On the Natural History of Preaspirated Stops

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ABSTRACT

Ian D. Clayton: On the Natural History of Preaspirated Stops
(Under the direction of Elliott Moreton)

This dissertation makes two contributions, one empirical, the other theoretical. Empirically, the dissertation deepens our understanding of the lifecycle and behavior of the preaspirated stop, an extremely rare phonological feature. I show that in most confirmed cases, preaspirated stops develop from earlier voiceless geminate stops, less commonly from nasal-voiceless stop clusters. When decaying, preaspirated stops typically develop into unaspirated voiceless stops, or undergo buccalization to become preaffricated. More rarely, decaying preaspirated stops may trigger tonogenesis, or undergo spirantization or nasalization. Phonologically, preaspirated stops usually function as positionally conditioned allophones of underlying aspirated voiceless stops contrasting with voiceless unaspirated stops.

The dissertation tests three theoretical frameworks. First, the State-Process model (Greenberg 1978, 1969, 1966) claims that the synchronic distribution of linguistic features offers insight into their rates of innovation and transmission. Conventionally, the rarity of preaspirated stops is attributed to a presumed low rate of transmission: they are rare because they are hard to hear (Silverman 2003, 1997; Bladon 1986). However, the geographic and genetic distribution of preaspirated stops fit the State-Process model's prototype of an infrequently innovated but robustly transmitted linguistic feature. Further, I show

experimentally that preaspirated stops are no more difficult to distinguish from unaspirated stops than are much more abundant postaspirated stops.

Second, the dissertation tests the success of two models, one cognitive, the other phonetic/diachronic, at accounting for two place-based asymmetries in Scottish Gaelic preaspiration. Whereas a conventional Optimality-Theoretic analysis of these asymmetries overgenerates, an analysis modified via Steriade's P-map Hypothesis (2001a, 2001b) resolves this overgeneration. The P-map analysis depends on congruent perceptual scales, which the perception experiment (above) confirms: participants' confusion rates closely match the place-based asymmetries observed in Gaelic.

The competing "innocent misperception" model (Ohala 2005, 1993; Blevins 2004) depends on the presence of phonetic precursors to produce an ambiguous phonological signal, which listeners may interpret differently than intended by the speaker, leading to an alteration in a segment's underlying form. A series of production experiments identifies potential precursors, but also reveals between-speaker variation more compatible with the P-map account than "innocent misperception," again lending support to Steriade's hypothesis.

To Tobie

my rock

ACKNOWLEDGEMENTS

This has been a very long journey, and I am pleased to finally have this opportunity to thank at least a few of the numerous people who helped show the way.

Elliott Moreton, my dissertation advisor, deserves far more thanks than I can possibly express here. The quality and vision of Elliott's own work have been my chief inspiration and model. If I can ever be half the scientist he is, I'll count that a landmark success. I must also thank him for his apparently bottomless patience through my periods of obtuseness and downright stubbornness, his ever-open door, and for the surprise bagpiper.

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Were it not for Patrick O'Neill, I would never have undertaken this project. In large part through his fascinating (and extraordinary challenging) introduction to Old Irish, I discovered a love for the Celtic languages that has never faltered. His encouragement led to the first of several summers on the Misty Isle, and my first encounter with preaspiration.

Paul Roberge and Erik Thomas have my gratitude for their expertise and patience. Their keen eyes caught many errors that would have otherwise gone unnoticed, and their numerous and excellent suggestions greatly improved the final product. It goes without saying that any remaining errors are my own.

Great thanks are due also to many in Scotland: to the wonderful people at Sabhal Mòr Ostaig (especially Caoimhín Ó Donnaíle) for their indispensable assistance and hospitality; to Domhnull MacIlliosa, Iain MacKenzie, and John MacLeod for their help at the Fountainbridge Library; and to so many study participants who offered their valuable time to the curious American with the microphone and laptop computer.

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Chapter One

Introduction

It is a fact of linguistic typology that some linguistic structures and patterns are widespread, even ubiquitous, while others are much rarer, even vanishingly so. Consider the crosslinguistic abundance of certain phonological segment types. The high front unrounded vowel [i] is nearly universal, occurring in 91% of the languages in UPSID (the UCLA Phonological Segment Inventory Database) (Maddieson and Precoda 1989), while its rounded counterpart [y] is much rarer at 8.4%. Similarly, 97% of UPSID languages feature voiceless velar stops and 89% have a voiceless bilabial stop, while only 13% have a voiceless uvular stop. Finally, there are the truly esoteric segments like clicks and velar implosives (1% each), or preaspirated stops (2 UPSID languages, perhaps two dozen or so confirmed examples worldwide; see chapter 2).

Consider also the fact that some phonological patterns are much more widespread than others—whatever the abundance of the segments they involve. For instance, in many languages voiced obstruents do not occur word-finally (Dutch, German, and Russian are three such languages), but both voiced and voiceless obstruents may occur in initial position. The inverse is very seldom true. Such crosslinguistic tendencies are abundant. To mention only a few: Nasal-voiceless obstruent sequences are frequently prohibited. Many languages license complex syllable onsets, but not codas, or else they prohibit codas altogether. No known language permits codas while prohibiting onsets. Finally, there is a crosslinguistic tendency for place assimilation in consonant clusters to proceed regressively ($C_1 < C_2$) when the cluster consists of alveolars, palato-alveolars, labials or velar consonants; whereas, when the cