstruents can only be recognised due to the fact that [p] is signalled by a preceding glottal stop, whereas [b̥] is recognised because vowels preceding this consonant are longer than before [p] (Harris 1994: 226; Jansen 2004: 54). Harris (1994: 226) argues that this difference in vowel length is the result of a process called prefortis clipping, whereby a vowel is shortened before fortis obstruents[5].

Secondly, obstruents in aspiration languages cannot cause assimilation to [voice] in adjacent segments, since obstruents are not inherently specified for this feature. Voice languages, in contrast, do show assimilation to [voice] caused by obstruents (Spaargaren 2009: 26). Hence, voice assimilation is active there, which implies that the obstruents are specified for voice. The presence or lack of voice assimilation is especially clear in obstruent clusters, where all obstruents need to have the same laryngeal specification (Spaargaren 2009: 25–26). Therefore, the direction of assimilation is always visible if the obstruents are underlyingly different, but are identical on the surface. Consider, for instance, the data from English and Dutch in (16):

[4] The laryngeal phonology of Dutch is of a "hybrid nature", in that the plosives have become Romance-like, whereas the fricatives have retained their Germanic properties (Iverson and Salmons 2003b: 2). Fully voiced stops contrast with plain voiceless plosives, while lenis fricatives contrast with fortis fricatives. Hence, English data on fricatives will not be compared with data on Dutch fricatives.

[5] Jansen (2004: 54) discusses the possibility that vowels are lengthened before lenis stops, instead. However, lengthening seems unlikely, as the length of vowels before sonorants is "roughly equal" to their length before lenis obstruents. A correspondence in length before lenis stops and sonorants seems more probable than a correspondence in length before fortis stops and sonorants, since lenis obstruents have more in common with sonorant sounds than fortis segments do (in terms of voice quality).

(16) Assimilation in obstruent clusters

a. English (Al-Ahmadi Al-Harbi: forthcoming)

Original obstruent		*Assimilated obstruent*	
[skraɪb̚]	scribe	[ˈskrɪptʃʊə]	scripture
[əbˈzɔːb̚]	absorb	[əbˈzɔːpʃn̩]	absorption

b. Dutch

Original obstruent			*Assimilated obstruent*		
[zɑk]	zak	‘pocket’	[ˈzɑgduk]	zakdoek	‘handkerchief’
[ɒp]	op	‘on’	[ɒb ˈdi fits]	op die fiets	‘on that bicycle’

The data in (16) show that English does not have assimilation to voice, whereas Dutch does. This is exactly what is to be expected, since English plosives are unspecified for [voice] whereas those of Dutch are specified for this laryngeal feature.

Thirdly, obstruents in aspiration languages undergo passive voicing: they are only voiced through spreading of voice from vowels and sonorant consonants (Spaargaren 2009: 56). If obstruents were inherently voiced, they could be fully voiced regardless of the presence of sonorants. Spaargaren (2009: 45) states that, if aspiration is a property of English obstruents, assimilation to aspiration is expected to take place. This is perceived as a delayed onset of voice for the vowel or sonorant consonant following an obstruent, which manifests itself as a partially voiceless vowel or sonorant devoicing: the spread of aspiration overrides inherent voicing in other sounds, causing initial devoicing in the sound following the obstruent (Spaargaren 2009: 46). Sonorant devoicing is also found in several other languages which display an aspiration contrast as opposed to a voice distinction. Examples are German and Icelandic (Iverson and Salmons 1995: 381, 391). The process is typically absent from voice languages, since their voiceless obstruents are unspecified for [spread glottis]. Consequently, obstruents cannot cause feature spreading and trigger devoicing. Some examples of sonorant devoicing in English and the lack of it in Dutch are provided in (17):

(17) Sonorant devoicing (Tillotson Jensen 1993: 130; Tsuchida et al. 2000: 167)

a. English

[p̥ɹeɪ]	pray
[p̥l̥iː]	plea
[p̥l̥eɪ]	play
[kɻ̥aɪ]	cry

b. Dutch

[praːt]	praat	‘talk’
[plaːt]	plaat	‘sheet’
[kraːx]	kraag	‘collar’
[klaːx]	klaag	‘complain’

In short, aspiration languages differ from voice languages in that [spread glottis] is the specified laryngeal property and spreads to adjacent sounds. In assimilatory processes, the fact that obstruents are specified for [spread glottis] has three possible results: 1) assimilation of a lenis obstruent to a fortis obstruent in obstruent clusters, 2) delayed VOT of a vowel following a fortis obstruent, and 3) sonorant devoicing. In addition, the obstruents of aspiration languages are never fully voiced independently. They can only become voiced due

to assimilation to inherently voiced segments. Obstruents can become voiced intervocalically or between sonorant consonants, for example.

2.4 Case study: aspiration in Old English

The aim of this section is to see whether Old English was an aspiration language, like Modern English. The language will be examined from its earliest (documented) stage onwards. If Old English turns out to have an aspiration contrast, the development of the distinction can be traced back to ca. 700, when the first Old English texts were written. Furthermore, if there is no evidence to suggest that the aspiration contrast developed independently in Old English, it is possible that the distinction is even older and that it even may have been a Germanic innovation.

2.4.1 Method

Materials

The corpus used for this case study was the *Dictionary Corpus of Old English*, a database that contains a copy of all known surviving Old English texts. The texts are categorized under several genres: prose, poetry, glosses, and inscriptions. The prose database is especially widespread with respect to text types. This is convenient, since it shows that texts have been written under different sociological and therefore different sociolinguistic circumstances. We find, for example, scholarly texts, medical guides, chronicles, and documents for use in the church, but also less formal texts such as charms and tables. This diversity made it possible to examine Old English from a wide range of backgrounds.

The *Online Bosworth-Toller Anglo-Saxon Dictionary* was used to examine the lexical forms of words with obstruent clusters. The database is based on *An Anglo-Saxon Dictionary*, the largest complete dictionary of Old English. The entries are based on texts from roughly 700 to 1100. Each entry is headed by a lexical form, under which all known varieties are listed. Consequently, it is possible to link non-standard spellings to their standard form, which makes it possible to analyse whether a writer has made certain changes.

The third tool used for this experiment was Wordsmith 5.0. Wordsmith is a concordance programme which generates word lists based on the selected texts. These word lists can be based either on a complete text or on a search term (so that only words containing the search term appear). The second option was chosen for this experiment, as only the obstruent clusters in the text were relevant.

Procedure

The first step was to select the obstruent clusters which would be analysed. Since the aim of the experiment was to see whether obstruents tend to assimilate to voice (<b, d, g> etc.) or to voicelessness (<p, t, c> etc.), I examined clusters containing either two voiced obstruents or two voiceless ones (on the surface). Assimilation to the voiceless obstruent would suggest assimilation to fortis, since <p, t, c, f, s> in Modern English also represent the fortis set of segments. The examined clusters were of the following types: 1) two voiceless plosives, 2) two voiced plosives, 3) two voiceless fricatives, 4) two voiced fricatives, 5) a voiceless plosive followed by a voiceless fricative, 6) a voiced plosive followed by a voiced fricative, 7) a voiceless fricative followed by a voiceless plosive, and 8) a voiced fricative followed by a voiced plosive. This method made it possible to examine whether the agreement in voicing stems from assimilation. The approach is essentially identical to the one in Spaargaren (2009: 81–85), though she only takes the plosives into account and limits her analysis to compounds. I decided to analyse the fricatives as well, and to examine all word forms. This decision enabled me to observe assimilation in other contexts, such as word-internally and across

morphological boundaries, as well. The list of possible obstruent combinations comprised 98 sequences. However, due to Old English spelling conventions, not all of these clusters were judged to be useful for a study on sound change. There is no orthographic contrast between /s/ and /z/, for example, since <s> is used for all alveolar fricatives in this period except in loanwords or names. Presumably, the reason was that [z] was an allophone of /s/ which was only perceived between voiced sounds, and therefore did not receive its own symbol (Al-Watban 2005: 309). Similarly, <f> is used for both <f> and <v>, although <u> is sporadically used to indicate /v/ as well (usually only intervocalically, however) (Al-Watban 2005: 309). Another problem is the spelling of the dental fricatives /θ/ and /ð/. Their orthographic symbols, respectively <þ> and <ð>, are used interchangeably, however. Hence, it is difficult to see whether they represent a voiceless or a voiced fricative (Al-Watban 2005: 309). In several manuscripts, a single word has multiple spellings. Al-Watban (2005: 309) provides an example from Beowulf. The word *syððan* 'since' occurs with various spellings: <syððan> (l. 6), <syþþan> (l. 604), <syðþan> (l. 132), and <syþðan> (l. 283). Taking the lack of <z> and <v> and the variation in the use of <þ> and <ð> into account, multiple orthographic clusters were excluded from the analyses. These are presented in appendix A, together with their probable pronunciation.

Not all of these clusters were ignored, however. Since it is known that /v/ was sometimes written as <u>, all clusters containing <v> were replaced by a cluster containing <u>. It was then checked whether <u> did, indeed, represent a voiced alveolar fricative or merely a vowel. The final list of obstruent sequences comprised a total of 78 obstruent clusters, which are presented in appendix B together with their assumed pronunciation.

Next, the clusters were entered in the *Dictionary of Old English Corpus*. This was done with a simple search, which made it possible to search for clusters of sounds rather than for complete words. The simple search method can be subdivided into three types: 1) fragmentary (fragments of words), 2) initial letters, and 3) whole word. The fragmentary search was most relevant for this experiment, since it would generate initial, medial, as well as final clusters. The text type was set to prose. I opted to exclude verse and gloss from the analysis, since glosses were often based on Latin or written in Latin. Furthermore, including poetry might influence the results because scribes desired to follow certain rhyming patterns.

The results of the search in the *Dictionary of Old English Corpus* were saved as text files. For each cluster, a concordance list was created in Wordsmith. These concordance lists were needed to be able to make word lists containing only those words which contained one of the 78 obstruent clusters. The word lists were then copied to Excel. In Excel, the items were placed under the heading 'word' and an extra column headed 'lexical form' was added next to it so that the corpus forms could be compared with their lexical forms.

I entered each corpus form into the *Online Bosworth-Toller Anglo-Saxon Dictionary* to find their lexical equivalents. By doing so, the obstruent clusters in the corpus were compared with the original ones. If an item turned out to be a personal name or a place name, it was deleted from the list[6]. If one of the obstruents in a voiced–voiced cluster turned out to have been voiceless in the lexical form it was assumed that assimilation to [voice] had taken place. Similarly, a voiced obstruent changing into a voiceless one would suggest assimilation to [spread glottis]. In each case, however, it was checked whether the change could reasonably represent assimilation (if only one scribe showed it, for instance, it is not very likely).

Lastly, the instances of assimilation to [voice] were compared with assimilations to [spread glottis] (per cluster as well as per text) in order to see which process is most likely to have occurred.

[6] This was necessary because different spelling conventions were sometimes applied to names than to words. Consequently, no reliable conclusions could be drawn from names.

2.4.2 Results

Assimilation to voicelessness

Assimilation to voiceless obstruents is found in six clusters: <tc, hh, hs, hþ, ts, cþ>. In the sequence <tc>, the first obstruent appears to become voiceless under influence of the second one. This is shown in (18):

(18) Regressive assimilation to voicelessness: <dc> → <tc> (appendix C1)[7]

Lexical form	*Corpus form*	
seld-cúþ	seltcuðan	'strange', 'different'

The form in (18) displays regressive assimilation. This is also what happens in Modern English. Roach (1991: 125) observes that assimilation is always regressive in Modern English and that it goes in the direction of voicelessness.

Old English regressive assimilation also results in the cluster <hs>, which, with regard to the forms in (19), was <gs> in the lexical forms. Again, there is possibly assimilation to voicelessness.

(19) Regressive assimilation to voicelessness: <gs> → <hs> (appendix C2)

Lexical form	*Corpus form*	
beorg-steal	borhstealles	'steep path up a hill'
burg-scír	burhscir	'township'
eág-sínes	eahsynes	'evidently'
earg-scipe	earhscype	'cowardice'
tintreg-stów	tintrehstowum	'place of torment'

The fact that there appears to be assimilation to voicelessness in fricative clusters is interesting, since assimilation due to fricatives in aspiration languages is not examined much in previous literature (Halle & Stevens 1971: 55–56; Stevens 1991: 402; Chang 2003: 62, 67; Jacques 2011: 2; see section 2.2). The data in (19) suggest that Old English fricatives were specified for [spread glottis]. Taking into account that, in voice languages, obstruents are either specified for [voice] or unspecified (and therefore cannot cause spreading of voicelessness), Old English fricatives cannot have been specified for [voice]. The findings on the cluster <hþ> support the presumption that Old English fricatives were fortis:

(20) Regressive assimilation to voicelessness: <gþ> → <hþ> (appendix C3)

Lexical form	*Corpus form*	
eág-þyrl	eahþyrl	'window'
mígan	myhþ	'to make water'
mirigþ	mirhþe	'pleasure'

Once again, the left fricative in the cluster seems to assimilate to the one on its right. <þ> appears to have been voiceless, since the left fricative takes on this property. Consequently, <þ> may have been specified for [spread glottis].

Regressive assimilation to voicelessness also seems to take place in Old English plosive–fricative clusters. Here, a voiced stop becomes voiceless under influence of the adjacent, voiceless fricative. This is suggested by corpus forms which contain the clusters <ts, cþ>. Consider the data in (21):

[7] The appendices mentioned after each table of examples contain all forms found in the corpus.

(21) Regressive assimilation to voicelessness in plosive–fricative clusters

a. <ds> → <ts> (appendix C4)

Lexical form	*Corpus form*	
andswarian	antswarude	'to answer'
findan	fintst	'to find'
ge-healdsum	gehealtsum	'modest'
méd-sceatt	metsceatte	'wages'
ildest	yltst	'oldest'

b. <gþ> → <cþ> (appendix C5)

Lexical form	*Corpus form*	
geþingþ	geðincþo	'intercession'
strengðu	strencþe	'strength'

The data in (21) suggest that fricatives are specified for [spread glottis], since assimilation to <s> and <þ> (the voiceless consonants in the clusters) is hinted at rather than assimilation to <d> and <g> (the voiced segments in the sequences). Another explanation for the assimilation of /d/ to /s/ is that most of the forms in appendix C4 are verbs with the second person singular indicative ending *-st*, which might be underlyingly voiceless and therefore does not provide evidence for underlying voicelessness in all fricatives (Borowsky 2000: 14). If so, the remaining data with <ts> could merely represent spelling errors. This appears to be unlikely, however. Firstly: to my knowledge there is no evidence that the second person singular indicative ending has a lexical laryngeal specification. Secondly, it is hard to believe that the change from <ds> to <ts> is a mere spelling error, considering the number of texts in which this change occurs without being triggered by the ending *-st*, namely eighteen.

(22) Assimilation of /d/ to /s/ in non-verb forms

Words		*Texts (short title)*[8]
geetstaðolode	'reassured'	ÆCHom I, 14.1
gehealtsum	'that takes care of'	Prog 2.3 (Först)
		Prog 3.5 (Först)
gehealtsume	'that takes care of'	ÆLS (Memory of Saints)
gehealtsumnesse	'modesty'	ÆHom 18
gehealtsumnysse	'modesty'	ÆCHom II, 15
		ÆCHom II, 27
		ÆLS (Maccabees)
		ÆIntSig
		Nic (A)
		BenRW
		ChrodR 1
metsceatte	'reward'	Deut
		CP
ungehealtsum	'incontinent'	ÆHom 20
ungehealtsume	'incontinent'	ÆHomM 8 (Ass 3)
ungehealtsumlice	'incontinently'	ÆLet 5 (Sigefyrth)
ungehealtsumnysse	'incontinence'	ÆLet 2 (Wulfstan 1)

[8] The short titles are those applied by the *Dictionary of Old English*. They refer to editions of Old English texts. A database of these titles, followed by information on the editions, can be found at http://tapor.library.utoronto.ca/doe/dict/bibl/st-AE-fr.html.

Recall that the potential cases of assimilation to voicelessness we have seen thus far have been regressive only. This correlates with what is found in Modern English. According to Roach (1991: 125), laryngeal assimilation is always regressive. The data in (23) suggest that the cluster <hh> sometimes seems to be the result of progressive aspiration, however.

(23) Regressive and progressive assimilation to voicelessness: <gh>, <hg> → <hh> (appendix C6)

Lexical form	*Corpus form*	
eág-hringas	eahhringas	'eyebrows', 'eyelids'
neáh-gebúr	neahheburas	'neighbour'

All of these words originally contained a <gh> or a <hg> cluster, where <g> was most likely voiced. However, voicelessness has seemingly spread from <h>. This change is suggested in four different texts. It occurs nine times in total. The fact that the change occurs in no fewer than nine texts reduces the chance that it was merely a scribal error. In short, Old English shows both regressive and progressive assimilation to voicelessness. In addition, fricatives as well as plosives cause assimilation.

The data that suggests assimilation to voicelessness is quite reliable, the only problem being the plosive–plosive cluster <tc> (representing the change /dk/ > /tk/). The unassimilated cluster <dc> is preferred in three out of the four texts in which assimilation is found. Only one texts shows assimilation of all <dc> clusters, however. In total, only 38% of the sequences suggests assimilation in writing. However, with respect to the other obstruent clusters, the data do imply that there was a tendency to assimilate to voicelessness. <hh> is preferred above its original form <hg> in three out of the four texts in which occurs. It completely replaces <hg> in two texts and in one text it replaces 75% of the <hg> sequences. In total, progressive assimilation to voicelessness is suggested in no fewer than 80% of the clusters.

<hs>, potentially the result of assimilation in the cluster <gs>, is found in no fewer than 39 texts. The assimilated form is not preferred in all texts. In seven of them the assimilated cluster is less common than the unassimilated one, with 14% of possible assimilation as the lowest frequency. However, the assimilated form entirely replaces <gs> in 26 texts. Consequently, there is relatively much evidence in favour of assimilation. Further support is provided by the total frequency of apparent assimilation: 64%.

Instances of <hþ> also suggest that assimilation to voicelessness took place in Old English. The assimilated cluster is found in 30 texts and the unassimilated sequence does not occur in 29 of these. Consequently, the assimilated cluster completely replaces its unassimilated counterpart in all these texts. The total frequency of assimilation is 97%.

The sequence <cþ>, the assimilated form of <gþ>, is found in only four texts. In three of these, it strongly suggests that assimilation to voicelessness did occur, however: it replaces 100% of the <gþ> clusters. Furthermore, the assimilated form replaces 50% of its unassimilated counterpart in the fourth text.

The cluster /ts/ requires a more elaborate discussion. /ts/ as a possibly assimilated form of /ds/ is found in 59 texts, but in most texts it is overshadowed by the much larger number of /ds/ sequences. The assimilated sequence forms a majority in eight texts, which, considering the total number of texts in which it occurs does not tell us much. I propose that this apparent lack of assimilated clusters is not an actual lack of assimilation, but that it might have been caused by the frequency of common words and words which are partially made up of the element *god-* 'god', which, in religious documents, is perceived as a name. Above, I explained why names are unreliable sources when dealing with sound change. Frequent words

can be misleading for the following reason: they are well-known and, therefore, their spelling may also be known relatively well so that they are less sensitive to spelling errors. In several texts where <ds> is much more frequent than <ts>, such common words are the cause. Examples of words that occur very frequently in Old English texts are *godspell* 'gospel', *hund* 'hundred', and *andswarian* 'to answer'. Take, for example, the word *godspell*. Including it in the search for words containing unassimilated /ds/ provides the following numbers:

(24) The influence of frequent words on the visibility of assimilation in spelling

a. Including *godspell*

Text	*Frequency of <ds>*	*Frequency of <ts>*
ÆLet 5 (Sigefyrth)	8	1
ÆHom 20	2	2
ÆCHom I (Pref)	3	1

b. Excluding *godspell*

Text	*Frequency of <ds>*	*Frequency of <ts>*
ÆLet 5 (Sigefyrth)	0	1
ÆHom 20	1	2
ÆCHom I (Pref)	0	1

In summary, the data suggest that there was a tendency to assimilate to fortis in Old English obstruent clusters. Assimilation could be either regressive or progressive. Furthermore, the data provide evidence for a [spread glottis] contrast in fricatives as well as in plosives, as spelling suggests that both types of obstruents may cause assimilation.

Assimilation to voice

There are several apparent cases of assimilation to voice. Finding potential assimilation of this type would suggest that Old English obstruents could have either a [spread glottis] contrast or a [voice] distinction. This case study has revealed even more results than were observed in Spaargaren (2009: 87–88). The data suggest that the following two clusters were sometimes the result of assimilation: <gg, gð>.

Five different texts contain <gg> where the lexical spelling is <cg>. (25) contains some examples:

(25) Assimilation to voice: <cg> → <gg> (appendix D1)

Lexical form	*Corpus form*	
frocga	frogga	'frog'
gancgan	ganggað	'to go'
sucga	sugga	(a bird species)

Since the apparent assimilation to voice is seen in five different texts, it cannot be said for certain that the change was a scribal error which was not based on actual pronunciation. Nevertheless, I propose that this must have been the case, since the <cg> spelling was clearly preferred in two of the five texts (90% and 75%) and only 50% of the words originally containing <cg> in another text was spelled <gg>. Overall, the total percentage of words in which the spelling suggests voicing is only 38%.

There is one example of the fricative–plosive cluster <hg> turning into <gg>. *Sulh-graf* appears as *sulig-graf* (*sulh-graf* is undefined, *sulh* means 'sunk road'). This example does not provide evidence for assimilation to voicedness, however. Firstly, it only occurs once in the entire corpus. Secondly, the first part of the compound (*sulh*) is spelled so differently from

its lexical form that it seems that the scribe misinterpreted the element as a different word (although the *Bosworth-Toller Anglo-Saxon Dictionary* does not list *sulig* as a headword).

Furthermore, the plosive–fricative cluster <gð> replaces instances of <cð> in three texts.

(26) Assimilation to voice: <cð> → <gð> (appendix D2)

Lexical form	*Corpus form*	
misþyncan (misþyncð)	misþingð	'to have mistaken ideas'
stincan (stincð)	stingð	'to smell'

<gð> completely replaces <cð> in one text, where the cluster occurs three times. However, the evidence for voicing remains quite weak. The other texts retain <cð> in 93% and 99% of the cases. Overall, the percentage of potentially assimilated clusters is merely 4%.

Since the lexical spellings with voiceless obstruents were clearly preferred in the few texts which provide potential evidence for assimilation to voicedness, I conclude that assimilation in this direction is unlikely to have occurred in Old English. Hence, the results suggest that Old English was an aspiration language.

2.5 Conclusion

The aim of this chapter was to see whether the emergence of the aspiration contrast can be reconstructed as a historical change. First, voice and aspiration were defined. It was argued that aspiration is gradual and present in all voiceless obstruents to a certain degree, rather than a feature which is added to obstruents in certain contexts. Evidence for this claim was drawn from Tyneside English word-final aspiration and the fact that, in syllable-final and word-final position in English, obstruents such as /b/ and /p/ are indistinguishable from another if the surrounding sounds are not taken into account. If there was a voice distinction, this would not be the case. Consequently, there can be no voice contrast in these positions and the contrast must be based on aspiration instead.

Furthermore, this chapter argued for a [spread glottis] contrast in English fricatives. Fricatives differ from plosives in that they do not have an aspiration contrast. Fortis fricatives differ from lenis fricatives in that they are articulated with a spread glottis, but a spread glottis does not always surface as aspiration.

The chapter also discussed the properties which distinguish aspiration languages from voice languages. The characteristics are as follows. Firstly, aspiration languages display a fortis/lenis contrast, so that initial and final obstruents are never fully voiced. Voice languages, on the other hand, have a voiced/voiceless contrast. Secondly, obstruents in aspiration languages cannot trigger assimilation to voicedness, since they are unspecified for voice. Obstruents in voice languages can cause this type of assimilation, but they cannot cause aspiration to spread. A typical assimilatory phenomenon found in aspiration languages is sonorant devoicing. In voice languages, voicing always starts immediately after an obstruents and the following sonorant is fully voiced. In aspiration languages, however, there is a longer VOT, so that a sonorant directly following an aspirated obstruent is devoiced. Thirdly, obstruents in aspiration languages are never actively voiced. They can become voiced through passive voicing only, which means that [voice] spreads from an adjacent vowel or sonorant consonant.

Finally, a case study was done to determine whether the development of aspiration language might have been a historical, Germanic change. Assimilation to voicelessness would suggest that the aspiration contrast was already present in Old English. If so, the emergence of aspiration languages was a historical change. The results showed possible assimilation to voicelessness in six clusters. As in Modern English, voicelessness seems to spread from plosives in Old English. Most interestingly, the data provide evidence that fricatives could

also cause spreading of [spread glottis]. Considering these data, it appears that fricatives were specified for [spread glottis] just like plosives. There was no concrete evidence for assimilation to voicedness. Consequently, taking the data into account, it seems plausible that the aspiration contrast found in Modern English was already present in Old English. There was no evidence that aspiration was absent from Early Old English or that the aspiration contrast was just developing. Hence, it seems probable that the aspiration contrast must already have existed then and that it may already have been present in Germanic. This was merely a case study on aspiration in old Germanic languages, but it has provided a motivation to examine other old Germanic languages in more detail in order to see whether the emergence of the aspiration distinction was a Germanic innovation or a parallel change in various old Germanic languages.

3. Germanic enhancement versus the glottalic theory: typological and phonetic considerations

3.1 Introduction

Various theories have been put forward regarding the development of Proto-Indo-European obstruents in Germanic. What these theories have in common is that they argue that the Germanic obstruents became different from their non-Germanic counterparts through Grimm's Law. This process involved the (phonemic) spirantisation of voiceless plosives, devoicing of plain voiced stops, and deaspiration of aspirated voiced plosives. The view suffices for broad approaches to [voice]. Chapter 2 explained that broad approaches do not acknowledge the existence of aspiration languages. Aspiration is claimed to be a phonetic feature and, hence, Grimm's Law (which describes phonemic changes) does not need to explain the fact that fortis obstruents are aspirated in many Germanic languages. Broad approaches argue that Grimm's Law was a simple drag chain or merely a push chain. McColl Millar (2007: 108) defines a drag chain roughly as follows: a chain of sound changes that is set in motion due to the emergence of sound gaps in a previously symmetrical sound inventory. Since these gaps must be filled to restore symmetry, existing sounds are transformed by being dragged into the holes. Consequently, the place previously filled by the transformed sound is left empty. This hole, in turn, drags another segment into it to fill the gap. Most recent literature, according to McColl Millar (2007: 109), identifies Grimm's Law as a drag chain which starts with the emergence of a new type of segment in Germanic: voiceless fricatives. These fricatives were created through the spirantisation of the Indo-European voiceless obstruents /p, t, k/, leaving the space which the Indo-European voiceless plosives had occupied empty. As a result, the plain voiced stops devoiced and took their place, thereby leaving yet another gap. This new hole was filled by the original Indo-European aspirated voiced plosives, which deaspirated to become plain voiced. The process is summarised in (1):

(1) Grimm's Law as a drag chain

Indo-European obstruents

p	t	k	k^w
b	d	g	g^w
b^h	d^h	g^h	g^{wh}

1. Spirantisation of /p, t, k/

Change	Result				Gap			
p > f	f	θ	x	x^w	p	t	k	k^w
t > θ	b	d	g	g^w				
k > x	b^h	d^h	g^h	g^{wh}				
k^w > x^w								

2. Devoicing of /b, d, g/ to fill the gap

Change	Result				Gap			
b > p	f	θ	x	x^w	b	d	g	g^w
d > t	p	t	k	k^w				
g > k	b^h	d^h	g^h	g^{wh}				
g^w > k^w								

3. Deaspiration of /b^h, d^h, g^h/ to fill the gap

Change	Result				Gap
b^h > b	f	θ	x	x^w	None
d^h > d	p	t	k	k^w	
g^h > g	b	d	g	g^w	
g^{wh} > g^w					

A push chain is the opposite development, which is triggered by one (type of) segment becoming too similar or identical to another one. The sound to which it has become similar or identical moves away, changing and thereby becoming more similar to another segment itself. That segment moves as well (McColl Millar 2007: 108). According to this view, Grimm's Law started with the deaspiration of the aspirated voiced stops. The Indo-European plain voiced plosives were forced to change and devoiced, thereby taking the place of the Indo-European plain voiceless stops, which changed into fricatives. The push chain is summarised in (2):

(2) Grimm's Law as a push chain

Indo-European obstruents

p	t	k	k^w
b	d	g	g^w
b^h	d^h	g^h	g^{wh}

1. Deaspiration of /b^h, d^h, g^h, g^{wh}/

Change	Result				Double set			
$b^h > b$	p	t	k	k^w	b	d	g	g^w
$d^h > d$	b	d	g	g^w				
$g^h > g$					Merged sets:			
$g^{wh} > g^w$					b	d	g	g^w
					b^h	d^h	g^h	g^{wh}

2. Devoicing of Indo-European /b, d, g, g^w/

Change	Result				Double set			
b > p	p	t	k	k^w	p	t	k	k^w
d > t	b	d	g	g^w				
g > k					Merged sets:			
$g^w > k^w$					p	t	k	k^w
					b	d	g	g^w

3. Spirantisation of Indo-European /p, t, k/

Change	Result				Double set
p > f	f	θ	x	x^w	None
t > θ	p	t	k	k^w	
k > x	b	d	g	g^w	
$k^w > x^w$					

Chapter 1 mentioned that most literature presumes that the voice contrast is older than the aspiration distinction (Beekes 1995: 24; Iverson & Salmons 1995: 387, 2003a: 54). If we assume that, somewhere along the way, the Germanic obstruent system became different from that of other language families due to the introduction of an aspiration contrast, the view of Grimm's Law as a simple drag chain or a push chain no longer suffices (Iverson & Salmons 1995: 56). It simply cannot explain the introduction of an aspiration contrast. Two main theories have been put forward with regard to the development of Germanic obstruents and the appearance of the aspiration contrast: Germanic enhancement (Iverson & Salmons 1995) and the glottalic theory (Hopper 1973). The aim of this chapter is to examine the development of aspiration languages from both points of view. In Chapter 1, three stages of Evolutionary Phonology were mentioned: 1) reconstruction, 2) analysis of phonetic probability and 3) phonetic experiments. This chapter will focus on stage two. Both Germanic enhancement and the glottalic theory will be judged on the basis of their phonetic plausibility. In addition, I discuss typological probability, so as to see whether certain changes are likely to take place based on actual occurrence in the world's languages. If a process is phonetically plausible but has never been observed in any language, I consider it less probable than a change which is both phonetically natural and typologically common. This approach ensures that, if two changes are both phonetically plausible, we can still argue in favour of one of them based on additional evidence.

Observing that most modern equivalents of aspiration and glottalisation in Germanic seem to come from aspirated stops rather than from glottalic ones and that only enhancement

can explain the presence of an aspiration contrast in the plosives as well as in the fricatives, I will argue that Germanic enhancement probably resulted in the development of aspiration languages.

3.2 Germanic enhancement

3.2.1 The reconstruction of Proto-Indo-European obstruents

A concise overview of Germanic enhancement is provided by Iverson & Salmons (2003a). Iverson & Salmons (2003a: 56) take as their starting point the traditional reconstruction of the Indo-European obstruents as first proposed by Lehmann (1955). This inventory is reproduced in (3):

(3) The traditional reconstruction of Indo-European obstruents (Lehmann 1955)

Plosives

	Voiceless	*Voiced*	*Voiced aspirated*
Labial	p	b	b^h
Alveolar	t	d	d^h
Velar	k	g	g^h
Labialvelar	k^w	g^w	g^{wh}

Fricatives

	Voiceless
Alveolar	s

According to this reconstruction, the plosive inventory is fully symmetrical and there are no gaps. Three phonation types are involved: voiceless phonation, voiced phonation, and voiced breath phonation (or voiced aspirated; see section 3.2.2). Stops may have one of four places of articulation, namely labial, alveolar, velar, or labialvelar. In addition to the plosives, Indo-European had a single, voiceless alveolar fricative.

3.2.2 Evidence for Germanic Enhancement

Phonetic enhancement: a definition

Iverson & Salmons (2003a: 45) acknowledge three contrastive laryngeal specifications in the world's languages, namely voice, aspiration, and glottalisation (see section 2.2.1 for a phonetic description of these specifications). They argue that languages tend to have only one contrastive specification. Languages which display a voice contrast do not have aspiration and vice versa. In Chapter 2, English was mentioned as an example of the former language type and Dutch was analysed as the latter type. Crucial to Iverson & Salmon's theory on the development of aspiration languages is the term 'phonetic enhancement', which I will explain briefly before discussing their analysis of Germanic obstruents.

The theory of phonetic enhancement places emphasis on the role of perception in linguistic change. Hall states that "phonological inventories exhibit a tendency toward maximising auditory distinctness" (Hall 2011: 1). In other words, sounds are as far apart from one another as possible to maximise ease of perception. Hall (2011: 1) takes three-vowel systems as an example to show that inventories with bigger contrasts between phonemes are preferrable. The inventory /i, u, a/ is quite common, whereas the system /ɨ, ʉ, ɘ/ is not. The first set consists of maximally distinctive vowels: /i/ is high and front, /u/ is high and back, and /a/ is low and front. The system /ɨ, ʉ, ɘ/, on the other hand, only contains centralised vowels, two of which are close and one of which is close-mid. Because the vowels /ɨ, ʉ, ɘ/ are

so similar, it is relatively hard to perceive the differences between them. Hence, the system is generally not preferred above /i, u, a/.

Contrastive features are effectively set apart from noncontrastive (phonetic) properties in linguistic systems — certain features are known to create distinctions between sounds, whereas the addition of others only emphasises such a distinction but is not required. This difference between contrastive and noncontrastive sounds is the basis of the theory of Modified Contrastive Specification, an approach which claims that change occurs through phonetic implementation (Avery & Rice 1989: 115). According to this theory, phonological representations should encode the differences between segments as minimally as possible (Hall 2011: 12). Representations of sounds are specified "only to the degree necessary to represent contrast within the system" (Avery & Idsardi 2001: 41). In other words, only the phonemic contrasts should be specified, since only phonemes are purely characterised by distinctive features. Predictable properties of sounds — that is, articulations of phonemes triggered by certain contexts — are specified at the phonetic level (Hall 2011: 16). Avery & Idsardi (2001: 41) state that these phonetic properties are redundant, because they overspecify segments: they contain information that is not required by listeners to interpret a sound correctly. Hall (2011: 3) posits that such redundant specifications may have a function, however, namely that of enlarging, and consequently emphasising, contrasts between relatively similar sounds. If the redundant features are added to phonemic representations, different sounds are set even further apart: "a feature with a particular acoustic/auditory correlate can be enhanced by a separate acoustic/auditory effect that increases the relative salience of that correlate" (Hall 2011: 20). Later on in this chapter, I will discuss the possibility that aspiration is sometimes added to voiceless sounds in order to enhance the distinction between voiceless and voiced segments, and that aspiration can enhance voicelessness due to the fact that it adds an extra voiceless puff of air to voiceless segments (see Chapter 2). As a result, the voiceless period lengthens and becomes easier to perceive.

In short, redundant specifications may be added at the phonetic level to increase the difference between two perceptually similar segments. Below, I will show that enhancement, according to the theory of Germanic enhancement, is what resulted in the distinction between voice languages and aspiration languages.

Grimm's Law as phonetic enhancement

Iverson & Salmons (2003a: 44) argue that languages with an aspiration contrast in the obstruent system emerged as a result of Grimm's Law. In the literature, this sound change is regarded as the development that separated Germanic from the other Indo-European dialects (Beekes 1995: 130; McColl Millar 2007: 119). In contrast to previous approaches, which (as was shown above) simply assumed a push chain or a drag chain without a clear phonetic explanation, Iverson & Salmons (2003a: 44) state that the changes which are part of Grimm's Law were introduced in order to decrease the perceptual similarity of certain sounds. Below, Iverson & Salmons' analysis of Grimm's Law is broken down into steps. Each step represents a single change.

As stated previously, Iverson & Salmons (2003a: 56) start off with the traditional reconstructed Indo-European obstruents. Since the single reconstructed fricative is not important at the moment, only the stops are repeated in (4):

(4) Stage 1: Indo-European plain stops (Lehmann 1955)

	Voiceless	*Voiced*	*Voiced aspirated*
Labial	p	b	b^h
Alveolar	t	d	d^h
Velar	k	g	g^h
Labialvelar	k^w	g^w	g^{wh}

Iverson & Salmons (2003a: 56) assume that Germanic emerged from Indo-European due to phonetic enhancement of the voice contrast in some Indo-European dialects. They hypothesise that the plosives acquired aspiration to become more voiceless perceptually. The second stage of the Germanic obstruent system is as follows:

(5) Stage 2: Germanic enhancement of the voice contrast (Iverson & Salmons 2003a: 56)

	Voiceless aspirated	*Voiced*	*Voiced aspirated*
Labial	$p > p^h$	b	b^h
Alveolar	$t > t^h$	d	d^h
Velar	$k > k^h$	g	g^h
Labialvelar	$k^w > k^{wh}$	g^w	g^{wh}

In other words, Iverson & Salmons assume an extra stage which is not recognised in other literature on Indo-European and Germanic, whereby the voiceless stops become aspirated. Aspiration may be used to enhance a voice contrast if another set of plosives is voiced, since (as was shown in Chapter 2) aspiration is basically a period of voicelessness. Hence, aspiration provides a longer voiceless period and therefore contrasts even more with a fully voiced obstruent than a simple voiceless plosive does. Gordeeva & Scobbie (2007: 1) support this view. They argue that "preaspiration functions as an important correlate of fricative voice" in Standard Scottish English (Gordeeva & Scobbie 2007: 16). They observe preaspirated fricatives in Standard Scottish English. Interestingly, preaspiration is found in the same prosodic context as the devoicing of voiced fricatives: phrase-finally (Gordeeva & Scobbie 2007: 28). Gordeeva and Scobbie hypothesise that preaspiration functions to enhance the voice contrast in phrase-final position, arguing that "preaspiration of voiceless fricatives might function [...] to prevent neutralisation of the phonological voice contrast in specific phrasal contexts" (Gordeeva and Scobbie 2007: 3). In order to test their hypothesis, Gordeeva and Scobbie conducted a production experiment, in which male and female speakers of Standard Scottish English were asked to read aloud several sentences containing target words which contained fricatives. "The materials varied phrasal accent location and voicing" and fricatives occurred in both final and non-final position (Gordeeva and Scobbie 2007: 8). The results showed that the speakers use aspiration do distinguish voiceless stops from originally voiced ones. One speaker, for example, had no voice contrast at all and he did not use other cues to voicing (such as vowel length and obstruent length) either.

Iverson & Salmons (2003a: 57) explain their inclusion of this hitherto unattested stage of aspiration as follows. The most common view is that the plain voiceless plosives immediately transform into fricatives, resulting in a system that contained fricatives, plain voiced plosives, and aspirated voiced plosives. Iverson & Salmons (2003a: 57) argue that the spirantisation of plain voiceless plosives is unnatural. They claim that such a change cannot have occurred without intervening steps, since voiceless plosives are the most consonantal sounds and therefore relatively resistant to lenition. Murray & Vennemann (1983: 519) state that, the stronger a sound is in terms of articulation, the more resistant it is to change (e.g. lenition or assimilation to other segments). Lass (1971: 17) proposes the following hierarchy

of consonant strength for Old English: voiceless stops > voiced stops > voiceless fricatives > voiced fricatives > nasals > liquids > vowels > glides (where > means 'stronger than'). Iverson & Salmons (2003a: 57) argue that there is no natural phonetic explanation for immediate spirantisation. Instead, they posit a stage of aspiration before spirantisation in order to explain how the voiceless plosives could have changed first. They provide two reasons why this is, phonetically speaking, more credible than immediate spirantisation. Firstly, the initiation of the change in the plain voiceless plosive could be explained as a natural development. Rather than needing to assume a phonetically unlikely sound change, the development of the plain voiceless plosives can be regarded as a simple case of phonetic enhancement of a voice contrast. Secondly, phonetic enhancement of a voice contrast through aspiration of the voiceless segments leads naturally to spirantisation. Buizza & Plug state that affricates are "natural intermediates" between fortis (i.e. aspirated) plosives and spirantised plosives (Buizza & Plug 2012: 2). In other words, aspirated plosives may sometimes develop gradually into fricatives by first transforming into affricates and then losing the stop element. Perceptually, aspirated plosives and affricates are very similar. Both involve the articulation of a stop and a following sound which is articulated with a spread glottis: aspiration or a voiceless fricative. Consequently, it is easy to see how aspiration may have led to spirantisation. Iverson & Salmons (2003a: 57) call this case of spirantisation hyper-enhancement, regarding the process as phonetic enhancement that has proceeded further than perceptually necessary. They hypothesise that the aspiration may have become spirantised over time. The third stage of Grimm's Law is presented in (6):

(6) Stage 3: Spirantisation of the voiceless aspirated stops (Iverson & Salmons 2003a: 56)

	Voiceless fricatives	*Voiced*	*Voiced aspirated*
Labial	$p^h > f$	b	b^h
Alveolar	$t^h > \theta$	d	d^h
Velar	$k^h > x$	g	g^h
Labialvelar	$k^{wh} > x^w$	g^w	g^{wh}

The next stage proposed by Iverson & Salmons 2003a: 56) is a drag chain effect caused by the spirantisation of the voiceless plosives. We are left with a gap in the system, having plain voiced plosives, aspirated voiced plosives, and voiceless fricatives, but no voiceless stops. This is a typologically unnatural inventory, since voiced obstruents are marked (Iverson & Salmons 2003a: 56). Iverson & Salmon's claim is supported by Wetzels & Mascaró (2001: 207). By studying various languages (Yiddish, Rumanian, Serbo-Croatian, French, Ya:thê, Yorkshire English, German, Dutch, and Berber), they come to the conclusion that voicelessness is unmarked: if languages have voiced obstruents, they also have the voiceless counterparts. However, languages with voiceless obstruents do not always have voiced ones. Iverson & Salmons (2003a: 56) posit a fourth stage on the basis of this markedness: /b/ and /b^h/ are both voiced and therefore marked. Hence, one of them has to become voiceless in order to regain an unmarked set of plosives. Their fourth hypothesised stage of Grimm's Law is shown in (7):

(7) Stage 4: devoicing of the plain voiced stops to create a new unmarked set (Iverson & Salmons 2003a: 56)

	Voiceless fricatives	*Voiceless aspirated*	*Voiced aspirated*
Labial	f	b > p^h	b^h
Alveolar	θ	d > t^h	d^h
Velar	x	g > k^h	g^h
Labialvelar	x^w	g^w > k^{wh}	g^{wh}

Although aspiration at this stage has not been reconstructed before, the decision to posit aspirated stops rather than plain voiceless ones is understandable if phonetic enhancement is taken into account. Recall that the only other remaining set of stops is voiced, but aspirated. Hence, these plosives are characterised by a following period of voicelessness, which makes them more similar to plain voiceless stops. Another hypothesis (Hopper 1973: 150) is that the voiced aspirated stops were in fact breathy voiced, which would mean that the vocal cords vibrate as for voice, but that they are further adducted than for normal voiced sounds (Laver 1994: 351). Since voicelessness is also characterised by an abducted glottis (see Chapter 2), listeners may have perceived breathy voiced plosives as not being fully voiced and therefore too similar to the voiceless stops. Consequently, the difference between these sounds and the plain voiceless plosives might have been enhanced by adding more voicelessness (e.g. aspiration) to the voiceless stops.

The system now contains voiced aspirated plosives, voiceless aspirated stops, and voiceless fricatives. This means that the two aspirated sets of plosives are overdifferentiated — the plosives contrast in terms of voice as well as in terms of aspiration. Consequently, according to Iverson & Salmons (2003a: 56), the voiced aspirated stops lose their aspiration, while the voiceless aspirated plosives retain it:

(8) Stage 5: deaspiration of the voiced aspirated plosives (Iverson & Salmons 2003a: 56)

	Voiceless fricatives	*Voiceless aspirated*	*Plain voiced*
Labial	f	p^h	b^h > b
Alveolar	θ	t^h	d^h > d
Velar	x	k^h	g^h > g
Labialvelar	x^w	k^{wh}	g^{wh} > g^w

At the fifth stage, the voiceless aspirated plosives are still differentiated from the plain voiced stops with two features: aspiration and voice. Iverson & Salmons (2003a: 46) argue that this overdifferentiation is unnecessary. In order to explain the lack of a voice contrast in modern Germanic obstruents and the presence of an aspiration contrast there, they conclude that the plain voiced stops must have lost their voice specification at some point. This change results in the final stage, shown in (9):

(9) Stage 6: loss of voice specifications (Iverson & Salmons 2003a: 56)

	Voiceless fricatives	*Voiceless aspirated*	*Plain devoiced*
Labial	f	p^h	b > b̥
Alveolar	θ	t^h	d > d̥
Velar	x	k^h	g > g̊
Labialvelar	x^w	k^{wh}	g^w > $g̊^w$

In conclusion, Iverson & Salmons posit that aspiration languages were created through the following developments known together as Grimm's Law:

(10) Summary of Iverson & Salmons' (2003a) analysis
1. Phonetic enhancement: aspiration of p, t, k, k^w
2. Hyper-enhancement: spirantisation of p^h, t^h, k^h, k^{wh}
3. Devoicing and enhancement: devoicing and aspiration of b, d, g, g^w
4. Loss of overdifferentiation: deaspiration of b^h, d^h, g^h, g^{wh}
5. Loss of overdifferentiation: voice specification removed from b, d, g, g^w

Aspiration languages develop starting from the traditional reconstruction of Indo-European obstruents and aspiration is triggered by phonetic enhancement. While the voiced aspirated plosives lose voice and aspiration through enhancement, the original voiced stops lose voice and gain aspiration.

3.2.3 Arguments against phonetic enhancement

Iverson & Salmons' (2003a) analysis of Grimm's Law as the trigger of the distinction between voice languages and aspiration languages consists of typological and phonetic arguments. According to Hopper (1973: 142), a combination of these is necessary to be able to reconstruct linguistic history as accurately as possible. Nevertheless, I argue that the analysis has several weaknesses.

Firstly, Hopper (1973: 143) states that the traditionally reconstructed system of Indo-European stops is typologically uncommon. Recall that this system contains three plosives: one that is voiceless and two that are voiced (one of them aspirated or articulated with breathy voice). Two voiced stops are opposed to a single voiceless one at each point of articulation: labial, alveolar, velar, and labialvelar. Linguistic systems in which two sets of voiced stops occur with one set of voiceless plosives are unattested in any of the languages descendant from Indo-European. Universally, Hackett (1955: 122–124) states, there are only two languages in which this system has been attested, namely Fijian (from the Austronesian family) and Chatino (of Mixtecan origin). Moreover, Hopper (1973: 149) states that the system of Fijian is "defective", which leaves only one language in which a system of two voiced stops and one voiceless plosive is indisputable. These observations correlate with the abovementioned claim that voice is marked. Naturally, a marked segment would be unlikely to occur more frequently in a system than its unmarked counterpart. The observation that a voiceless–voiced–voiced system is marked affects the credibility of Germanic enhancement as proposed in Iverson & Salmons (2003a), since the markedness is not removed until the fourth stage of Germanic enhancement. Recall that, at stage three, the system still contains two voiced stops as opposed to a single voiceless fricative: a plain voiced plosive and a voiced aspirated stop. Iverson & Salmons (2003a: 56) propose, indeed, that markedness is reduced: the plain voiced stop is devoiced in order to create a new, unmarked set of plosives. This results in an obstruent system where a voiceless fricative is opposed to one voiceless aspirated stop and one voiced aspirated plosive. However, I argue that this development comes too late; as Hopper (1973: 145) states, there is no typological validity in claiming that Indo-European contrasted two voiced stops with a single voiceless one. Note, however, that positing two voiceless stops (the second of which then must have been differentiated from the plain voiceless one by some extra characteristic) and one voiced plosive for Indo-European does not necessarily go against Iverson & Salmons' theory of enhancement. The process is merely delayed until stage five, where the voiced aspirated plosives are deaspirated to become more different from the aspirated voiceless stops. This would entail however, that it is not Germanic enhancement that separates Germanic from Indo-European, but spirantisation of the plain voiceless plosives. In addition, Germanic enhancement would only have become

characteristic of the Germanic language family when Germanic had already split off from Indo-European.

Secondly, Hopper (1973: 155) mentions the problematic nature of a Indo-European */b/, which appears to have been absent from Indo-European or very rare. This entails that there was a gap in the obstruent system: there was a three-way contrast between voiceless, voiced, and voiced aspirated plosives at all points of articulation except labial.

Thirdly, Indo-European is unlikely to have had plain voiced plosives, because the root constraints of the proto-language could not be "given a natural phonetic-typological interpretation" if that were the case (Gamkrelidze 2008: 141). Indo-European had several constraints on the cooccurrence of plosives within a root:

(11) Root constraints affecting the cooccurrence of consonants in Indo-European (Lehmann 1955: 17–18; Hopper 1973: 158)
1. The consonants must have different places of articulation, regardless of the manner of articulation.
2. The root cannot contain two plain voiced plosives.
3. A plain voiceless stop may not cooccur with a voiced aspirated stop within a root.

The second constraint is especially important here. It prohibits roots such as **deg-*, whereas **deg^{h}-* and **d^{h}eg-* are allowed in this system. Hopper (1973: 159–160) argues against the existence of plain voiced stops in Indo-European due to the apparent arbitrariness of the abovementioned set of root constraints. There is no phonetic motivation for prohibiting two plain voiced consonants within a root, yet allowing the similar combination of a plain voiced plosive with a voiced aspirated plosive, as in **deg^{h}-* and **d^{h}eg-*. Consequently, a development such as Germanic enhancement could not have started with an obstruent inventory containing plain voiceles, plain voiced, and voiced aspirated plosives (unless the traditional reconstruction is a result of change taking place within the glottalic system, but the literature does not provide arguments in favour of such a development). Although this is not a direct argument against Germanic enhancement, it does suggest that a different change may have resulted in Germanic */p^{h}/.

Lastly, the marked behaviour of the Indo-European plain voiced obstruents is unnatural for plain voiced segments. Plain voiced stops are less marked than voiced aspirated or breathy voiced stops, but the behaviour of the latter class of segments is relatively unmarked (Hopper 1973: 159). As discussed above, all obstruent types except the plain voiced plosives can occur twice within a root. In addition, he observes that the plain voiced stops were less essential in Indo-European than the plain voiceless plosives and the voiced aspirated ones. One motivation for this claim is the rarity of */b/. Furthermore, Hopper mentions that the plain voiced plosives play a minimal part in the formation of suffixed forms. This is typologically unnatural, since "languages in general display a preference for 'simple' phonemes in affixes" (Hopper 1973: 156). Tobin (2006: 63) argues that this preference is universal. Inflectional morphology has a very high functional load and occurs extremely often in human speech production. Consequently, affixes should be easy to produce. Tobin does indeed observe that there is a tendency in languages such as English for affixes to contain unmarked segments or sounds that are relatively easy to utter (Tobin 2006: 63). In fact, the tendency to use unmarked phonemes in suffixes was already noticeable in Old English (Tobin 2006: 76). Firstly, suffixes containing short vowels are preferred above suffixes containing long vowels in Old English. Suffixes rarely contain the latter. Possibly, according to Tobin, the reason for the lack of long vowels in suffixes is that short vowels are easier to produce (because they are shorter and consequently require less effort) and therefore unmarked. Secondly, Tobin claims that the majority of the final consonants in Old English suffixes are

produced with the lips and the apex of the tongue. This manner of articulation is unmarked, as it is the least complicated way of producing consonants: "the apex of the tongue followed by the lower lip are the most flexible, sensitive and the easiest to control of all the active articulators" (Tobin 2006: 76).

In short, the minimal use of plain voiced stops in Indo-European suffixes is rather unlikely, since these sounds are typologically unmarked. Consequently, the Indo-European obstruent system from which, according to Iverson & Salmons (2003a: 56), Germanic enhancement developed is quite improbable — the universal lack of markedness in suffixes and the comparatively minimal role in suffixes of the plain voiced stops suggest that Indo-European */b, d, g, g^w/ cannot have been unmarked plain voiced plosives. Hence, the English voiceless aspirated plosives cannot have developed directly through devoicing of Indo-European */b/ and subsequent enhancement through aspiration. Though the argument presented here does not directly disprove enhancement, Germanic enhancement cannot have been triggered by simple devoicing only, since it is probable that /b, d, g/ were actually consonants with a complex articulartion.

3.2.4 Summary

The theory of Germanic enhancement proposes that aspiration languages emerged due to Grimm's Law. Grimm's Law is perceived as a series of sound changes triggered by the need to enhance the contrast between perceptually similar sound. A nondistinctive feature is added to a (type of) sound to make it more distinctive. Iverson & Salmons (2003a: 56) claim that the enhancing feature is aspiration and that aspiration became contrastive when voiced obstruents lost their voice specification at a later stage. For convenience, the summary of the approach that was provided in (10) is repeated below:

(12) Summary of Iverson & Salmons (2003a) analysis
1. Phonetic enhancement: aspiration of p, t, k, k^w
2. Hyper-enhancement: spirantisation of p^h, t^h, k^h, k^{wh}
3. Devoicing and enhancement: devoicing and aspiration of b, d, g, g^w
4. Loss of overdifferentiation: deaspiration of b^h, d^h, g^h, g^{wh}
5. Loss of overdifferentiation: voice specification removed from b, d, g, g^w

The analysis is problematic in several respects, all of which have to do with the proposed Indo-European obstruent system. The subsequent changes are much less problematic. The proposed first change of devoicing followed by aspiration and spirantisation is unlikely to have been the first instance of Germanic enhancement, considering the fact that the plosives traditionally reconstructed as plain voiced possibly had a more complex articulation. Firstly, because a system with two voiced plosives opposed to one voiceless stop is typologically extremely uncomon, it is unlikely that Indo-European had such a system. Secondly, the plain voiced stop */b/ has not been attested for Indo-European. Therefore, it seems improbable that it existed and that an aspirated voiceless plosive could have developed from a voiced plosive. Thirdly, Indo-European root structure constraints suggest that the proposed plain voiced plosives may not have been plain voiced after all, as this would imply that the root structures of Indo-European are typologically unique and, lastly, the marked behaviour of the plain voiced plosives has no natural explanation.

3.3 The glottalic theory

3.3.1 An alternative reconstruction of Proto-Indo-European plosives

Hopper (1973: 152) attempts to provide an alternative reconstruction of the Proto-Indo-European obstruent inventory, which is typologically more likely than the traditional reconstruction and which can explain the development of Indo-European obstruents in a natural way. The result is the 'glottalic theory', which states that the obstruents traditionally reconstructed as plain voiced were in fact voiceless and glottalic. This section will discuss whether and, if so, how, this new reconstruction removes the problems mentioned in 3.2.3.

The previous paragraph addressed several problems with respect to the traditional reconstruction of Indo-European obstruents. Firstly, it is typologically improbable for a language to have two voiced plosives and only a single voiceless stop. Secondly, it is unusual for an obstruent system with voiced plosives to lack /b/. Hence, a type of segment needs to be reconstructed to replace the plain voiced stops which is not voiced and for which the lack of a labial articulation is plausible. Hopper (1973: 155–156) argues that these characteristics are to be expected with glottalised or ejective stops.

Positing glottalic stops would remove of the first problem, since there are no longer two sets of voiced plosives (plain and aspirated). In addition, it is usual for a set of voiceless glottalic stops to lack the labial articulation (Hopper 1973: 155). This claim is supported by Ladefoged & Maddieson (1996), who show that labial glottalic stops are extremely rare across the languages of the world. Furthermore, Miller-Ockhuizen (2004: 19) suggests that even in languages which contain many different ejectives, the labial stop is often absent. Ju'hoansi (spoken in Namibia and Botswana), has alveolar and velar ejectives, but lacks labial ones. The phonemic system does contain plain voiceless and voiced aspirated stops at all three points of articulation, just like the proposed obstruent inventory for Indo-European. Hence, the glottalic reconstruction is typologically realistic. In addition, various studies suggest that the lack of a bilabial, glottalic stop has a natural, phonetic explanation, unlike the absence of a bilabial, plain plosive: it is marked due to its relative articulatory difficulty. Glottalic plosives tend to have a back articulation rathern than a front articulation (Haudricourt 1950; Wang 1968; Greenberg 1970; Fordyce 1980; MacEachern 1999: 52). Crucially, Maddieson (1984) reports that, out of all glottalised plosives, the bilabial articulation is avoided particularly often. These analyses show that /ˀk/ is much less problematic than /ˀp/. /ˀt/ could still be regarded as a counterargument to the observation that front ejectives are disfavoured, however, since it is produced at the alveolar ridge. There are natural reasons for the complete lack of /ˀp/, however, which do not apply to /ˀt/. Hence, it is possible that /ˀp/ is even rarer than /ˀt/ (that is, absent), due to the fact that there are more reasons to avoid bilabial glottalic consonants than alveolar ones. The literature provides three reasons for the absence of /ˀp/. Firstly, bilabial stops are produced with a larger supraglottal space than alveolar and velar plosives. Crucially, the production of glottalic stops requires the air to be compressed in this space (MacEachern 1999: 53). The larger the supraglottal space, the less noticeable the effect of the air compression. Consequently, bilabial glottalic consonants are relatively nondistinctive and therefore may often not be perceived as glottalised consonants at all (MacEachern 1999: 52). Secondly, the supraglottal chamber of labials involves a large area of elastic cheek wall [...] making compression difficult" (Mackenzie 2009: 159). It is rather difficult to create strong air compression when producing bilabial glottalics, since a larger part of the cheek wall can interfere than with alveolar and velar glottalised stops (MacEachern 1999: 53). The elasticity of the cheek wall may result in insufficient air compression if the cheek wall collapses: "the supraglottal chamber of labials is larger than that of other stops leading to a weaker compressive effect when the larynx is raised" (Mackenzie 2009: 159).

Another problem with the traditional reconstruction of Indo-European obstruents was that the reconstruction of plain voiced plosives cannot explain the constraints on root structure that have been posited for Indo-European. Recall the constraints repeated in (13):

(13) Root constraints affecting the cooccurrence of consonants in Indo-European (Lehmann 1955: 17–18; Hopper 1973: 158)
1. The consonants must have different places of articulation, regardless of the manner of articulation.
2. The root cannot contain two plain voiced plosives.
3. A plain voiceless stop may not cooccur with a voiced aspirated stop within a root.

Hopper (1973: 159–160) argues that the second constraint can be explained if we assume voiceless glottalised plosives instead of plain voiced stops. The second rule must then be rephrased as follows: the root cannot contain two voiceless glottalised plosives. Typologically, such a constraint seems to be more plausible than the one under (13.2). There is no evidence for the original constraint in any attested language and no phonetic motivation either. However, the prohibition of two ejectives within a root seems to be widespread and typologically relatively common. There are several languages which do not allow two voiceless glottalised consonants within a single root (Hopper 1973: 160; Gamkrelidze 1981: 609; 1995: 169; 2008: 141). Gamkrelidze (1995: 169) notes that the root constraint exists in at least three different language families, namely Amerindian, African, and Caucasian. Gamkrelidze & Ivanov observe the restriction in three Amerindian languages: Shuswap, Yucatec, and Quechua. In Shuswap roots of the structure C_1VC_2, C_1RVC_2, and C_1VRC_2, the first consonant cannot be glottalised if the second one is an ejective. Yucatec and Quechua also have this constraint (Gamkrelidze & Ivanov 1994: 18). In addition, Hausa roots may not contain two heteroganic ejectives (Gamkrelidze & Ivanov 1994: 18). Several languages from the Semitic language family prohibit the cooccurrence of certain ejectives within roots (Gamkrelidze & Ivanov 1994: 18). Georgian is an example of a Caucasian language which does not allow the cooccurrence of two glottalised plosives within a root. Roots may not contain two identical glottalised consonants (Gamkrelidze & Ivanov 1994: 18).

In short, by positing voiceless glottalic stops instead of plain voiced plosives, the system of Indo-European no longer has the typological flaw of having two voiced obstruents next to a single voiceless one. In addition, the second constraint on Indo-European root structure is explained if the plain voiced stops are replaced by voiceless glottalised plosives.

3.3.2 The reconstruction of Proto-Indo-European obstruents

Section 3.2.3 addressed the issues connected with the traditional reconstruction of Proto-Indo-European obstruents and Germanic enhancement as the factor triggering the emergence of aspiration languages. On the basis of these issues, Hopper (1973: 151–152) argues for breathy voiced plosives instead of aspirated voiceless plosives and for voiceless glottalic stops instead of plain voiced ones. Hence, the system proposed by the glottalic theory is as follows:

(14) The Indo-European obstruents according to the glottalic theory (Hopper 1973: 152)[9]

Plosives

	Voiceless	*Voiceless glottalised*	*Voiced (breathy)*
Labial	p	pʔ	b^h
Alveolar	t	tʔ	d^h
Velar	k	kʔ	g^h
Labialvelar	k^w	$k^wʔ$	g^{wh}

Fricatives

	Voiceless
Alveolar	s

The typological and phonetic credibility this system will be discussed in section 3.3.3.

3.3.3 Further evidence for the glottalic theory

In this chapter, three key observations have been made regarding the development of aspiration languages. Grimm's Law states that the Indo-European plain voiced stops became voiceless in Germanic, and evidence from the modern Germanic languages shows that these stops are aspirated. Moreover, the glottalic theory posits that the traditionally reconstructed plain voiced stops were, in fact, glottalic plosives. It follows, then, that the modern aspirated voiceless stops may have developed from Indo-European voiceless glottalic plosives instead. This section will examine whether this is probable.

Links between glottalisation and aspiration

Recall the revised second restriction on Indo-European root structure: two glottalised plosives may not cooccur within the same root. The word 'cooccurrence' is crucial here. As Jany (2010: 1) notes, phonotactic restrictions are based on the interaction of the auditory properties of segments. The cooccurrence of two segments may be prohibited if they are too similar to listeners (due to shared phonetic properties, for example). Gallagher explains the motivation for phonotactic restrictions as follows: "the hypothesis about laryngeal cooccurrence restrictions, and long-distance phonological interactions more generally, is that those segments that exhibit long-distance phonological restrictions are just those segments that exhibit long-distance perceptual interactions, as is found for ejectives and aspirates" (Gallagher 2010: 87). Naturally, this observation does not say much about the restriction on roots with two glottalised consonants, since these segments are obviously identical and therefore nondistinct. However, Gallagher hypothesises that roots with one instance of a laryngeal feature perceptually are frequently confused with forms which contain two consonants with that feature. Consequently, the second element is neutralised. Roots with one instance of a laryngeal feature are insufficiently different from roots with two such cases and therefore, the form with two laryngeally marked consonants is disallowed (Gallagher 2010: 87)

Another point which needs to be made is that, in many cases, laryngeal cooccurrence restrictions are motivated by the need to "neutralise perceptually indistinct contrasts" (Gallagher 2010: 87). Cooccurrence restrictions in Indo-European roots do not merely apply when roots contain two identical laryngeal types. The restrictions may also be "based on

[9] Although Hopper (1973: 153) argues for ejectives, Gamkrelidze (1988: 3) posits glottalised plosives. These different interpretations show that the precise nature of the stops is unclear. I therefore think it is best to work with a more general term, such as 'glottalic' (which is the class all glottalised consonants belong to). This approach is also found in some of the literature, such as Kortlandt (1985: 183).

similarity issues", so roots are also adapted when the consonants within them are too similar perceptually (Jany 2010: 2). In order to argue for perceptual similarity between glottalised and aspirated stops, then, evidence must be found for restrictions prohibiting the cooccurrence of glottalic stops and aspirated plosives within one root. The existence of such a constraint would imply that glottalisation and aspiration are too similar in perceptual terms (Gallagher 2010: 87). The prohibition of roots containing either two ejectives or two aspirated segments could exist due to restrictions on just ejectives or aspirated stops. However, the prohibition of combinations of glottalised stops and aspiratd plosives cannot be accounted for by restrictions on only glottalic consonants or aspirated stops, since these combinations do not violate such constraints (Gallagher 2010: 40). Next, therefore, it must be determined what the feature is that makes glottalic sounds and aspirated plosives perceptually almost nondistinct.

There are various examples of languages which pose restrictions on the cooccurrence of glottalic stops and aspirated plosives. In Cuzco Quechua, Dakota, and Peruvian Aymara, for instance, these sounds may not cooccur within a root at all. Furthermore, in Old Georgian, Hausa, and Bolivian Aymara, aspirated plosives may not occur within the same root as glottalised stops if the two segments are homorganic (Jany 2010: 3). In short, there is evidence of aspirated plosives and ejectives interacting as segments of a shared class of features. Gallagher (2010: 19) claims that aspirated and glottalised segments are perceptually similar because they are both characterised by a long-lag VOT: after both types of segments, a vowel or sonorant consonant displays a delay in the onset of voicing. Aspirated plosives and glottalic consonants may cooccur with plain stops, because plain stops have a short-lag VOT and are therefore easily distinguishable from glottalised and aspirated segments. Gallagher's (2010: 41) data from Quechua support this view, as do Maddieson et al.'s (1996) data on Tlingit, and Ham's (2008: 38) data on Tsilhqut'in. All data (as presented in Gallagher (2010)) are provided in (15):

(15) The VOT of plain, glottalic, and aspirated stops in Quechua, Tlingit, and Tsilhqut'in

	VOT of plain, glottalic, and aspirated stops		
Laryngeal type	Quechua	Tlingit	Tsilhqut'in
Plain	23 ms	25 ms	46 ms
Ejective	126 ms	103 ms	102 ms
Aspirate	120 ms	128 ms	105 ms

In all three languages, ejectives and aspirated stops have a long-lag VOT. The difference in VOT between aspirated plosives and ejectives is especially small in Quechua and Tsilhqut'in (six and three seconds, respectively). In contrast, the plain stops have a short-lag VOT — the VOT after plain plosives is very short compared to the VOT of ejectives and aspirated stops.

Ham (2008: 38) observes that the long-lag VOT is the only shared property of glottalic sounds and aspirated stops and that, therefore, a long-lag VOT must be the cause of the restriction on their cooccurrence. Otherwise, glottalic and aspirated segments are very different. Firstly, ejectives appear to be articulated with creaky voice, since their F0 perturbation at the onset of the following vowel is much higher than that of aspirated and plain stops. Hence, F0 perturbation is a prominent cue for glottalised plosives — it plainly distinguishes them from aspirated stops. Ham (2008: 44) also notes that vowels following ejectives (–5 Hz difference) show a rise of F0 from their midpoint onwards. After aspirated stops and plain plosives, in contrast, F0 decreases (8 Hz difference for both). Secondly, ejectives are characterised by a larger increase in energy between their 30 ms point and the peak of the following vowel (4.5 dB). Aspirated and plain stops show an increase of 1.4 dB (Ham 2008: 47). Hence, glottalic plosives have a slower rise time (Ham 2008: 47). The same

differences were observed for Witsuwit'en alveolar stops in initial position (Wright et al. 2002: 70). Thirdly, Gallagher (2010: 41) observes that glottalised plosives have a loud burst amplitude, which is absent from aspirated stops. Lastly, only aspirated plosives are characterised by aspiration noise and a partially breathy articulation of the following vowel (Gallagher 2010: 41).

In short, aspirated and glottalised plosives perceptually form a natural class due to their long-lag VOT. Articulatorily, the two laryngeal types are different: glottalic sounds are produced with a constricted glottis, whereas the articulation of aspirated stops requires a spread glottis (Gallagher 2010: 39). Hence, I hypothesise that glottalic stops and aspirated plosives may be confused due to their perceptual similarity[10]. As a result, glottalic plosives may sometimes change into aspirated ones. Consequently, it seems plausible that the aspiration of the voiceless stops in aspiration languages may have been caused by the misinterpretation of glottalised plosives.

The following sections will deal with evidence for modern remnants of Indo-European glottalisation in modern Germanic languages. The discussion will focus on modern Germanic glottalised stops as well as on modern Germanic aspirated plosives for two reasons. Firstly, finding glottalic segments in modern languages where they are reconstructed for Indo-European will suggest that the stops traditionally reconstructed as plain voiced may indeed have been voiceless and glottalic. Secondly, if some languages have aspiration where others have glottal stops, it is probable that aspiration languages are the result of the misinterpretation of glottalic consonants. This section will focus on four modern types of possible residues of the Indo-European voiceless glottalic plosives: 1) preglottalisation, 2) preaspiration, 3) gemination, and 4) oralisation with subsequent spirantisation (Kortlandt 1997: 176). In order to argue for voiceless glottalised stops in Indo-European on the basis of these four phenomena, we need to find out whether the phenomena can somehow be connected to glottalic sounds and whether it is likely that they come from the same Indo-European sounds. First, the individual typological and phonetic probability of the four phenomena will be discussed. Secondly, in an attempt to find a relationship between the processes, I will examine whether there are languages in which more of these changes take place where we would expect an Indo-European glottalic stop to have occurred.

Preglottalisation in English and Danish

Kortlandt (1997: 175) argues for Indo-European and Proto-Germanic voiceless glottalised plosives by claiming that the English glottal stop before plosives seems to have lost its ability to differentiate meaning, as it does not play a distinctive role. This assumption is based on the observation that the glottal stop has become less frequent. Whereas almost all speakers of British English used to glottalise stops, glottalisation is now characteristic of certain age groups and social classes: "glottalization is pervasive in pre-1930 audio recordings of people born in the second half of the 19th century, even in formal delivery [...]. It follows that glottalization was well-established in upper-class English speech in the 19th century and must have been widespread in the standard language of that time" (Kortlandt 1997: 6). Liberman's (1982: 236–237) claims that the glottal stop no longer has a distinctive role. Earlier studies suggest that preglottalisation was characteristic of certain social groups, such as "the working classes in the big industrial areas" (Andrésen 1968: 24). Furthermore, they note that

[10] Kingston (1985: 175) states that in some languages, like Hausa, glottalised segments are completely different from aspirated ones. Some glottalised stops have a short–lag VOT and are therefore different from aspirated plosives. Such ejectives are characterised by slack vocal folds and are consequently voiced. Since the glottalic theory posits voiceless glottalised stops and we find voiceless aspirated or voiceless glottalised plosives in Germanic languages (see the following four sections), however, Kingston's observation is not problematic for the glottalic theory.

preglottalisation is limited to informal speech (Collins & Mees 1994: 75). Hence, it was thought that preglottalisation was an innovation in certain groups, rather than a retention of an older laryngeal plosive present in the speech of all speakers of English (Andrésen 1968: 24). Kortlandt (1997: 175), however, argues that preglottalisation has lost its distinctiveness and that it therefore is a retention, based on Collins & Mees' analysis of recordings from the first half of the twentieth century. Collins & Mees (1994: 75) observe that preglottalisation was extremely pervasive in the pre-1930 recordings: all speakers were found to use it, even those from the upperclasses. In addition, preglottalisation was recorded in both informal and formal conversations (Collins & Mees 1994: 75). Kortlandt (1997: 175) takes the fact that almost all speakers used glottalisation as evidence that glottalisation used to be a distinctive feature.

Kortlandt (1988b: 353) links English preglottalisation to the Danish vestjysk stød. The vestjysk stød is frequently realised as a period of creaky voice or glottalisation before voiceless plosives following a voiced sound, and it only occurs in medial position in polysyllabic words (Kortlandt 1988b: 353). Like preglottalisation in English, the vestjysk stød of Danish appears to be a remnant of an older language rather than an innovation. Otherwise, there is no clear explanation for why, apart from in western Denmark, it is only found on the island of Fyn, which is completely isolated and therefore is unlikely to have shared an innovation (Kortlandt 1997: 176). At the very least, one would have expected an innovation to spread further on the continent than the western dialects of Danish if it managed to reach an isolated island.

More evidence for glottalic obstruents in Indo-European could be gained by analysing the other supposed remnants of glottalisation in the Germanic languages. The aim of the next few sections is to see whether it is typologically and phonetically plausible that these developed from glottalic stops and, if so, whether they all derive from the same set of (glottalic) consonants.

Preaspiration in North Germanic

Preaspiration is found in various North Germanic languages and dialects, namely Icelandic, Faroese, and West Norwegian. It also occurs in Scottish Gaelic (Kortlandt 1988b: 354). Preaspiration is characterised by the partial final devoicing of the vowel or sonorant preceding a syllable-final plosive. Preaspiration occurs before /p, t, k/ only (Kortlandt 1988b: 354). Recall that, in English and Danish, this is exactly where we find glottalised stops and stød, respectively. In Icelandic, Faroese, West Norwegian, and Scottish Gaelic, /p, t, k/ are only distinguishable from /b, d, g/ due to their additional aspiration; all plosives in the abovementioned North Germanic varieties are voiceless. However, the aspirated plosives are neutralised — that is, deaspirated — after fricatives and after long vowels in Icelandic, Faroese, West Norwegian, and Scottish Gaelic (Kortlandt 1988b: 354). Recall also that neutralisation affects the aspirated voiceless plosives in English after /s/ as well, since only one laryngeal specification is allowed per consonant cluster. Hence, there is another parallel between English and other Germanic languages.

Kortlandt (2010: 354) states that it is common for glottal stops preceding plosives to turn into preaspiration. If so, glottalic segments becoming aspirated is typologically plausible. An example of a language which has ample evidence for preglottalisation turning into preaspiration is Burmese. Bradley (1979: 130) observes a process whereby a voiced preglottalised plosive (/ˀb/) first devoices ([ˀp]) before the glottalisation is replaced by preaspiration ([ʰp]). This is almost the process Kortlandt (2010: 354) hypothesises for Germanic languages which have preaspiration. According to the glottalic theory, Indo-European starts off with a voiceless glottalic stop, which appears to become preaspirated in Icelandic, Faroese, West Norwegian, and Scottish Gaelic. Wanano provides additional

evidence for glottalic segments becoming aspirated. Preglottalisation may be realised phonetically as preaspiration in this language (Stenzel 2004: 94):

(16) Glottalisation → aspiration in Wanano (Stenzel 2004: 94)

Underlying form	*Surface form*	
/kuʔtu/	[kuʰtu]	'clearing'
/waʔtʃe/	[waʰtʃe]	'to be happy'
/doʔka/	[doʰka]	'crash'
/phuʔti/	[phuʰti]	'leftover manioc meal'

Wanano preaspirates preglottalised stops in CVʔ.CV words (Stenzel 2004: 94). Furthermore, Ofo provides evidence of glottalisation turning into aspiration in the fricative inventory:

(17) Glottalisation → aspiration in Ofo (Jacques 2011: 12)

Proto-Dhegiha	*Quapaw*	*Biloxi*	*Ofo*	
*/nãxʔõ/	[nõxʔõ]	[nãxe]	[nasʰe]	'to hear'
*/wãxʔõ/	[wãxʔõ]	xohi	[sʰohi]	'old'

The data in (17) show that an originally postglottalised fricative becomes postaspirated in Ofo. Although the Germanic languages mentioned here all display preaspiration rather than postaspiration, the data from Ofo are relevant. Silverman (2003: 576) argues that preaspiration is a completely different process from postaspiration, in which case the data from the Germanic languages and Ofo would not be comparable. His argument is that there is more variation in the realisation of preaspiration, since these aspirated stops may surface as fricatives whereas postaspirated ones do not (Silverman 2003: 576). As I will show below, however, this claim is incorrect. Spirantisation of aspiration (resulting in an affricate, because the fricative is preceded by a stop) is found after syllable-initial stops in Old High German and Swiss German, for example, as in *kind* [kxint] (German [kʰint]) 'child'. With no other arguments for separation of preaspiration and postaspiration, I propose that the two phenomena are connected. Since the effect of aspiration always has effect on an adjacent vowel, it makes sense to have postaspiration initially (where a vowel follows the obstruent) and preaspiration finally (where a vowel preceeds the consonant). Only there can aspiration influence a vowel. Below, I will argue that this view can explain the distribution of glottalisation and aspiration in English. For now, it is sufficient to remember that Ofo shows that it is possible for glottalisation to develop into aspiration. Hence, Kortlandt's claim that this process takes place in Icelandic, Faroese, West Norwegian, and Scottish Gaelic is plausible.

Earlier, I argued that the preglottalisation observed in English may have been a remnant of Indo-European. Also, I proposed that, if it can be shown that all of Kortlandt's assumed surface realisations of glottalisation appear in the same environment in a single language (due to dialectal variation), it is likely that these realisations all come from the same source. Though not wide-spread, preaspiration does occur in some dialects of English. Recall the data from Tyneside English that were provided in Chapter 2, repeated in (28):

(18) Preaspiration in Tyneside English (Local 2003: 325)

[tʰʊʰkʰ][11]	took
[baʱkʰ]	back

[11] Local (2003: 325) does not explain why the preaspiration in 'back' is voiced, whereas it is voiceless in 'took'.

Jones & Llamas detect preaspiration in Newcastle and Middlesbrough English. In these varieties, word-final/pre-pausal stops are preaspirated rather than preglottalised. Crucially, /p, t, k/ in Newcastle and Middlebrough are preglottalised or glottalised medially (Jones & Llamas 2003: 655). This distribution suggest that there is a relationship between preglottalisation and preaspiration, since both phenomena are found where standard English only displays preglottalisation in all of these positions.

Oralisation and spirantisation in High German

Kortlandt (2010: 7) also proposes that the High German Consonant Shift provides evidence for Indo-European glottalic stops. The shift encompasses three smaller changes. Firstly, the voiceless stops were spirantised after vowels. These fricatives were geminated between vowels, resulting in [ff, ss, xx]. Elsewhere, they became the affricates [pf, ts, kx] (Barrack 1976: 152). Secondly, the voiced plosives were devoiced (Barrack 1976: 152). Some analyses include a third development, namely voicing and despirantisation of /θ/. The High German sound shift is summarised in (19):

(19) The High German Consonant Shift

West Germanic obstruents involved in the High German Consonant Shift

p	t	k
b	d	g
	θ	

1. /p, t, k/ spirantise and become geminates intervocalically, /pf, ts, kx/ elsewhere

Change	Result		
p > ff, pf	ff/pf	zz/ts	kk/kx
t > ss, ts	b	d	g
k > xx, kx		θ	

2. /b, d, g/ devoice

Change	Result		
b > p	ff/pf	zz/ts	kk/kx
d > t	p	t	k
g > k		θ	

3. /θ/ becomes voiced and despirantises

Change	Result		
θ > d	ff/pf	zz/ts	kk/kx
	p	t	k
		d	

For the present analysis, only the first change is relevant, however. According to Kortlandt (2010: 7), the resulting sounds suggest a complex articulation of their Indo-European counterparts. He states that the High German sound shift is a lenition process whereby the voiceless plosives were lenited to fricatives. The next step, then, must have been oralisation of the preceding glottal stop (Kortlandt 2010: 7).

Typologically, the change proposed by Kortlandt seems implausible, however. I have not found any examples of languages where a glottalised plosive has turned directly into a simple fricative, a geminate fricative, or an affricate by spirantisation of the plosive and subsequent oralisation (and, in the case of fricative geminates, spirantisation) of the glottal

stop. Spirantisation before or after stops is, however, attested with originally aspirated plosives. In Icelandic, for example, /ʰp/ sometimes surfaces as [fp] and in Scottish Gaelic, /hk/ may be realised as [xk] (as in /klaʰk/ ‘grasp’ (imperative) > [klaxk]) (Silverman 2003: 580, 583). Spirantisation of aspiration before a stop is also found in Tarascan. Here, /pʰaʰtani/ ‘to touch the mortar’ alternates with /pʰastani/, for example (Silverman 2003: 578). Consequently, I see no reason to assume that a glottal stop was spirantised.

There is no strong phonetic evidence for Kortlandt’s hypothesis either. His claim that the geminate fricatives and the affricates of High German arose due to spirantisation of the plosives and oralisation of a preceding glottal stop is unnatural compared to other scenarios. Kortlandt’s version would require two separate changes. First, the completely closed glottis involved in the articulation of stops would need to be opened in order to allow air to pass through the vocal folds. Second, the active articulators need to create a partial obstruction in the vocal tract rather than in the glottis to form /f, z, x/. I propose that a simple spirantisation process due to the misperception of aspiration is much more likely. According to this view, the plosives are retained, but aspiration is turned into a fricative noise. Miller-Ockhuizen (2004: 116) argues that aspiration noise is perceptually similar to a fricative, since both types of segments are articulated with a spread glottis. She claims that the resemblance is especially confusing in the case of uvular fricatives, as these are articulated nearer to the glottis than any other fricatives (Miller-Ockhuizen 2004: 116). Consequently, friction noise caused by the velar obstruction may be similar to aspiration noise. Since velar fricatives are also articulated at the back of the oral tract, it seems plausible that these could be confused with glottal fricatives as well. Furthermore, the setting of the muscles in the oral tract and the lips for aspiration are the same as those for velar fricatives: there is no occlusion by the tongue, teeth, or lips, and the lips are spread. Of course, these phonetic similarities cannot explain why aspiration would be confused with /s, f/, since these consonants require an obstruction at the front of the oral tract, /s/ being alveolar and /f/ labialvelar. I agree with Miller-Ockhuizen’s (2004: 116) observation that aspiration may be misperceived as /s, f/ due to the fact that all of these sounds are articulated with a spread glottis. Furthermore, both fricatives and aspiration are characterised by continuous aperiodic noise, as opposed to plosives. Fricatives and aspiration are created through turbulent air flow which is continuous rather than pulsed (see Chapter 2). These similarities are not dependent on the place of articulation of fricatives, which could explain why aspiration would sometimes be perceived as the front fricative /s/ or /f/. In short, affrication can be caused by the misinterpretation of phonetic cues. Preaspiration or postaspiration changing into a fricative (which, combined with a preceding plosive, forms an affricate) may simply be the result of misperception and subsequent adaptation, whereas glottalisation developing into a plosive due to spirantisation of a following stop is unattested.

Spirantisation of aspiration after plosives is also found in English, in the Liverpool dialect. Hughes et al. (1987: 66) state that aspiration tends to be strengthened in this variety. There are two observed outcomes. Firstly, friction may simply be increased, so that aspiration is more audible. Secondly, fortition may go so far that spirantisation takes place, in which case an aspirated stop becomes an affricate:

(20) Spirantisation of aspiration (resulting in an affricate) in Liverpool English (Hughes et al. 1987: 66)

/tʰ/ > [tθ], [ts]	[tsɪn]	‘tin’
/kʰ/ > [kx]	[kxɑːnt]	‘can’t’

The observation that the process has two possible outcomes is a crucial, since it shows that an increase of aspiration naturally leads to spirantisation. Spirantisation of aspiration may simply be the result of a slight obstruction in the oral tract leading to friction noise (Thorum 2012:

184). Spirantisation is, therefore, caused by forcing a large amount of air through a relatively small gap. Unlike Kortlandt's proposed process, this change requires fewer and less complicated steps: aspiration simply becomes spirantised when the gap through which air escapes is reduced in size. Hence, change in the articulation of a glottal stop does not need to be directly involved in spirantisation and affrication.

Gemination of voiceless plosives in the Scandinavian languages

The fourth proposed modern reflection of the Indo-European glottalic plosives is gemination of voiceless stops. Kortlandt (1997: 176) states that several Scandinavian languages and dialects have geminate stops where other Germanic and Indo-European languages have singleton plosives. He claims that the West Norse dialects have preaspiration due to weakening of a glottal stop. The East Norse varieties, on the other hand, have geminates. The only exception to gemination is West Danish, where we find glottalisation in the form of the vestjysk stød (Kortlandt 1997: 176). Due to this exception, Kortlandt (1997: 176) links gemination to glottalisation.

There are four gemination processes in the Scandinavian languages, which are found where English has glottalised stops. Firstly, some Norwegian and Swedish dialects show gemination of /p, t, k/ after short, stressed, non-low vowels. Some data are given in (21):

(21) Gemination of /p, t, k/ after short, stressed, non-low vowels (Kortlandt 1997: 176)

Old Norse	*Swedish*	
vika	vecka	'week'
dropi	droppe	'drop'
skip	skepp	'ship'

Secondly, Old Norse /k/ geminated after short vowels and before the sonorants /j, w/. Germanic **bakjar* 'book', for instance, became *bekkr* in Old Norse. Again, gemination occurs finally in a stressed syllable, where English has glottalisation (Ringe 2006: 296). Thirdly, West Germanic aspirated the fortis stops as well. Like Old Norse, this language geminated the plosives before sonorants. The only difference is that the triggering sonorants were /r, l/ and not /w, j/ (Ringe 2006: 296). Lastly, clusters consisting of a nasal followed by a homorganic fortis plosive later appeared as geminated fortis stops in most of Scandinavia. /mp, nt, ŋk/ turned into /pp, tt, kk/, respectively. Old Norse *drekka* 'to drink' presumably comes from Germanic **drinkana*, based on the observation that most Germanic languages have /ŋk/ and not /kk/: Old English *drincan*, Old Frisian *drinka*, Old Saxon *drinkan* (Ringe 2006: 296). Recall Kortlandt's hypothesis for gemination in Old High German, which is that the cause for gemination was the oralisation of a glottal stop preceding the oral plosive. In the case of Old High German, I argued that this change was implausible, since a much more natural change could be proposed. Perridon (2008: 417) states, however, that oralisation sporadically occurs in Danish: /huʔs/ 'house' is sometimes pronounced as [huks] and /tiʔ/ 'time' as [tik]. Nevertheless, I argue that oralisation of a glottal stop cannot provide an explanation for the abovementioned cases of gemination in Scandinavia.

Kortlandt (1997: 176) argues that, if we assume that the voiceless stops were originally glottalised, the following scenario can be posited: loss of the glottal stop in modern Germanic languages which now have simplex consonants, and retention of the complex articulation in the form of gemination in Germanic languages which now have geminates. Recall, however, that Old Norse, Norwegian, and Swedish display aspiration before plosives under several conditions. Crucially, one of these is that the vowel preceding the plosive is short. At least for Swedish, a rule has been attested which states that syllable rhymes must

either consist of a short vowel followed by a long consonant, or a long vowel followed by a singleton consonant. Taking this restriction into account, gemination of the plosives /p, t, k/ may have been caused by the shortness of the preceding vowels. There is no evidence that gemination was created through oralisation of a glottal stop. This becomes clear if we look at attested surface realisations of the geminates in Icelandic. Underlyingly, *epli* 'apple' has a geminated consonant cluster. Hence, the expected pronunciation would be ['ɛppli]. More often, however, the surface pronunciation is ['ɛ^{h}pli]: the geminated plosive is realised as a preaspirated singleton stop (Perridon 2008: 423). According to this example, the Icelandic geminates are allophones of preaspirated fortis plosives rather than allophones of preglottalised stops. Consequently, it seems plausible that the geminates arose due to aspiration following a vowel in the following context: V^{h}T (where V represents a vowel and ^{h}T a preaspirated voiceless stop). I propose that the silence preceding the stop is the effect of aspiration and that it could have resulted in misperception of the vowel as being short. If so, speakers would simply have applied the rule stating that short vowels must be followed by geminates, therefore lengthening the following plosive. Glottalisation might have resulted in the same correction, but since there is no evidence for preglottalisation alternating with geminates in Icelandic, gemination due to preaspiration seems more likely.

In the case of gemination after the loss of a preceding /n/, Kortlandt (1997: 177) states that gemination after the loss of a preceding /n/ must have been the result of sonorant devoicing through aspiration of the following stop, which partially devoiced /n/. The nasal therefore became difficult to perceive and was deleted. Subsequently, compensatory lengthening geminated the stop following the nasal in order to restore the number of morae in the syllable. Kortlandt assumes that this gemination process is similar to the one found in Old High German, which he explains as spirantisation of a plosive followed by oralisation of a preceding glottal stop (Kortlandt 2000: 7–8). I have argued that preaspiration explains the Old high German consonant shift, however, so a parallel between these sound changes would not be an argument for preglottalisation. I also propose that the gemination of /p, t, k/ after nasals in Scandinavian languages does not require a stage in which there were preglottalised stops. In Chapter 2, it was stated that aspiration may be realised as sonorant devoicing. Crucially, all nasals are sonorants. I have not found any evidence for glottal stops having the same effect. Hence, if sonorant devoicing has indeed resulted in the loss of nasals before final stops, preaspiration seems more probable than preglottalisation.

Like the previous three changes, gemination of fortis plosives is also found in English. The Northumbrian dialect of Old English had several geminated forms, which are not found elsewhere in Britain (Kortlandt 2000: 17).

(22) Gemination in the Northumbrian dialect of Old English (Luick 1964: 400, 886; Brunner 1965: 189)

Northumbrian dialect	*Other Old English dialects*	
gætt	gæt	'gate'
scipp	scip	'ship'
fætt	fæt	'vessel'
eatta	eata	(undefined)
brecca	–	'violator'

These data are somewhat unreliable, however, and therefore do not pose a solid argument in favour of the assumption that Germanic geminates are a reflection of Indo-European glottalic segments. Firstly, Luick (1964: 400, 886) and Brunner (1965: 189) state that all of the forms in the left column of (24) contain geminated consonants. I argue that the fact that we find gemination in Northumbrian Old English does not necessarily mean that English and the

Scandinavian languages shared a glottalic stop, however. Kortlandt (2000: 17) states that the fact that Scandinavian and Old English show similar gemination processes must mean that this process was widespread and therefore not an innovation. Consequently, both cases of gemination originate from a common Germanic or Indo-European complex plosive (a glottalic stop) (Korlandt 2000: 17–18). However, the presence of Scandinavian-like gemination in the north of England can also be the result of borrowing. It would certainly explain why only the Norhumbrian dialects have. Lindisfarne was one of the first locations to be raided by the Vikings during the period of Viking invasions. Contact resulted in numerous other borrowings which are not found elsewhere in Britain. In fact, Miller (2012: 108) observes that the Northumbrian dialect has more Scandinavian elements than any other, ranging from loanwords to Scandinavian spelling of cognates. *Fro* and *fra*, for example, are found where Old English *from/fram* 'from' is expected. This could be due to confusion with the Scandinavian equivalent *fro* (Miller 2012: 107). Furthermore, Old Icelandic *til* 'to' coexists with native *to* in northern late Old English and Middle English dialects (Miller 2012: 108). Another Scandinavian remnant found in Northumbrian is *if* 'if' instead of native *gif*. In Scandinavia, the equivalent was *ef*. Miller (2012: 108) proposes that the presence of this northern form may have been the result of confusion of the Scandinavian and Old English pronunciations.This would mean that, since Scandinavian did not have an initial consonant, the palatal consonant from Old English is deleted. The vowel remains that of Old English, however. In short, the fact that we find gemination in Old English does not mean that it is a reflex of an earlier, apparently common, complex plosive. Hence, there is no real evidence for a connection between gemination and glottalisation.

3.3.5 Summary

The glottalic theory proposes that the Indo-European stops originally reconstructed as plain voiced were, in fact, voiceless and glottalic. In several articles, Kortlandt claims that this reconstruction can provide a unified explanation for preglottalisation in English and Danish, preaspiration in Icelandic, oralisation of a glottal stop with subsequent spirantisation of the following plosive in Old High German, and gemination in several Scandinavian dialects. He argues that these phenomena may develop naturally from glottalic stops. Typological and phonetic evidence, however, suggests that it is more likely that these four phenomena are reflexes of an older aspirated stop.

With the possible exception of gemination, all phenomena are found in English, in the same phonological position in different dialects. Hence, it seems probable that glottalisation, aspiration, and spirantisation have the same origin. I have argued that misperception of glottalic plosives as aspirated is typologically and phonetically plausible. Consequently, the observation that glottalisation, aspiration, and spirantisation are more likely to have come from an aspirated stop does not directly go against the glottalic theory. It merely suggests that glottalisation must have turned into aspiration at some point. Otherwise, it is difficult to explain the presence of glottalisation, aspiration, and spirantisation in different dialects. The next section will discuss whether the aspirated stops are original or whether glottalisation was, indeed, present before aspiration lenited the stops.

3.4 Germanic enhancement versus misperception of glottalic plosives

As the above analyses have shown, both Germanic enhancement and the glottalic theory require a stage in Germanic where the middle series of the Indo-European plosives (traditionally reconstructed as /b, d, g/) were aspirated. First, I argued that this is a weak point in the theory of Germanic enhancement, since no such stage has been attested. However, typological and phonetic evidence later suggested that aspiration must have led to preglottalisation, preaspiration, spirantisation, and gemination of the Indo-European stops that

are traditionally reconstructed as Indo-European /b, d, g/. These phenomena do not prove that Indo-European had glottalic plosives. Since we find three out of the four realisations in English, they appear to be connected in some way. Their presence in several other Germanic languages suggests that the type of plosive from which these realisations originated was widespread beyond English as well, and may have been a common Germanic sound. Consequently, aspiration must already have been present in Germanic. Iverson & Salmons (2003a: 56) place aspiration of /b, d, g/ in Germanic.

Despite the evidence in favour of Germanic enhancement, glottalisation cannot be ignored, since English and Danish preglottalised final, stressed plosives whereas several other Germanic languages aspirate them. I propose that glottalisation fits perfectly into the theory of Germanic enhancement. Ringgaard (1960: 107) and Perridon (2008: 419) state that Danish provides evidence for phonetic enhancement through the phonemicisation of the vestjysk stød. Recall that the vestjysk stød is preglottalisation of an originally medial voiceless stop. Hence, preglottalisation used to occurr medially and preaspiration took place finally. During the thirteenth century, however, final short vowels were lost in the dialect of West-Jutland, so that the stops preceding them became final (Perridon 2008: 419). The deletion of final short vowels resulted in many minimal pairs, such as those in (23):

(22) Minimal pairs after the loss of final short vowels in Danish (Perridon 2008: 419)

Original final position (allophonically aspirated)			*Final position after vowel-deletion (vestjysk stød)*		
[hænt]	hent	'fetch' (imperative)	[hænt]	hend	'to fetch'
[skærp]	skarp	'sharp' (singular)	[skærp]	skarb	'sharp' (plural)
[hæt]	hat	'hat'	[hæt]	had	'hats'

In Chapter 2, I argued that aspiration is difficult to perceive in final position. Hence, the contrast between the forms in (25) may have been unclear. Ringgaard (1960: 107) and Perridon (2008: 419) support this view and state that, in order to distinguish the apocopated forms from forms with originally final stops, the allophonic distinction between aspiration and stød was phonemicised. In short, the opposition between the new minimal pairs was emphasised by enlarging the distinction between final and originally medial plosives.

Possibly, English preglottalisation is the result of enhancement. If so, there is no reason to assume that glottalisation is a remnant of Indo-European. While I have not been able to find literature on this topic, previous observations made in this thesis provide evidence that preglottalisation may be the result of enhancement. Data from Tyneside English indicate that final preaspiration exists (or, at least, that final fortis obstruents are articulated with a spread glottis), but that aspiration is commonly only perceived after a stressed, syllable-initial plosive (Local 2003: 325; see Chapter 2). Furthermore, recall that in several northern dialects, we find preaspiration instead of glottalisation before a final stop. Since English syllable-final fortis and lenis plosives are solely distinguishable due to contrasts in length of the preceding vowel and glottalisation before a final stop, it may be possible that glottalisation was added before fortis plosives in order to increase the contrast between fortis and lenis stops. This remains speculation as long as no evidence is found, however.

There is one crucial argument which suggests that the aspiration contrast has appeared in certain languages due to enhancement rather than due to misperception of Indo-European glottalic plosives. Whereas Germanic enhancement takes both plosives and fricatives into account, the glottalic theory only addresses the stops. Consequently, the latter does not explain why some languages have an aspiration contrast in the fricative system as well as in the plosives, even though the contrast between aspirated and plain fricatives (as in English), is

only underlyingly present. If we are to look for a unified explanation for the presence of an aspiration contrast in both plosives and fricatives, The glottalic theory certainly provides the less ideal solution. In short, the above analyses have provided the following arguments in favour of Germanic enhancement: 1) spirantisation and gemination are more likely to come from aspirated consonants, 2) preglottalisation in English and Danish may be the result of enhancement, and 3) only Germanic enhancement can provide a unified account of the emergence of an aspiration contrasts in fricatives and plosives.

3.5 Conclusion

This chapter has compared the typological and phonetic probability of two theories: Germanic enhancement and the glottalic theory. Germanic enhancement argues for the addition of aspiration as phonetic enhancement of a voice contrast, whereas the glottalic theory posits Indo-European voiceless glottalic plosives instead of plain voiced ones, which naturally may have led to aspiration of the Germanic fortis stops. More evidence was found in favour of Germanic enhancement. There is no evidence for glottalisation being required to generate aspiration in Germanic. Furthermore, preglottalisation may be the result of enhancement, in which case it would be an innovation rather than a retention. And, crucially, only phonetic enhancement can provide a unified explanation for the development of an aspiration contrast in Germanic plosives and fricatives. Ultimately, more evidence is found in favour of phonetic enhancement.

The analysis has revealed several unresolved issues. Firstly, it should be determined whether English preglottalisation, like the Danish vestjysk stød, could be the result of the enhancement of syllable-final voicelessness. Secondly, since the traditional reconstruction of the Indo-European obstruents is quite problematic and glottalisation does not appear to be required in the development of aspiration languages either, it is possible that the Indo-European obstruents were neither plain voiced nor voiceless glottalised. Further research should examine whether the Indo-European obstruents traditionally reconstructed as /b, d, g/ could, in fact, have been voiceless and aspirated.

4. Germanic enhancement versus the glottalic theory: proposals for further research

4.1 Introduction

Chapter 3 discussed the typological and phonetic probability of Germanic enhancement and glottalic plosives turning into aspirated ones. The present chapter will expand on Chapter 3 by developing a method for generating experimental evidence. To my knowledge, this has not been attempted before in connection to the emergence of aspiration languages. Evidence other than theories based on reconstruction and assumptions about phonetic structure is lacking. As explained in Chapter 1, the framework of Evolutionary Phonology argues that common and crosslinguistic sound changes frequently have a phonetic motivation. As a result, sound change can be analysed in the laboratory by examining similar, synchronic processes or variations. Chapter 2 concluded that the development of the aspiration contrast is a phenomenon which is either Germanic in origin, or which was a parallel change in various old Germanic languages. Hence, a phonetic analysis of modern-day processes leading to aspiration via misperception could reveal the motivation behind the emergence of aspiration languages. The aim of this chapter is to develop a method with which the cause(s) behind the change can be revealed.

Section 4.2 will discuss the role of phonetics in sound change and argue that misperception frequently appears to be the cause of common and crosslinguistic processes. On the basis of the typological and phonetic observations concerning Germanic enhancement and the misperception of glottalisation that were provided in Chapter 3, section 4.3 will discuss what kind of evidence to look for when researching the probability of both processes. Based on these observations, a method will be developed with which the credibility of both sound changes can be analysed. The proposed experiments could not be carried out, since time did not allow for it. However, in section 4.4, I will discuss the implications of possible outcomes and provide solutions to potential open issues related to those results. Lastly, section 4.5 contains the conclusion to this chapter.

4.2 Phonetic triggers of sound change

4.2.1 Causes of sound change

Blevins (2006: 120) distinguishes between five potential sources of similar processes across languages:

(1) Potential sources of crosslinguistic similarities
   a. Inheritance from a shared ancestor
   b. Parallel evolution in the form of parallel phonetically motivated sound change
   c. Physical constraints on form and function (innate aspects of speech production and potential phonological universals)
   d. Unnatural or external factors (language contact, prescriptivism, second language learning)
   e. Chance

A and b are especially relevant for this thesis, since one of the goals is to examine whether the aspiration contrast was already present in Germanic or whether it developed independently in its daughter languages.

In addition to determining potential sources of crosslinguistic phenomena, it is important to figure out what the factors are that trigger the actual changes leading to such phenomena. The literature argues that variability in pronunciation is the main factor. Ohala states that "variability exists in what we regard as the 'same' events in speech, whether this sameness be phones, syllables, or words" (Ohala 1993: 239). Due to this variability, it is likely that a sound is not always pronounced and perceived in exactly the same way. This variation in pronunciation, therefore, may lead to confusion and subsequent sound change. Blevins, too, argues that variation causes change: human beings construct a grammar for their language based on "the environment in the form of utterances of surrounding speakers" (Blevins 2006: 125). In other words, variability can lead to sound change if something in the transmission of speech goes wrong and a sound is not recognised as what it should be.

Variation does not automatically lead to sound change, however. There must be something that makes this variation difficult to process and which therefore initiates a sound change if the processing goes wrong. The literature distinguishes between physiological causes and acoustic–auditory triggers (Ohala 1993: 238–239). The speaker is regarded as the initiator of change in the first case, whereas the listener is viewed as the cause in the latter. In most literature, the causes are referred to as articulatory and perceptual factors. These terms will also be adopted in this thesis. The arguments for both views will be treated in the next two sections, where I will argue that perceptual causes are most likely to trigger sound change.

4.2.2 Articulatory factors

Ohala (1989: 176) and Milroy (1993: 146) claim that speakers play a role in the initiation of sound change, due to physiological constraints of the vocal tract. Pronunciation will vary if the effects of the physical constraints vary (Ohala 1989: 176). Pronunciation, therefore, is the result of one's intended pronunciation plus the effect of physical limitations. Some types of physical constraints are 1) anatomical, 2) elasto-inertial, 3) neuro-muscular, 4) aerodynamic, and 5) acoustic (Ohala 1989: 176). An example of a change caused by physical constraints is F0 perturbation in vowels following voiceless consonants. If voicelessness is maintained throughout a consonant, there is an increased tension of the vocal folds as opposed to voicing. The change in a vowel from voiced vowel to voiceless after a voiceless consonant is caused by the restriction in the "contraction rate of the cricothyroid muscles in the larynx" — the contraction is not released on time, so that a following vowel has a voiceless initiation (Ohala 1993: 240).

Ultimately, however, it is difficult to explain sound change by referring solely to articulatory factors. Variation in one speaker is not a reason for a whole community to change its pronunciation. Ohala (1993: 244) states that variation in pronunciation cannot lead to sound change on its own, because it does not include "change in pronunciation norm" (what speakers perceive as the phonemic pronunciation). He provides the following argument: most types of variation occur widely in many languages. Universal phonetic features are likely to have a physical cause and listeners can often explain phonetic variations by analysing the environment in which a sound occurs. Because variation is so widespread and occurs so frequently, listeners have learned to normalise predictable variants (e.g. variation caused by contextual influences) to their phonemic form. Such correction prevents sound change, since the 'changed features' (e.g. variations) are deleted from the segment in the mind. The following section will argue that sound change can be explained if variation in speech is followed by perceptual issues, which make reanalysis of segments and spread throughout communities possible.

4.2.3 Perceptual factors

Ohala (1993: 244) argues that the misperception of sounds may result in sound change, since it can include a change of norms (phonologisation of a previously phonetic variant when listeners fail to normalise a phonetic pronunciation to its phonemic form). Misperception leads sound change if "noise in a signal" becomes part of the signal in a listener's mind. Ohala's main argument for stating that perceptual factors play a crucial role in sound change is that "sounds shown to be similar by acoustic analysis and/or perceptual data are those which figure often in sound changes" (Ohala 1989: 182). Crucially, sound change also occurs when two segments are very different articulatorily, yet similar perceptually. If articulatorily different, but perceptually similar segments undergo change, the trigger must be a perceptual factor. Ohala (1989: 189) proposes two perceptual causes of sound change: hypocorrection and hypercorrection (similar to Blevins' 'chance' (Blevins 2006: 126)). Crucially, synchronic variation is a precondition for both types of sound change.

Hypocorrection occurs when "a listener fails to correct the perturbations in the speech signal" (Ohala 1993: 246). The phonetic features are not distinguished from the phonemic ones. Consequently, they are not recognised as mere noise. As a result, these nondistinctive features become part of the speaker's conception of the phoneme. Hypocorrection is a good example of the interaction of articulatory and perceptual factors leading to sound change. Recall that phonetic features may originate from physical constraints (i.e. overlap with neighbouring sounds due to the limited contraction rate of muscles). Listeners copy the results of these constraints into their new conception of a phoneme (Ohala 1993: 246). Ohala (1993: 246–247) identifies two potential causes of hypocorrection. Firstly, first language learners and inexperienced second language learners can initiate hypocorrection due to their lack of experience in dealing with phonetic perturbations. They do not yet know what perturbation is predictable and, hence, cannot distinguish it from the intended pronunciation. Secondly, in case of a conditioned sound change, listeners may fail to observe the environment which causes phonetic variation. If there is no evidence that certain features in a sound only exist due to a conditioning environment, listeners may reanalyse them as being part of the phonological form. According to Ohala (1993: 247), this becomes more likely the farther away the conditioning environment is temporally from the segment in question. It is much harder for listeners to identify the connection when they are far apart.

Hypercorrection results from perceptual confusion in the sense that a feature is wrongly identified as distinctive by a listener (Ohala 1993: 256). This type of sound change explains dissimilation, which is unnatural in articulatory terms. Physical constraints cannot explain why sounds become less similar. In the case of hypercorrection, a listener deletes a certain feature from his or her phonological analysis of a segment because he or she suspects that that feature is the result of a segment assimilating to a nearby sound which has this feature in its phonemic representation. The uttered sound is ambiguous, as it may or may not consist of both phonological features and phonetic features (Blevins 2006: 126).

Blevins proposes an additional perceptual cause of sound change, which she calls 'change': "multiple phonetic variants of a single phonological form are accurately perceived by the listener. The listener […] acquires a prototype or best exemplar which differs from that of the speaker; and/or […] associates a phonological form with the set of variants which differs from the phonological form in the speaker's grammar" (Blevins 2006: 126). Unlike Ohala's causes of sound change, Blevins' 'change' does not require a conditioning environment. The various phonetic variants heard by the listener may merely be the result of physical constraints which make it difficult to pronounce a certain sound in exactly the same way each time. They may also arise out of sheer coincidence, as is also suggested by Ohala's claim that mere chance may sporadically cause sound change (see above). This trigger of

sound change will become important in later sections of this chapter, as most of the sound changes which will be analysed do not require a conditioning environment either.

4.2.4 Forms of sound change

Blevins acknowledges two types of sound patterns which can be tested within the framework of Evolutionary Phonology. Some processes are exceptionless, which means that they are "linguistic universals" (Blevins 2006: 117). Others are common and therefore recognised as linguistic tendencies. These changes are relevant for evolutionary analyses because, if they occur in many different languages, it is likely that they are caused by physical or perceptual factors which human beings have in common (Blevins 2006: 119). Ohala emphasises that these factors are timeless, since there is no evidence that the human vocal tract and auditory system have changed drastically since the first human language. If so, the influence of these factors could be analysed experimentally by examining similar, synchronic sound patterns (Ohala 1981: 186).

The idea behind analysing synchronic processes in order to explain sound change is as follows. Synchronic variation is a kind of mini sound change, in that there is only misperception between a few speakers and a few listeners (Ohala 1993: 243). The only difference between synchronic variation and sound change is that the latter spreads throughout the lexicon and a community and that it involves phonologisation (Ohala 1993: 268). In order to examine the causes of a certain sound change, then, one could "duplicate the conditions under which [it] occurred historically" in the laboratory and observe whether subjects produce synchronic variation that parallels the sound change (Ohala 1993: 261). This method has been proven effective in previous analyses, such as Kawasaki (1986) and Wright (1986). Kawasaki (1986), for example, has shown that phonemic vowel nasalisation originated most likely from phonetic nasalisation, which used to occur alongside non-nasalised vowels adjacent to nasal consonants. In addition, Wright (1986) has argued that misperceptions are the cause of phonological changes in the height of nasal vowels.

4.3 Method: analysing the motivation behind the development of aspiration languages

4.3.1 Introduction

Above, I stated that the existence of common sound changes can often be attributed to languages sharing their ancestor or to languages showing some parallel development. Ohala (1993: 238) and Blevins (2006: 119) propose that such frequent patterns are likely to have a phonetic cause. Chapter 2 suggested that the development of the aspiration contrast must have happened in Old English at the latest, since aspiration appears to spread in obstruent clusters. In addition, the literature provided evidence for the existence of the aspiration contrast in other Germanic languages, such as Old Norse. Consequently, we are faced with two possibilities regarding the development of aspiration languages: the aspiration distinction either appeared in Germanic (the shared ancestor), or it is a parallel development in several Germanic languages. The observation that similarities are caused by a shared ancestor or a parallel development in various languages correlates with Blevins's (2006: 120) proposed causes of similarity. Hence, it is probable that the aspiration contrast came into existence due to phonetic factors. This would mean that we can provide phonetic data on whether phonetic enhancement or glottalisation turning into aspiration is the most probable sound change. It is the goal of this section to construct a method with which such data could be generated. The research design will be multi-method (e.g. the results will be obtained through a series of different experiments), since various theories are tested. Each experiment will be motivated with arguments found in the literature as discussed in Chapter 2 and Chapter 3. The result will

be a model for a method which should resolve the issue of which sound change is most likely to have led to aspiration languages. I will discuss the implications of possible outcomes elaborately.

4.3.2 Experiment 1: Misperception of plain voiceless obstruents as plain voiced obstruents in English and French

The overall aim of this experiment is to test the credibility of Germanic enhancement leading to the emergence of aspiration languages. Recall the definition of phonetic enhancement: a feature is added to a sound in order to increase its auditory distinctiveness from another, similar segment. The theory of Germanic enhancement argues that perceptual difficulties were the motivation behind Grimm's Law: listeners may have found it difficult to distinguish between plain voiceless and plain voiced obstruents. As a result, the voicelessness of voiceless obstruents was increased (through aspiration) in order to make the obstruents more distinctive. A way to test phonetic enhancement of voicelessness, then, is to see whether listeners find it easier to distinguish aspirated voiceless obstruents from plain voiced ones than they find it to differentiate between plain voiceless obstruents and plain voiced ones. If so, phonetic enhancement is probable. If not, another motivation for the emergence of the aspiration contrast may be more likely. Below, I will describe in detail how the likelihood of Germanic enhancement can be tested experimentally.

Subjects

The experiment has a quantitative design. In addition, it is between-subject: participants are either part of an experiment group or a control group, not both. This design makes it possible to test whether the emergence or the lack of the aspiration contrast in a language has a certain cause.

The target population consists of native speakers of English (an aspiration language) and native speakers of French (a voice language). The inclusion of these two groups is necessary because otherwise it could never be stated with certainty whether a certain result is due to a change that only took place in aspiration languages. The English participants form the experiment group, since the reason behind the emergence of the aspiration contrast is examined. The French subjects form the control group. Since the experiment examines the influence of perceptual factors, the following inclusion and exclusion criteria should be kept in mind when recruiting participants. Firstly, the subjects should all belong to the same age group, so as to control for age factors. The age group 20–50 is chosen here, because age is unlikely to influence the results with relatively young participants. Secondly, participants should speak a variety which does not display dialectal influence on obstruents, unless this is relevant to one of the subexperiments. Lastly, they should have lived in the area where that variety is spoken since birth. This ensures that they do not speak an imperfect form of their dialect due to moving to the area after acquiring their mother tongue. Excluded fron the experiments are people with a hearing or speech impairment and second language learners.

The participants will be recruited through probability sampling in the form of simple random sampling) within the groups that conform to the selection criteria. Consequently, all speakers of French and English are equally likely to be selected as participants, as long as they belong to the target group. An advantage of simple random sampling is that the results can be analysed statistically.

Data collection

As stated earlier, the goal of this experiment is to see whether the aspiration contrast in the obstruent system of aspiration languages is the result of phonetic enhancement of an original voice contrast, whereby the voicelessness of the voiceless segment was enhanced. Hence, the participants' perception of plain voiceless stops as well as aspirated obstruents is compared

with their perception of plain voiced obstruents in order to see whether aspiration entails that a voiceless segment is distinguished from a voiced one more often. Recall that, according to Iverson & Salmons (2003a: 59–66), phonetic enhancement affected fricatives as well as plosives. Hence, both types of obstruents will be examined, even though voiceless fricatives in Germanic are no longer aspirated on the surface. If phonetic enhancement can, indeed, explain the fricative and plosive systems of aspiration languages, we should expect aspiration to enhance the voicelessness of fricatives as well. The obstruents that are tested are presented in (2):

(2) Target segments for experiment 1[12]

	Plain voiceless	*Aspirated voiceless*	*Plain voiced*
Labial plosives	[p]	[pʰ]	[b]
Alveolar plosives	[t]	[tʰ]	[d]
Velar plosives	[k]	[kʰ]	[g]
Labiodental fricatives	[f]	[fʰ]	[v]
Alveolar fricatives	[s]	[sʰ]	[z]

The experiment consists of two smaller experiments:

1. An ABX task
2. Identification of obstruents in various prosodic domains

An ABX task is a type of discrimination task, which can be used to analyse feature perception. Each item ('trial') consists of three fragments ('intervals' or 'stimuli'), labelled A, B, and X, respectively. Listeners have to decide whether X is identical to A or whether it is the same as B (Gerrits & Schouten 2004: 364). The ABX task serves to examine how well speakers of aspiration languages and voice languages can distinguish plain voiceless obstruents and aspirated voiceless obstruents from plain voiced obstruents. Participants are asked to listen to several audio fragments, in which two types of obstruents are opposed to one another. Since aspiration is a period of voicelessness, obstruents cannot be presented in isolation. Hence, the obstruents in (2) are presented in nonce words. This is necessary because speakers are more capable of normalising sounds to their phonemic pronunciation when segments are presented in known words (Ohala & Feder 1994: 112). Each nonce word will consist of the obstruent in question plus a preceding or following vowel and a sonorant consonant (e.g. [pim, mip]). Sonorants are included to avoid confusion among the English participants due to the glottal stop which precedes vowel-initial words in their language. Word-finally this is not a problem, but sonorants were inserted nevertheless, to make it more difficult for participants to deduce the purpose of the experiment.

The participants listen to twenty ABX trials. Each trial contains three audio fragments, labelled A, B, and X respectively. After listening to these recordings, the listeners must decide whether X is identical to A or the same as B. (3) provides two sample items:

[12] Although English also has dental fricatives, I decided not to include these in the experiments, since French lacks them. Hence, the potential misperception of these sounds by English and French listeners cannot be compared.

(3) The ABX task: sample items

A	B	X
[pim]	[bim]	[bim]
[pʰim]	[bim]	[bim]

The identification task serves to see how well subjects are able to distinguish plain voiceless obstruents and aspirated voiceless obstruents from plain voiced obstruents in various prosodic contexts. Chapter 2 discussed the potential influence of stress on the degree of aspiration: more stress tends to entail stronger aspiration. The goal of this task is to test whether misperception (and therefore the need for enhancement) increases when the height of the prosodic boundary increases. Since English aspiration is clearest in high prosodic domains (see Chapter 2), it would be interesting to see whether aspiration is merely an effect of stress or the result of enhancement (motivated by a greater difficulty in distinguishing plain voiceless obstruents from their plain voiced counterparts). Some examples of prosodic environments are the stressed syllable of a foot, the unstressed syllable of a foot, the syllable carrying the main stress or no stress in the word domain, the phrase domain, and the sentence domain. In other words, the experiment examines whether aspiration is a context-bound phenomenon or the result of stress-dependent enhancement. Once more, the obstruents will be presented within nonce words consisting of the obstruent plus a vowel and a sonorant, though this time within sentences.

Data analysis

The results of the experiment group (English speakers) will be compared to those of the control group (French speakers) in order to see whether the outcomes can be attributed to English being an aspiration language. The outcomes of the ABX task should reveal whether English speakers, as opposed to French ones, are likely to misperceive plain voiceless obstruents as plain voiced ones, thus justifying the theory that the aspiration contrast arose due to the phonetic enhancement of voicelessness. If this is the case, and the result is visible in both plosives and fricatives, an additional explanation needs to be provided for why fricatives have lost the aspiration contrast.

The outcome of the identification task should show whether prosodic domains play a role in the distribution of aspiration. If plain voiceless plosives are often misperceived in high domains compared to lower domains and this is not the case with voiceless aspirated obstruents, it can be argued that phonetic enhancement itself determines where aspiration is used to enhance voicelessness, rather than stress.

4.3.3 Experiment 2: aspiration due to misperception of glottalisation versus syllable-final phonetic enhancement of voicelessness through glottalisation

The overall aim of this experiment is to test whether it is probable that the aspiration contrast arose due to the misperception of glottalisation. If so, the experiment provides potential evidence for the glottalic theory and aspiration languages arising due to the misperception of glottalisation as aspiration. Because we still find both glottalisation and aspiration in some Germanic languages (i.e. English), two experiments are required to determine whether misperception of glottalisation is a likely trigger. In English, aspiration is found syllable-initially after voiceless stops, whereas syllable-final plosives are preglottalised in most dialects. One experiment should test whether listeners are likely to confuse glottalised plosives with aspirated ones. Since syllable-final preglottalisation in English could not be explained if this was the case, another experiment should test whether final preglottalisation was retained because confusion in this position was less common. In addition, if the

experiment does not provide evidence that preglottalisation predates preaspiration, there is no solid evidence for a glottalic origin of the Germanic stops. Another experiment, then, could test whether preglottalisation may have been enhancement of voicelessness in syllable-final position. This would explain why the glottal stop is found before syllable-final plosives, but aspiration is retained elsewhere.

Subjects

The experiment has a quantitative between-subject design. The target population consists of two groups. One group contains speakers from Liverpool. This dialect of English is relevant because syllable-final plosives are preaspirated or preceded by a fricative rather than preglottalised (Watson 2007: 352). Hence, Liverpool English could be a dialect where glottalisation tends to be misperceived as aspirated. The other group contains speakers of another dialect, where syllable-final stops are preglottalised. The participants will be selected by simple random sampling. The inclusion and exclusion criteria are the same as in experiment 1, with the exception, of course, that dialectal influence on stops must be present in the speech of the subjects from Liverpool, as the use of preaspiration is relevant.

In each subexperiment, one group functions as the experiment group, while the other forms the control group. In the first task, the speakers from Liverpool function as the experiment group. Since these speakers have preaspiration instead of preglottalisation, misperception is expected to be observed here rather than in the other group. The speakers from Liverpool form the control group in the second task. If English syllable-final preglottalisation is phonetic enhancement, enhancement does not occur in Liverpool, after all.

Data collection

The aim of experiment 2 is to see whether aspiration originates from glottalisation (in which case the syllable-final glottalisation in many English dialects may be a remnant of an Indo-European glottalic stop) or whether glottalisation is an enhanced realisation of aspiration in syllable-final position (in which case the hypothesis that misperception of glottalisation as aspiration occurs is unlikely). The experiment consists of two tasks:

1. An ABX task
2. Judgment of voicelessness in syllable-final position

Each task has the following target sounds:

(4) Target segments for experiment 2

	Preglottalised voiceless	*Preaspirated voiceless*
Labial plosives	[ˀp]	[ʰp]
Alveolar plosives	[ˀt]	[ʰt]
Velar plosives	[ˀk]	[ʰk]

The ABX task examines whether misperception of glottalised stops as aspirated stops is likely to have resulted in the aspiration contrast. The subjects listen to twenty ABX trials. Each trial presents three audio fragments labelled A, B, and X respectively, as in experiment 1. Plosives are presented next to a vowel within a nonce word and a sonorant is inserted as well. The participants decide whether X is the same as A or identical to B.

The judgment task functions to reveal whether preglottalisation may have been enhancement of a voicelessness contrast in syllable-final position. Nonce words contaning either a preglottalised plosive or a preaspirated stop will be presented within sentences, so as to control for prosodic influence. While hearing these sentences, the subjects are shown two

possible orthographic representations of the nonce word: one containing a voiceless plosive (<p, t, k>) and one containing a voiced stop (<b, d, g>), as in (5):

(5) Judgment of syllable-final voicelessness

Audio fragment	*Possible answers*
The [miˀp] ate the apple.	meep, meeb
The [mi^{h}p] ate the apple.	meep, meeb

Data analysis

The ABX task examines whether speakers whose dialect has preaspirated stops syllable-finally rather than preglottalisation are more likely to misperceive glottalisation as aspiration than speakers who preglottalise. If speakers from Liverpool misidentify preglottalised stops as aspirated stops relatively often, the outcome supports the theory that aspirated stops in Germanic find their origin in glottalised plosives.

The judgment task serves to show whether it is likely that glottalisation rather than aspiration is used to enhance voicelessness in syllable-final position. The results would indicate that preaspirated stops are misidentified as voiced plosives in this context more often than preglottalised stops. If so, preaspiration is hypothesised to represent the original state of 'voiceless' plosives instead and glottalisation is regarded as an innovation.

4.4 Possible scenarios and their implications

The previous section discussed briefly what results would confirm the two hypotheses discussed in this thesis: Germanic enhancement and misperception of glottalic obstruents as aspirated. This section will elaborate on potential results by discussing their and suggest solutions to potential issues that some results might entail.

4.4.1 Experiment 1: Germanic enhancement

The ABX task

Experiment 1 consisted of two tests, the first of which was an ABX. The goal was to determine whether speakers of aspiration languages tend to misperceive plain voiceless obstruents as voiced more often than speakers of voice languages. Furthermore, the effect of aspiration on voiceless obstruents was examined. The possible outcomes of the ABX task are as follows. Firstly, speakers of English might misperceive plain voiceless obstruents as voiced, whereas speakers of French might not. If the results indicate that English speakers do not misperceive voiceless obstruents as voiced when these are aspirated, they support the theory of Germanic enhancement. This would be the case because French speakers, unlike English ones, have a voice contrast in obstruents rather than an aspiration distinction. Hence, they are expected not to need phonetic enhancement of the voice contrast in order to distinguish between /p/ and /b/, etc.

Other outcomes would be difficult to explain. It is possible, for example, that both the English and French participants misperceive plain voiceless obstruents as voiced. This would imply that misperception of voicedness has nothing to do with the developent of an aspiration contrast. If both English and French participants tend to misperceive plain voiceless obstruents as voiced, misperception cannot immediately be said to be the reason behind the emergence of aspiration languages. Hence, another cause should be hypothesised and examined.

Another possible outcome would be that neither English nor French subjects tend to misperceive plain voiceless obstruents as voiced. If so, there is no evidence for phonetic enhancement. In that case, the hypothesis that aspiration is the result of the misperception of glottalisation should be examined carefully in order to see whether that change is possible. A

negative consequence would be that it would be much harder to find a unified explanation for the surface aspiration in plosives and the underlying aspiration in fricatives in aspiration languages, since the glottalic theory takes solely stops into account.

The results with respect to the misperception of plain voiceless fricatives as voiced require an explanation regardless of their implication. It is possible that aspiration is not perceived in fricatives, so that the phonetic enhancement of voicelessness through aspiration does not result in fewer misperceptions of voiceless fricatives. This could either mean that phonetic enhancement is an incorrect hypothesis (another cue for voicelessness may have been used from the beginning, such as length or F0 perturbation on a following vowel), or that speakers can no longer perceive aspiration in fricatives and that, therefore, only the surface aspiration has been lost but other cues to voicelessness have remained. The precise cause could be analysed with another perception experient, which tests whether speakers can distinguish between plain and aspirated voiceless fricatives when these are pronounced in succession.

If the aspiration of voiceless fricatives results in fewer misperceptions of the voice contrast, the results with respect to fricatives support Germanic enhancement. Such an outcome would provide a single explanation for the aspiration contrast in plosives and the underlying distinction in fricatives. However, an additional explanation would have to be provided for the lack of an aspiration contrast on the surface.

The identification task

The goal of the identification task is to examine whether the prosodic variation in the realisation of aspiration is the cause of listeners not perceiving the voiceless–voiced distinction in higher domains. The experiment could generate several results. It is particularly interesting to see what would be implied combined with the results of the ABX task. If voicelessness is more difficult to perceive for English speakers in high prosodic domains and the ABX task supports phonetic enhancement, we can postulate that the need for enhancement increases when the height of the prosodic domain increases. The gradual realisation of aspiration can then be explained as a reflection of listeners' need for enhancement. If so, aspiration is not merely the effect of prosodic factors, but of a combination of these factors and phonetic enhancement.

However, if prosody does not play a role in speakers' perception of voicelessness, we can state that prosodic factors and phonetic enhancement are unrelated. In that case, the gradienct nature of aspiration only has a prosodic motivation. In other words, enhanced voicelessness becomes more emphasised in positions that carry a lot of stress, but this does not mean that speakers tend to misperceive plain voiceless obstruents more often on higher prosodic levels.

4.4.2 Experiment 2: misperception of glottalisation as aspiration

The ABX task

The hypothesis that aspiration is the result of the misperception of glottalisation would be confirmed if the following results are observed. Firstly, we would expect Liverpool speakers to tend to misperceive glottalisation in any position, since plosives are always aspirated, even word-finally, where other dialects preglottalise stops. In addition, non-Liverpool participants should misperceive glottalisation as aspiration as well, but crucially not syllable-finally, since they preglottalise there. It is also possible that both groups misperceive glottalisation as aspiration in all positions, in which case syllable-final glottalisation in many English dialects requires an additional explanation. It could, for example, be the result of extra phonetic enhancement of syllable-final voicelessness. This hypothesis should be tested with another experiment.

Judgment of syllable-final voicelessness

The results could indicate that non-Liverpool speakers perform better when a syllable-final stop is preglottalised than when it is preaspirated. This would suggest that glottalisation is added for the phonetic enhancement of voicelessness in syllable-final position. This outcome would be phonetically natural. Chapter 2 explained that syllable-final aspiration is much less perceptible than initial and medial aspiration. However, this hypothesis would not hold if the ABX task suggests that glottalisation and aspiration tend to be confused, in which case glottalisation turning into aspiration in certain positions may be the more likely change. If so, a study should be done on why non-final position in a word is more likely to cause misperception than word-final position.

4.5 Summary

The goal of this thesis is to uncover whether the aspiration contrast was already present in Germanic and, if so, to develop a method for uncovering the cause of the change that led to the aspiration distinction in Germanic obstruent systems. Chapter 2 established that the contrast is, indeed, likely to have existed in Germanic. Chapter 3 then discussed the nature of the change by analysing two proposed processes: Germanic enhancement and glottalic segments being misperceived as aspirated segments. The current chapter built on the findings by proposing a method aimed at analysing the probability of these sound changes. The framework of Evolutionary Phonology formed an effective starting point, as it provides a means for analysing the naturalness of historical processes. The criteria of this framework were kept in mind while designing a method for phonetic analysis, which was presented in this chapter. The methodology was based on the assumption that perception plays a crucial role in sound change. Arguments for this claim were put forward in the current chapter. I argued that listeners often trigger a change by misperceiving a sound as something else and not being able to correct their mistake. By providing an experimental method for finding evidence in favour of one of the competing theories on the emergence of the aspiration contrast, I hope to have contributed to the literature on aspiration languages.

5. Results and implications of a pilot study

5.1 Introduction

In Chapter 4, I proposed a method for analysing the development of the Germanic aspiration contrast. The present chapter will describe a pilot study, which was based on this methodology. The pilot study serves a dual purpose. Firstly, it tests the effectiveness of the method. If nothing can be concluded from the findings, it is clear that another approach must be chosen. On the other hand, the method works if there are clear results and if it tests what is meant to be tested. Secondly, the pilot study functions to provide suggestions for further research. If the results are clearly in favour of a certain theory and that theory therefore looks promising, future research should pay more attention to that approach.

The results of the pilot study will be described in 5.2 (experiment 1) and 5.3 (experiment 2). Section 5.4 will discuss possible implications of the outcomes. Furthermore, section 5.5 will provide suggestions on how to improve the methodology. Finally, section 5.6 contains the conclusion to the present chapter.

5.2 Experiment 1: misperception of plain voiceless obstruents as plain voiced obstruents

5.2.1 Method

As stated in Chapter 4, the aim of this experiment is to test whether it is likely that the aspiration contrast which is present in many Germanic languages is the result of Germanic enhancement. Although the method used for the pilot study is based on the one proposed in Chapter 4, some adaptations were made. The method for experiment 1 of the pilot study is described below.

Subjects

The experiment had a between-subject design and included an experiment group and a control group. The target population consisted of speakers of an aspiration language and speakers of a voice language. The experiment group contained the subjects whose first language is an aspiration language, whereas the control group consisted of the participants who speak a voice language. In contrast to the methodology presented in Chapter 4, each group contained speakers of multiple nationalities. There were six participants in total. The groups were formed as follows:

(1) Participants in experiment 1

Experiment group			*Control group*		
L1	age	gender	L1	age	gender
English	24	female	Dutch	24	female
Swedish	28	female	Belgian French	22	male
Swedish	40	male	Italian	22	male

While selecting the participants, the inclusion and exclusion criteria were kept in mind (see Chapter 4).

Materials

In order to carry out the experiment, several stimuli had to be recorded first. The following procedure was followed. The stimuli were recorded in the phonetic laboratory of Leiden University using Praat, a microphone, headphones, and a direct-to-disc recording system. The

speakers were asked to sit down in a sound-proofed experiment booth, so that background noise would be absent from the sound files. To ensure that the recordings ran smoothly, the microphone of the speakers was attached to a patch panel, to which another set of headphones and a microphone was attached for the experimenter. Hence, the experimenter was able to listen to the speaker while recording. Furthermore, by switching on the intercom function on the patch panel, the experimenter could communicate with the speaker. Consequently, mistakes on the part of the speaker could be detected during the recording process and the experimenter could ask the speaker to repeat an item until it had been recorded correctly.

The stimuli were read aloud by two speakers: a native speaker of English and a bilingual speaker of English and Dutch. Both speakers recorded stimuli which contained English obstruents, such as aspirated voiceless plosives and lenis stops[13]. The bilingual speaker also recorded plain voiceless plosives and plain voiced stops, which are found in voice languages. The two speakers received a thorough instruction beforehand, so that they were prepared when the recording started. They were told to pronounce the stimuli exactly as presented to them and to speak naturally and at a regular pace. The stimuli were read from a word document on a computer screen. The obstruents had been transcribed phonetically, so that it was clear to the speakers which type of obstruent they had to produce.

The recordings were analysed and edited in Praat. They were first saved as wav files. Next, the wav files were annotated to a textgrid, which made it possible to label certain fragments within the recordings. Each stimulus was labelled with its item number, its phonetic transcription and, in the case of the ABX task, as stimulus A, B, or X. The labelled fragments were extracted to separate wav files with the option 'extract non-empty intervals' in Praat. In some items, it turned out that A was clearly different from B due to factors other than the absence or presence of voice or aspiration in the obstruents. Stimuli that the speakers had interpreted as English-like words, for example, had much longer and vowels than stimuli which had been interpreted as Dutch. Furthermore, the vowels in the former were sometimes nasalised, whereas the vowels in the latter were not. To ensure that only the obstruents were different in an ABX set, such stimuli were edited with the option 'new sound' and 'concatenate'. While the obstruent of a stimulus was retained, the vowel and following sonorant were replaced by the vowel and sonorant of the stimulus which did not provide clues on voice quality.

Each item (an ABX set in the case of the first task and a sentence in the case of the second task) was put on a separate Powerpoint slide. The playback settings were changed to 'automatically', so that the files started playing when the experimenter (manually) switched to the next slide.

Like the recordings, the experiment itself also took place in the phonetic laboratory of Leiden University. Beforehand, the subjects looked at the answer sheets carefully to make sure they understood what to do. Before each task, extra instructions were provided on the computer screen. The participants listened to the stimuli in a sound-proofed experiment booth. They also wore headphones, as the headphones ensured a better sound quality than the speakers. Before the actual experiment, each participant listened to a test item. If necessary, the volume was adapted.

Data collection

The data collection was done according to the description in Chapter 4. The experiment consisted of two tasks. The first task was an ABX task where participants had to decide whether a third fragment (X) was the same as the first one (A) or the second one (B). In other words, two different sounds are played and one of them is repeated. A wrong answer could

[13] Consequently, the stimuli containing these obstruents were recorded twice. This was not according to plan, but the result of the fact that the first speaker was unable to produce plain voiceless and plain voiced plosives.

suggest that misperception of sound A as sound B (or vice versa) is likely to occur. Each subject listened to twenty-four trials. Sounds were presented in the following pairs (and X represented one of each pair): 1) plain voiceless and plain voiced, 2) aspirated voiceless and voiced, 3) aspirated voiceless and lenis. The first combination tested whether misperception of plain voiceless obstruents as plain voiced is likely. This kind of misperception is what the theory of Germanic enhancement assumes to be the reason behind the emergence of the aspiration contrast. The second and third pairs tested whether enhancement as suggested by the theory of Germanic enhancement is plausible. If misperception no longer takes place, the results suggest that aspiration enhances voicelessness. The deletion of the voice contrast (as represented by the third pair) would correlate with the hypothesis that the voice contrast was deleted after the introduction of aspiration if voice is not required to distinguish between obstruents.

The identification task served to show whether the lack or presence of aspiration in certain prosodic domains is the result of Germanic enhancement. Chapter 4 argued that, as aspiration increases when the prosodic level increases, enhancement may be more necessary at higher levels – misperception is less likely to occur in lower domains. If not, the gradual nature of aspiration may just be the effect of variation in stress. The participants listened to twenty-four items: carrier sentences within which a nonce word containing a plain voiceless or voiceless aspirated obstruent. Three different domains were analysed: the head of the intonation phrase, the head of the word, and the head of the foot. Both weak and strong domains were analysed. Each time, the subjects had to decide whether the obstruent in the nonce word was voiced or voiceless.

Fricatives were left out of the pilot study, as none of the speakers could produce postaspirated fricatives. Consequently, it was impossible to test whether Germanic enhancement affected the fricatives as well.

5.2.2 Results

As explained in Chapter 3 and 4, Germanic enhancement states that the Germanic aspiration contrast was introduced to avoid the misperception of plain voiceless obstruents as voiced. Aspiration emphasised the voicelessness of voiceless segments, thereby making them more distinctive from voiced ones. Crucially, the theory of Germanic enhancement claims that speakers of Romance did not tend to misperceive plain voiceless obstruents as voiced. If so, enhancement would not have occurred in this language. This situation is reflected in the following hypothesis: if the aspiration contrast is the result of Germanic enhancement, speakers of aspiration languages would be more likely to mistake plain voiceless stops for voiced ones than speakers of voice languages. However, (2) shows that the results of the pilot study do not seem to support this hypothesis:

(2) Results of experiment 1a: misperception of obstruents in isolated words

	Aspiration language	*Voice language*
Misperception of plain voiceless as voiced	0%	4.76%
Misperception of voiceless aspirated as voiced	12.50%	16.67%
Misperception of voiceless aspirated as lenis	20%	13.33%

There was only one instance where a plain voiceless obstruent was identified as a voiced one, but this did not occur in the experiment group. Rather, the error was made by the Belgian French speaker. The experiment group identified all plain voiceless obstruents correctly, which suggests that speakers of aspiration languages are able to distinguish between plain

voiceless and plain voiced plosives. If so, Germanic enhancement would not have been necessary.

Crucially, the results suggest that, even if misperception had occurred, enhancement of the voice contrast through aspiration of the voiceless obstruents might not have solved the problem. (2) shows that the speakers of aspiration languages found it even harder to distinguish between aspirated voiceless and plain voiced plosives: 12.50% of the aspirated voiceless segments were incorrectly identified as voiced. Furthermore, the experiment group misperceived 20% of the voiceless aspirated stops as lenis. If the outcome of this pilot study were to represent what happened in Germanic, the last stage of Germanic enhancement would be improbable. At this stage, the voice contrast was removed from the obstruent system, as aspiration already served to distinguish /p^h, t^h, k^h/ from /b, d, g/. If listeners had continued to misperceive voiceless stops as voiced, Germanic enhancement would not have solved the problem at all. Consequently, the results of experiment 1a do not support Germanic enhancement.

Experiment 1b tested whether the degree of aspiration depends on the prosodic domain in which a fortis obstruent occurs. Chapter 4 hypothesised that, since aspiration is most audible in higher domains, perhaps the need for enhancement was greater there. This would entail that the misperception of plain voiceless plosives increases when the height of a prosodic boundary does. The results suggest that, whereas speakers of voice languages do not tend to misperceive voiceless sounds in any prosodic domain, speakers of aspiration languages may tend to misperceive plain voiceless obstruents in the following domains:

(3) Results of experiment 1b (experiment group): misperception of plain voiceless obstruents as voiced in various prosodic domains

	Unstressed	*Stressed*
Head of the foot	11.11%	3.70%
Head of the word	22.22%	22.22%
Head of the intonation phrase (IP)	22.22%	44.44%

At first glance, the outcomes seem to support Germanic enhancement. Misperception may increase in higher domains when voiceless plosives are unaspirated, whereas voiceless aspirated plosives were not misperceived in this experiment. However, the fact that misperception does not increase above unstressed word domains would be unexpected in that case. A closer look at the individual results suggests that misperception is not related to the height of a prosodic domain at all:

(4) Results of experiment 1b per participant (experiment group): misperception in various prosodic domains

	Unstressed			*Stressed*		
	English	Swedish	Swedish	English	Swedish	Swedish
Foot	33.33%	0%	0%	22.22%	22.22%	22.22%
Word	33.33%	33.33%	0%	22.22%	11.11%	22.22%
IP	33.33%	33.33%	66.67%	33.33%	33.33%	0%

Individually, the participants do not show a gradual increase of misperception. There is more misperception at higher levels in some cases, but no difference between lower levels. Furthermore, one Swedish participant even shows a decrease in misperception at the intonational-phrase level. In short, neither experiment 1a nor experiment 1b seems to support Germanic enhancement.

5.3 Experiment 2: aspiration due to misperception of glottalisation versus syllable-final phonetic enhancement of voicelessness through glottalisation

5.3.1 Method

The aim of experiment 2 is to test the probability of glottalisation being misperceived as aspiration. The method used for the pilot study is largely identical to the one proposed in Chapter 4. Some adaptations were made, however. The method for experiment 2 of the pilot study is described below.

Subjects

The experiment had a between-subject design. There was an experiment group and a control group. The target population consisted of preaspirating speakers and preglottalising speakers. In contrast to the methodology presented in Chapter 4, the experiment group did not consist of speakers from Liverpool. Instead, speakers from Swedish were chosen. There were three participants in total and they were sorted as follows:

(5) Participants in experiment 2

a. Experiment 2a

Experiment group			*Control group*		
L1	age	gender	L1	age	gender
Swedish	28	female	English	24	female
Swedish	40	male			

b. Experiment 2b

Experiment group			*Control group*		
L1	age	gender	L1	age	gender
English	24	female	Swedish	28	female
			Swedish	40	male

The inclusion and exclusion criteria that had been set in Chapter 4 were kept in mind.

Materials

The stimuli were recorded in the phonetic laboratory of Leiden University with Praat, a microphone, headphones, and a direct-to-disc recording system. The stimuli were recorded in a sound-proofed experiment booth, so that there would be no background noise. The microphone of the speakers was attached to a patch panel. A second set of headphones and a microphone was attached for the experimenter. Lastly, the intercom was switched on. Hence, the experimenter could immediately detect mistakes with regard to pronunciation and ask the speaker to repeat a stimulus if necessary. The stimuli were pronounced by a native speaker of Icelandic, as preglottalisation as well as aspiration may occur in this language depending on the dialect, and she was able to produce both. Before recording, the experimenter provided a thorough explanation of the task. The speaker was told to pronounce the stimuli exactly as presented to them and to speak at a natural pace. The (phonetically transcribed) stimuli were read from a computer screen.

The recordings were analysed and edited with Praat. First, the sound files were annotated to a textgrid, so that each stimulus could be labelled. Labels included the item number, the phonetic transcription, and (in the case of the ABX task), the letter A, B, or X. Using the 'extract non-empty intervals' command in Praat, these labelled sounds were extracted from the recording to separate wav files. All items were inserted into separate

Powerpoint slides and the playback settings were changed to 'automatically'. As in experiment 1, the experimenter manually switched to the next slide when a question had been answered.

The perception experiment also took place in the phonetic laboratory of Leiden University, where the participants listened to the stimuli in a sound-proofed experiment booth (again wearing headphones). Before the experiment, instructions were provided orally by the experimenter in order to ensure that the participants understood the tasks. The instructions were briefly repeated on the computer screen before each task. The experiment started with one test item, to make sure that the volume was high enough.

Data collection

The data were gathered according to the method proposed in Chapter 4. However, only syllable-final preaspiration and preglottalisation were compared, since none of the speakers who had recorded the stimuli was able to produce glottalisation elsewhere.

The experiment consisted of two tasks. The first task was an ABX task where subjects were asked to decide whether a third fragment (X) was identical to the first one (A) or the same as the second one (B). As in experiment 1, a wrong answer could suggest that misperception of sound A as sound B (or vice versa) is probable. A, B, and X could contain either a preaspirated or a preglottalised stop, as long as A and B were different. Each participant listened to fifteen ABX trials.

The second task was a judgment task, where listeners had to decide whether a nonce word in a carrier sentence ended in a voiceless or voiced plosive. A nonce word contained either a preglottalised or a preaspirated stop. If misperception of aspirated stops as voiced took place considerably more often than misperception of glottalised ones as voiced, the results would suggest that glottalisation enhances voicelessness more effectively than aspiration. This task consisted of twenty-four items. As in experiment 1, the potential need for enhancement was analysed in various prosodic domains: the head of an intonation phrase, the head of a word, and the head of a foot.

5.3.2 Results

Chapter 3 and 4 explained that, if the glottalic theory is correct, we would expect speakers who preaspirate to misperceive glottalisation as aspiration more often than speakers who preglottalise. The results suggest that this is the case:

(6) Results of experiment 2a

English	33.33%
Swedish	46.67%

Glottalisation is wrongly perceived relatively often by both groups. The English speaker made fewer mistakes. This is interesting, as Modern English still has glottalisation in one position: syllable-finally. The small difference between the performance of both groups could be explained by English syllable-final preglottalisation: though English speakers preaspirate syllable-initially, they are less likely to misperceive glottalisation as aspiration, as they still use and hear it syllable-finally. The Swedish speakers who took part in this experiment do not glottalise anywhere, and are therefore expected to find it more difficult to identify glottalic stops correctly.

The results might have been distorted by the fact that perception of glottalisation was only tested syllable-finally. Another possibility is that speakers of Old English already found it easy to perceive syllable-final glottalisation, so that it was retained in that position. Despite these uncertainties, experiment 2a suggests that misperception of glottalisation as aspiration is plausible.

Experiment 2b tested whether glottalisation might be an innovation rather than a retention. Chapter 3 argued that English preglottalisation may be the result of syllable-final enhancement of voicelessness. The results of of experiment 2b suggest that this is unlikely. Neither the Swedish nor the English participants misidentified any of the preaspirated plosives as voiced. Both preaspirated and preglottalised stops were judged to be voiceless in all cases. Hence, glottalisation does not seem to be the result of enhancement.

5.4 Implications of the results

Of course, the pilot study did not test enough subjects to provide a definite answer to the question of what triggered the emergence of the Germanic aspiration contrast. Nevertheless, the outcomes provide some interesting suggestions.

Firstly, the few results that were gathered suggest that phonetically speaking, misperception of glottalisation is more probable than Germanic enhancement. To my knowledge, this has not been suggested by experimental data before. By suggesting that the glottalic theory seems to be most likely from a phonetic standpoint, the pilot study provides a platform for more research on this development. This is an important implication, as the glottalic theory has been rejected by a considerable number of scholars.

Secondly, the results suggest that typologically unlikely changes may still be probable due to their phonetic naturalness. If the outcomes were to reflect the historical, Germanic and Romance situation, the typologically least probable change of the two discussed in this thesis is the most plausible phonetically. This would show that sound changes should not be rejected immediately due to a lack of typological evidence. Phonetic evidence could be just as important. This observation supports the framework of historical phonology, rather than traditional, comparative approaches to sound change. In short, the results have led to the following insights: 1) more phonetic research should be done on the glottalic theory and 2) when attempting to explain sound change, we should always consider phonetics as well as typology.

5.5 Evaluation of the methodology and suggestions for improvement

Although the pilot study cannot provide conclusions on the nature of the change which led to the Germanic aspiration contrast, it has shown that the method proposed in Chapter 4 is effective. The outcomes are not random and undecipherable, but seem to point towards one answer. Hence, we should expect further research to generate useful results. Furthermore, the outcomes suggest that the method tested what was meant to be tested: participants' ability to distinguish between voiced and voiceless obstruents and between glottalisation and aspiration. While the experiment was being conducted, it was very clear that the participants understood their tasks. All experiments went smoothly and the participants did not need to ask many questions.

However, there is room for improvement. Firstly, the pilot study has shown that testing only a few people per group is not enough. The results can be skewed by the answers of a single participant. Naturally, this should be avoided. An example is the misidentification of a plain voiceless plosive as voiced by one participant in the control group (the speaker of Belgian French). As was explained in Chapter 4, it is unlikely that speakers of Romance languages in general have this problem. In a small group, one participant has a lot of influence on the results, however, so that unlikely results are not reflected and hence not filtered out. The effect of a single person would be much less noticeable in a larger group.

Another important observation is that the stimuli should have been recorded by a single phonetician who is able to produce all required types of obstruents. This would have saved a considerable amount of time, as I now had to record speakers of three languages.

English for voiceless aspirated and lenis plosives, Dutch for plain voiceless and voiced stops, and Icelandic for preaspirated and preglottalised stops[14].

Furthermore, a future experiment should be designed in such a way that when a participant has answered a question, the computer screen should automatically switch to the next one. During the pilot study, the experimenter had to do this manually. Manual control entailed that participants had to tell the experimenter when they were ready for the next question. One participant confided that this might have distracted him.

Lastly, when stimuli are presented within carrier sentences, these sentences should be recorded by a native speaker. In experiment 2b, the English carrier sentences were recorded by an Icelandic speaker, as she was the only speaker who could preaspirate. However, the English participant later mentioned that the foreign accent had influenced how she had listened to the recordings, as she had "tuned in to the accent". Hence, her answers may have been affected in a way that the answers of non-native speakers had not been.

In short, the method seems to work. The results that the pilot generated did not appear to be random. Furthermore, the method tested what was meant to be tested. Nevertheless, some adaptations should ensure that a future experiment will run more smoothly, that all obstruents can be tested in all positions, and that distraction is avoided.

5.6 Conclusion

This chapter has described the results and implications of a pilot study which was conducted on the basis of the methodology described in Chapter 4. Although the results cannot provide definitive conclusions, they have led to two important observations. Firstly, they suggest that the results of a larger experiment might be in favour of the glottalic theory, which was judged to be less likely than Germanic enhancement typologically. Further research might reveal that the theory is more important than previously assumed. Secondly, the outcomes suggest that typologically uncommon changes may not necessarily be the least likely – they can be very probable from a phonetic perspective. This observation shows that phonetics may be crucial for the analysis of sound change, as is suggested by the theory of Evolutionary Phonology as well.

The results of the pilot study have revealed that, although there were some flaws, the methodology proposed in Chapter 4 should be effective.

[14] I could have recorded an English speaker to obtain stimuli with glottalic stops as well, but the English speaker who recorded the voiceless aspirated and lenis stops was unable to produce preaspirated plosives. To avoid a situation in which participants would guess answers correctly because they could associate certain voices with certain answers, I only had the Icelandic speaker produce glottalic plosives.

6. Conclusion and discussion

6.1 Main findings

The aim of this thesis was to analyse the development of the aspiration contrast in the obstruent systems of aspiration languages and to find a method which could explain how the contrast developed historically. Two competing theories were examined, namely Germanic enhancement and glottalic Indo-European stops being misperceived as aspirated plosives. The analysis consisted of three stages: 1) arguing that the change was a diachronic change that took place in Germanic, 2) providing a description of the kind of changes that could have led to the development of the aspiration contrast and discussing their phonetic and typological probability, and 3) developing a method which can reveal which change is the most probable.

6.1.1 A definition of aspiration

Chapter 2 focused on defining aspiration, how to determine whether a language is of the voice or aspiration type, and finally on determining whether the development of aspiration languages is likely to have taken place in Germanic. It was argued that aspiration is non-rule-based rather than rule-based. Aspiration is always present, but not always perceived, because it is a gradual phenomenon: its perceptibility depends on its prosodic environment. Hence, there is no, light, or heavy aspiration, depending on stress. Crucially, it was determined that aspiration is often overlooked in final position. Tyneside dialects can provide evidence that aspiration occurs in this environment.

In addition, Chapter 2 discussed the properties which define aspiration languages. Firstly, voice is never contrastive. Secondly, only aspiration can spread to other segments. Voice never assimilates. Thirdly, only passive voicing occurs. Obstruents are not voiced inherently and can only be voiced under the influence of surrounding, inherently voiced segments, such as vowels.

6.1.2 The development of aspiration languages as a historical change

Chapter 2 argued that the aspiration contrast developed as a historical sound change and that the distinction therefore should be reconstructed at some stage before the modern Germanic languages. The chapter focused on one example: Old English obstruents were analysed in a case study. The presence or absence of an aspiration contrast was determined by analysing orthography and what it suggested with respect to the direction of assimilation in obstruent clusters. If Old English was an aspiration language, we would expect the fortis consonants to cause assimilation, since the fortis sounds would be specified for a laryngeal feature rather than their lenis counterparts. The results suggested that it was indeed aspiration that spread rather than voice. Assimilation to fortis was found in six obstruent clusters. Spaargaren (2009: 92–93) already suggested that this was the case with plosive sequences in which the stops were separated by a word boundary. This thesis revealed that assimilation can also be found word-internally. More importantly, it was found that fricatives seem to have been specified for aspiration as well, whether underlyingly or superficially. Devoicing was found in clusters consisting of two fricatives as well as in sequences containing a fricative and a plosive. There were a few examples of words which did not suggest assimilation. However, all exceptions could be explained by word frequency: since the exceptions were multiple instances of a few common words, it was hypothesised that words that were common and which were used relatively frequently were subject to fewer spelling adaptations based on aspiration in speech.

Potential assimilations to voice occurred in three clusters only and could be explained as scribal errors that were not based on pronunciation, as they were rather disputable: either single occurrences or used multiple times by a single scribe. Based on these results, I

concluded that the aspiration contrast was probably already present in Old English and perhaps in other old Germanic languages as well.

6.1.3 Possible sound changes resulting in the aspiration contrast and their phonetic and typological probability

Chapter 3 focused on two competing theories on the nature of the change leading to the aspiration contrast and discussed their phonetic and typological probability. The two analyses identified were 1) Germanic enhancement and 2) glottalic segments changing into aspirated ones (based on the idea that the Indo-European plain voiced stops were actually voiceless and glottalic).

Germanic enhancement argues that the aspiration contrast is the result of Grimm's Law, a sound change affecting plosives (and later fricatives), through which Germanic split off from Indo-European. The reason behind the change is claimed to be the need to enlarge the distinction between sets of sounds that are perceptually similar. The theory of Germanic enhancement assumes that plain voiceless stops were perceptually indistinguishable from plain voiced plosives. Hence, the voice distinction was emphasised by enhancing voicelessness through the addition of a feature which would make the voiceless set (more) voiceless perceptually. This is claimed to have been aspiration, which adds a period of voicelessness after obstruents (see Chapter 2). Chapter 3 identified several problems with this analysis, largely based on the fact that there is a lack of evidence for the proposed set of plain voiced Indo-European plosives which became voiceless due to Grimm's Law. The original reconstruction cannot explain root structure (cooccurrence) constraints or the lack of *b, for example. Hence, the exact change proposed is problematic in that the initial stage may not have existed. Therefore, the second change of devoicing and the third stage of aspiration may not have occurred.

The glottalic theory attempts to solve the abovementioned problems by positing voiceless glottalic stops for Indo-European rather than plain voiced ones. Typological evidence suggests that glottalic stops often cannot occur twice within a root and that the bilabial glottalic plosive lacks in several languages which do have glottalic stops at other places of articulation. Chapter 3 provided several arguments in support of glottalic sounds turning into aspirated ones. Firstly, glottalisation and aspiration often interact in cooccurrence constraints, which are frequently based in similarity issues. Hence, misperception of glottalisation as aspiration seems to be phonetically natural. Secondly, we find preaspiration in North Germanic, where other Germanic languages such as English and Danish have preglottalisation. It was found that preglottalised stops often turn into preaspirated stops, which could explain the distribution in the Germanic languages. The literature provides other evidence for Indo-European glottalic plosives which is rejected here, as the same results can be achieved by assuming original preaspirated stops. However, all processes related to glottalisation and aspiration are found within a single language: English. This makes the idea that all processes, and therefore aspiration and glottalisation, are related in Germanic quite attractive. I proposed that glottalisation may be an innovation in English and Danish. Possibly, it was inserted before syllable-final voiceless stops to enhance voicelessness.

Ultimately, I concluded that Germanic enhancement is the most probable change. Firstly, there is no strong evidence which suggests that Indo-European glottalic sounds are necessary to explain Germanic aspiration. The stops originally reconstructed as plain voiced may just as well have been voiceless aspirated. Secondly, the glottalic theory has the disadvantage that it cannot provide a single explanation for the emergence of the aspiration contrast in plosives as well as in fricatives.

6.1.4 A methodology for analysing the development of the aspiration contrast

Chapter 4 built on Chapter 3, taking the proposed sound changes and their typology into account and developing a method for revealing the motivation behind the emergence of aspiration languages based on these. The framework of Evolutionary Phonology was taken as the starting point. This framework suggests that common and crosslinguistic sound changes frequently have a phonetic motivation. Although speakers are involved in that they cause variation, listeners are needed to transform such variation into sound change. Consequently, Evolutionary Phonology states that sound change often involves perceptual factors. Since the aspiration contrast is common in the Germanic languages, Evolutionary Phonology was deemed useful for finding an explanation for the emergence of aspiration languages.

The method revolves around the idea that sound change may be caused by misperception — a sound changes into another one because two segments are perceptually similar. Several perception experiments were set up to test the probability of Germanic enhancement as well as glottalic segments becoming aspirated. Germanic enhancement can, for example, be analysed by checking how well speakers of aspiration languages can distinguish between plain voiceless and plain voiced obstruents as opposed to speakers of voice languages, where phonetic enhancement of a voice contrast is not claimed to occur. Furthermore, the effect of adding aspiration to the voiceless obstruent should be analysed.

The method also includes a perception experiment where misperception is tested in various prosodic domains, so as to exclude the possibility that aspiration is purely present due to stress and to see whether the strength of aspiration varies due to variation in the need of enhancement (depending on the height of prosodic levels).

The idea that a glottalic sound may have become aspirated can be tested with additional experiments. The first tests whether speakers who preaspirate instead of preglottalise (e.g. speakers from Liverpool) tend to misperceive glottalisation as aspiration, in contrast to speakers who preglottalise. A second test examines whether it is likely that glottalisation is used for syllable-final phonetic enhancement instead, thereby reducing the likelihood of glottalisation having turned into aspiration except syllable-finally (as in English and Danish).

The combination of these experiments should reveal which process is most likely to have led to the emergence of the aspiration contrast.

6.1.5 The implications of the pilot study

The results of the pilot study suggest that the proposed methodology works. The results are interpretable and as the participants understood their tasks well, the method tested what had to be tested: participants' perception of voiceless and voiced obstruents and whether they can distinguish between glottalisation and aspiration. Although no definite conclusions can be drawn on the basis of the pilot study, two important observations were made on the basis of the outcomes. Firstly, the results seem to be in favour of the glottalic theory, which argues that aspiration developed from glottalisation. Whereas there is no evidence for Germanic enhancement, misperception of glottalisation as aspiration occurred frequently. It would be useful to carry out a large-scale study to see whether the results based on a larger population would be the same. Such an outcome would be interesting, as the glottalic theory has failed to gain much popularity on the basis of typological and comparative arguments. A phonetic analysis could show that the glottalic theory may have more potential than previously thought.

Secondly, the preliminary results suggest that typologically unlikely sound change are not necessarily the least likely to occur. Typological and phonetic probability do not go hand in hand, so sound changes which are typologically uncommon may be very likely to occur due to phonetic factors.

6.2 Discussion

This thesis has contributed to studies on aspiration languages by analysing how the aspiration contrast developed in Germanic and by creating and testing an experimental method which makes it possible to analyse the nature of the sound change with phonetic data on similar, synchronic processes.

The case study on Old English in Chapter 2 suggests that the emergence of aspiration can be placed at least as far back as early Old English. Based on this observation and what the literature claims about other old Germanic languages, I hypothesised that aspiration may already have been present this early in other Germanic languages, thereby suggesting that the development of aspiration is a historical change which can be reconstructed in Germanic. However, more research on aspiration in other old Germanic languages is necessary to see whether this hypothesis is correct. This thesis mentioned that aspiration is present in various modern Germanic languages, such as High German, Icelandic, and Swedish. Hence, analyses of assimilation in Old High German and Old Norse could be useful.

This thesis has also contributed to the existing literature on aspiration languages by analysing the sound changes which are hypothesised to have led to the aspiration contrast. A comparative analysis has not been carried out before. One key observation was that glottalic plosives, rather than being an original, Indo-European series of stops, may be the result of the enhancement of voicelessness in syllable-final position. However, I have not been able to find previous literature on the possibility that glottalisation is an enhancing feature. Therefore, the statement remains hypothetical and future studies should analyse whether it is probable. One potential flaw of this idea is that, in Newcastle and Middleborough, glottalisation is found in codas word-medially only, even though I argued that final aspiration is most difficult to perceive and therefore most sensitive to enhancement (see Chapter 3). Future research on aspiration languages should analyse why speakers from Tyneside would apply enhancement medially, but not finally.

Another interesting finding was that most Germanic supposed reflections of a potentially glottalic Indo-European obstruents are, phonetically and typologically speaking, more likely to have come from aspirated consonants instead. Kortlandt (2000: 9) discusses this possibility briefly, but rejects the idea in favour of glottalic obstruents. Since several of his arguments were argued to be incorrect, however, future research should discuss whether Indo-European may have had voiceless aspirated plosives rather than voiceless glottalic ones. If so, the aspiration contrast, rather than the voice distinction, would be oldest and we would need to analyse possible sound changes leading to the emergence of the voice contrast instead. It would be interesting if this were the case, since, until now, studies have generally assumed that the voice contrast is older. Such a result would go against phonetic enhancement through aspiration. However, if aspiration can only be reconstructed for Germanic and not for Indo-European, the phonetic enhancement of a voice contrast in Germanic is plausible.

Lastly, the thesis examined the role of phonetic factors in sound change. A phonetic experiment has not been proposed for the analysis of the emergence of aspiration languages before. The pilot study revealed that the method should be effective. Hence, this thesis has provided a novel way of analysing the historical development of aspiration languages.

Appendix A: orthographic clusters excluded from the case study

Fricative–fricative

Voiceless–voiceless	Voiced–voiced
ff	vv
fs	vh
fþ	vz
ss	vð
sf	hv
sþ	hz
þþ	hð
þs	zz
þf	zh
	zv
	zð
	ðð
	ðv
	ðz

Plosive–fricative

Voiceless–voiceless	Voiced–voiced
–	bv
	bz
	dv
	dz
	gv
	gz

Fricative–plosive

Voiceless–voiceless	Voiced–voiced
vb	–
vd	
vg	
zb	
zd	
zg	

Appendix B: Old English obstruent clusters for the case study

B1 Plosive–plosive

B1.1 Voiceless–voiceless

Output (corpus form)		*Assumed input (lexical form)*			
Orthography	Pronunciation	Orthography		Pronunciation	
		Regressive	*Progressive*	*Regressive*	*Progressive*
<pp>	[pp]	<bp>	<pb>	/bp/	/pb/
<pt>	[pt]	<bt>	<pd>	/bt/	/pd/
<pc>	[pk]	<bc>	<pg>	/bk/	/pg/
<tt>	[tt]	<dt>	<td>	/dt/	/td/
<tp>	[tp]	<dp>	<tb>	/dp/	/tb/
<tc>	[tk]	<dc>	<tg>	/dk/	/tg/
<cc>	[kk]	<gc>	<cg>	/gk/	/kg/
<cp>	[kp]	<gp>	<cb>	/gp/	/kb/
<ct>	[kt]	<gt>	<cd>	/gt/	/kd/

B1.2 Voiced–voiced

Output (corpus form)		*Assumed input (lexical form)*			
Orthography	Pronunciation	Orthography		Pronunciation	
		Regressive	*Progressive*	*Regressive*	*Progressive*
<bb>	[bb]	<pb>	<bp>	/pb/	/bp/
<bd>	[bd]	<pd>	<bt>	/pd/	/bt/
<bg>	[bg]	<pg>	<bc>	/pg/	/bk/
<dd>	[dd]	<td>	<dt>	/td/	/dt/
<db>	[db]	<tb>	<dp>	/tb/	/dp/
<dg>	[dg]	<tg>	<dc>	/tg/	/dk/
<gg>	[gg]	<cg>	<gc>	/kg/	/gk/
<gb>	[gb]	<cb>	<gp>	/kb/	/gp/
<gd>	[gd]	<cd>	<gt>	/kd/	/gt/

B2 Fricative–fricative

B2.1 Voiceless–voiceless

Output (corpus form)		*Assumed input (lexical form)*			
Orthography	Pronunciation	Orthography		Pronunciation	
		Regressive	*Progressive*	*Regressive*	*Progressive*
<fh>	[fx]	<vh, uh>[15]	<fg>	/vx/	/fɣ/
<hh>	[xx]	<gh>[16]	<hg>	/ɣx/	/xɣ/
<hf>	[xf]	<gf>	<hv, hu>	/ɣf/	/xv/
<hs>	[xs]	<gs>	<hz, hs>	/ɣs/	/xz/
<hþ>	[xþ]	<gþ>	<hð>	/ɣθ/	/xð/
<sh>	[sx]	<zh, sh>[17]	<sg>	/zx/	/sɣ/
<þþ>	[þþ]	<ðþ>	<þð>	/ðθ/	/þð/
<þh>	[þx]	<ðh>	<þg>	/ðx/	/þɣ/

B2.2 Voiced–voiced

Output (corpus form)		*Assumed input (lexical form)*			
Orthography	Pronunciation	Orthography		Pronunciation	
		Regressive	*Progressive*	*Regressive*	*Progressive*
<vv, uu>	[vv]	<fv>	<vf>	/fv/	/vf/
<vg, ug>	[vɣ]	<fg>	<vh>	/fɣ/	/vx/
<vz >	[vz]	<fz, fs>	<vs, us>	/fz/	/vs/
<vð, uð>	[vð]	<fð>	<vþ, uþ>	/fð/	/vθ/
<gg>	[ɣɣ]	<hg>	<gh>	/xɣ/	/ɣx/
<gv, gu>	[ɣv]	<hv>	<gf>	/xv/	/ɣf/
<gz>	[ɣz]	<hz>	<gs>	/hz/	/ɣs/
<ðð>	[ðð]	<þð>	<ðþ>	/θð/	/ðθ/
<ðv, ðu>	[ðv]	<þv, þu>	<ðf>	/θv/	/ðf/
<ðg>	[ðɣ]	<þg>	<ðh>	/θɣ/	/ðx/

[15] Old English <f> may represent both [f] and [v] in Old English. <v> only appears in names. However, [v] is sometimes written as <u> in Old English (Al-Watban 2005: 309).

[16] Although velar fricatives usually appear as <h>, when voiced they may be written as <g> Baker 2007: 15).

[17] Orthographically, [z] is never disitnguished from [s] in Old English (with the exception of [z] in names) (Al-Watban 2005: 309). However, if <s> occurs next to another (usually voiceless) obstruent (such as <h>) and that obstruent is spelled as if it has acquired [voice] (e.g. <g>, it is possible that <s> represents a voiced fricative.

B3 Plosive–fricative

B3.1 Voiceless–voiceless

Output (corpus form)		*Assumed input (lexical form)*			
Orthography	Pronunciation	Orthography		Pronunciation	
		Regressive	*Progressive*	*Regressive*	*Progressive*
<pf>	[pf]	<bf>	<pv, pu>	/bf/	/pv/
<ph>	[px]	<bh>	<pg>	/bx/	/pɣ/
<ps>	[ps]	<bs>	<pz, ps>	/bs/	/pz/
<pþ>	[pθ]	<bþ>	<pð>	/bθ/	/pð/
<tf>	[tf]	<df>	<tv, tu>	/df/	/tv/
<th>	[tx]	<dh>	<tg>	/dx/	/tɣ/
<ts>	[ts]	<ds>	<tz, ts>	/ds/	/tz/
<tþ>	[tθ]	<dþ>	<tð>	/dθ/	/tð/
<cf>	[kf]	<gf>	<gv, gu>	/gf/	/kv/
<ch>	[kx]	<gh>	<gg>	/gx/	/kɣ/
<cs>	[ks]	<gs>	<gz, gs>	/gs/	/kz/
<cþ>	[kθ]	<gþ>	<gð>	/gθ/	/kð/

B3.2 Voiced–voiced

Output (corpus form)		*Assumed input (lexical form)*			
Orthography	Pronunciation	Orthography		Pronunciation	
		Regressive	*Progressive*	*Regressive*	*Progressive*
<bv, bu>	[bv]	<pv, pu>	<bf>	/pv/	/bf/
<bg>	[bɣ]	<pg>	<bh>	/pɣ/	/bx/
<bð>	[bð]	<pð>	<bþ>	/pð/	/bθ/
<dv, du>	[dv]	<tv, tu>	<df>	/tv/	/df/
<dg>	[dɣ]	<tg>	<dh>	/tɣ/	/dx/
<dð>	[dð]	<tð>	<dþ>	/tð/	/dθ/
<gv, gu>	[gv]	<cv>	<gf>	/kv/	/gf/
<gg>	[gɣ]	<cg>	<gh>	/kɣ/	/gx/
<gð>	[gð]	<cð>	<gþ>	/kð/	/gθ/

B4 Fricative–plosive

B4.1 Voiceless–voiceless

Output (corpus form)		*Assumed input (lexical form)*			
Orthography	Pronunciation	Orthography		Pronunciation	
		Regressive	*Progressive*	*Regressive*	*Progressive*
<fp>	[fp]	<vp, up>	<fb>	/vp/	/fb/
<ft>	[ft]	<vt, ut>	<fd>	/vt/	/fd/
<fc>	[fk]	<vc, uc>	<fg>	/vk/	/fg/
<hp>	[xp]	<gp>	<hb>	/ɣp/	/xb/
<ht>	[xt]	<gt>	<hd>	/ɣt/	/xd/
<hc>	[xk]	<gc>	<hg>	/ɣk/	/xg/
<sp>	[sp]	<zp, sp>	<sb>	/zp/	/sb/
<st>	[st]	<zt, st>	<sd>	/zt/	/sd/
<sc>	[sk]	<zc, sc>	<sg>	/zk/	/sg/
<þp>	[θp]	<ðp>	<þb>	/ðp/	/θb/
<þt>	[θt]	<ðt>	<þd>	/ðt/	/θd/
<þc>	[θk]	<ðc>	<þg>	/ðk/	/θg/

B4.2 Voiced–voiced

Output (corpus form)		*Assumed input (lexical form)*			
Orthography	Pronunciation	Orthography		Pronunciation	
		Regressive	*Progressive*	*Regressive*	*Progressive*
<vb, ub>	[vb]	<fb>	<vp, up>	/fb/	/vp/
<vd, ud>	[vd]	<fd>	<vt, ut>	/fd/	/vt/
<vg, ug>	[vg]	<fg>	<vc, uc>	/fg/	/vk/
<gb>	[ɣb]	<hb>	<gp>	/xb/	/ɣp/
<gd>	[ɣd]	<hd>	<gt>	/xd/	/ɣt/
<gg>	[ɣg]	<hg>	<gc>	/xg/	/ɣk/
<ðb>	[ðb]	<þb>	<ðp>	/θb/	/ðp/
<ðd>	[ðd]	<þd>	<ðt>	/θd/	/ðt/
<ðg>	[ðg]	<þg>	<ðc>	/θg/	/ðk/

Appendix C: assimilation to voicelessness

1. Regressive assimilation to voicelessness: <dc> → <tc>

Corpus form	*Lexical form*	
seltcuð	seld-cúþ	‘strange’, ‘different’
seltcuða		
seltcuðan		
seltcuþe		
seltcuþe		

2. Regressive assimilation to voicelessness: <gs> → <hs>

Corpus form	*Lexical form*	
ahst	agan	‘to come to pass’
borhstealles	beorg-steal	‘steep path up a hill’
burchshlede	burg-slæd	(undefined)
burhslædes		
burhscipe	burg-scipe	‘municipal’
burhscir	burg-scír	‘township’
burhscira		
burhscire		
burhscirum		
burhscyre		
burhscyrum		
burhstaðola	burg-staþol	‘foundation of the wall of a stronghold’
burhstræt	burg-stræt	‘town road’
burhstræte		
dolhsealf	dolg-sealf	‘wound salve’
dolhsealfa		
dolhsealfe		
eahsalf	eág-sealf	‘eye salve’
eahsalfe		
eahsealf		
eahsealfe		
ehsealfe		
eahsynes	eág-sínes	‘evidently’
earhscype	earg-scipe	‘cowardice’
gealhswile	geagl-swile	‘swelling of the jaw/cheek’
onbihst	on-búgan	‘to bend’
tintrehstowum	tintreg-stów	‘place of torment’
uppastihst	up-a-stigan	‘to climb’

3. Regressive assimilation to voicelessness: <gþ> → <hþ>

Corpus form	*Lexical form*	
eahþyrl	eág-þyrl	‘window’
eahþyrle		
ehþyrl		
ehþyrle		
ehþyrlu		
ehþyrlum		
myhþ	mígan	‘to make water’
mirhþe	mirigþ	‘pleasure’
myrhþ		
myrhþa		
myrhþe		
oferstihþ	ofer-stígan	‘to mount’, ‘to rise above’

4. Regressive assimilation to voicelessness: <ds> → <ts>

Corpus form	*Lexical form*	
ætbretst	æt-bredan	‘to take away’, ‘to withdraw’
ætbrytst		
agyltst	a-gyldan	‘to pay’
andwyrtst	and-wyrdan	‘to answer’
antswaru	and-swaru	‘answer’
antswarude	andswarian	‘to answer’
awentst	á-wendan	‘to avert’
bebeotst	bebeódan	‘to order’
bebytst		
bintst	bindan	‘to tie’
bitsð	biddan	‘to ask’
bitst		
bytst	beodan	‘to order’
fetst	fédan	‘to feed’
fintst	findan	‘to find’
forstentst	for-standan	‘to defend’
gebitst	ge-bídan	‘to abide’
geeadmetst	ge-eáþmédan	‘to humiliate’
geetstaðolode	ge-edstaþelian	‘to re-establish’
gefretst	ge-frédan	‘to feel’
gehealtsum	ge-healdsum	‘modest’
gehealtsume		
gehealtsumnesse	ge-healdsumnes	‘modesty’
gehealtsumnysse	ge-healdsumnes	
gehyltst	gehealdan	‘to hold’
gemenigfyltst	ge-manigfildan	‘to multiply’
gestentst	ge-standan	‘to stand’
healtst	healdan	‘to hold’
metsceatte	méd-sceatt	‘wages’
ondrætst	on-drǽdan	‘to dread’
rætst	rǽdan	‘to counsel’
sentst	sendan	‘to send’

stentst	standan	‘to stand’
unbintst	un-bindan	‘to untie’
understentst	under-standan	‘to understand’
ungehealtsum	un-gehealdsum	‘incontinent’
ungehealtsume		
ungehealtsumlice	un-gehealdsumlice	‘incontinently’
ungehealtsumnysse	un-gehealdsumnes	‘incontinence’
weltst	wealdan	‘to have power over’
wentst	wendan	‘to cause to move’
yltst	ildest	‘oldest’
yltstan		

5. Regressive assimilation to voicelessness: <gþ> → <cþ>

Corpus form	*Lexical form*	
geþincþan	geþingþ	‘intercession’
geðincþo	geþingþ	‘intercession’
strencþe	strengðu	‘strength’

6. Regressive and progressive assimilation to voicelessness: <gh>, <hg> → <hh>

Corpus form	*Lexical form*	
eahhringas	eág-hringas	‘eyebrows’, eyelids’
neahheburas	neáh-gebúr	‘neighbour’
nehhebur		
nehheburas		
nehhebyryna		

Appendix D: Assimilation to voice

1. Assimilation to voice: <cg> → <gg>

Corpus form	*Lexical form*	
frogga	frocga	‘frog’
froggon		
ganggað	gancgan	‘to go’
sugga	sucga	(bird species)

2. Assimilation to voice: <cð> → <gð>

Corpus form	*Lexical form*	
misþingð	misþyncan	‘to have mistaken ideas’
stingð	stincan	‘to smell’

Appendix E: Stimuli used in experiment 1

a. ABX task

A	*B*	*X*
[d̥æɬ]	[tʰæɬ]	[d̥æɬ]
[pʰiːn]	[b̥iːn]	[pʰiːn]
[pʰim]	[bim]	[bim]
[g̊iːŋ]	[kʰiːŋ]	[kʰiːŋ]
[dɑɬ]	[tɑɬ]	[dɑɬ]
[piŋ]	[biŋ]	[piŋ]
[gim]	[kʰim]	[kʰim]
[kʰʌŋ]	[g̊ʌŋ]	[kʰʌŋ]
[kɒn]	[gɒn]	[kɒn]
[tʰiŋ]	[diŋ]	[tʰiŋ]
[pʰiːŋ]	[b̥iːŋ]	[pʰiːŋ]
[g̊ʌŋ]	[kʰʌŋ]	[kʰʌŋ]
[guŋ]	[kuŋ]	[kuŋ]
[g̊ɔːɬ]	[kʰɔːɬ]	[g̊ɔːɬ]
[pɑm]	[bɑm]	[pɑm]
[giŋ]	[kʰiŋ]	[kʰiŋ]
[tʰæm]	[dæm]	[dæm]
[pin]	[bin]	[pin]
[duːŋ]	[thuːŋ]	[duːŋ]
[kʰuŋ]	[guŋ]	[kʰuŋ]
[bɑɬ]	[pɑɬ]	[pɑɬ]
[gɒɬ]	[kʰɒɬ]	[gɒɬ]
[tʰiːŋ]	[d̥iːŋ]	[tʰiːŋ]
[kʰɒn]	[g̊ɒn]	[kʰɒn]
[tʰæm]	[d̥æm]	[d̥æm]

b. Identification task

Stimuli in carrier sentence

[pim] says: this is awesome.
[tʰæɬ] says: this is awesome.
[kʰim] says: this is awesome.
[pɪŋ] says: this is awesome.
[tɪŋ] says: this is awesome.
[pʰin] says: this is awesome.
I [tʰæɬ]: this is awesome.
I [pim]: this is awesome.
I [piŋ]: this is awesome.
I [kʰim]: this is awesome.
I [tiŋ]: this is awesome.
I [pʰin]: this is awesome.
I say: [kʰim]ee-water.
I say: [tɪŋ]ee-water.
I say: [pʰin]ee-water.
I say: [tʰæl]ee-water.
I say: [pim]ee-water.
I say: [pɪŋ]ee-water.
I say: water-[tʰæɬ].
I say: water-[pim].
I say: water-[pɪŋ].
I say: water-[kʰim].
I say: water-[tɪŋ].
I say: water-[pʰin].

Appendix F: Stimuli used in experiment 2

a. ABX task

A	*B*	*X*
[neʰk]	[neˀk]	[neʰk]
[miʰp]	[miˀp]	[miʰp]
[mɑˀk]	[mɑʰk]	[mɑˀk]
[nuʰt]	[nuˀt]	[nuʰt]
[luˀp]	[luʰp]	[luˀp]
[yiˀt]	[yiʰt]	[yiˀt]
[æʰk]	[æˀk]	[æʰk]
[yiˀp]	[yiʰp]	[yiˀp]
[nɑˀk]	[nɑʰk]	[nɑˀk]
[yeʰk]	[yeˀk]	[yeʰk]
[neʰp]	[neˀp]	[neʰp]
[yɑˀt]	[yɑʰt]	[yɑˀt]
[bɔˀp]	[bɔʰp]	[bɔˀp]
[riʰt]	[riˀt]	[riʰt]
[ryˀk]	[ryʰk]	[ryˀk]

b. Judgment-of-voicelessness task

Stimuli in carrier sentence

[ɬuʰt] says: this is awesome.
[nɪˀk] says: this is awesome.
[nɪʰp] says: this is awesome.
[mɪʰt] says: this is awesome.
[nɪˀp] says: this is awesome.
I [lyʰt]: this is awesome.
I [miˀp]: this is awesome.
I [niˀp]: this is awesome.
I [mɑʰk]: this is awesome.
I [nɑʰt]: this is awesome.
I [niˀp]: this is awesome.
I say: [niˀk]-water.
I say: [reʰt]-water.
I say: [niˀp]-water.
I say: [ɬuʰt]-water.
I say: [miˀp]-water.
I say: [yeʰp]-water.
I say: water-[ɬuʰt].
I say: water-[meʰp].
I say: water-[niˀp].
I say: water-[yeʰk].
I say: water-[wɪˀt].

Appendix G: Answer sheet experiment 1

Gender: Age: First language:

Experiment 1a
Is sound X the same sound as sound A or the same sound as sound B? Circle the correct answer.

1. A B
2. A B
3. A B
4. A B
5. A B
6. A B
7. A B
8. A B
9. A B
10. A B
11. A B
12. A B
13. A B
14. A B
15. A B
16. A B
17. A B
18. A B
19. A B
20. A B
21. A B
22. A B
23. A B
24. A B
25. A B

Experiment 1b
Which word did you hear? Circle the correct answer.

1. peem beem
2. tal dal
3. keem geem
4. ping bing
5. ting ding
6. peen been
7. tal dal
8. peem beem
9. ping bing
10. keem geem
11. ting ding
12. peen been
13. keem geem
14. ting ding
15. peen been
16. tal dal

17. peem beem
18. ping bing
19. tal dal
20. peem beem
21. ping bing
22. keem geem
23. ting ding
24. peen been

Appendix H: Answer sheet experiment 2

Gender: Age: First language:

Experiment 2a
Is sound X the same sound as sound A or the same sound as sound B? Circle the correct answer. Note: word-final <b, d, g> represent voiced sounds.

1. A B
2. A B
3. A B
4. A B
5. A B
6. A B
7. A B
8. A B
9. A B
10. A B
11. A B
12. A B
13. A B
14. A B
15. A B

Experiment 2b
Which word did you hear? Circle the correct answer.

1. lut lud
2. neek neeg
3. nip nib
4. mit mid
5. neep neeb
6. lut lud
7. meep meeb
8. neep neeb
9. mak mag
10. nat nad
11. neep neeb
12. neek neeg
13. reet reed
14. neep neeb
15. lut lud
16. meep meeb
17. yeep yeeb
18. lut lud
19. meep meeb
20. neep neeb
21. yeek yeeg
22. yit yid

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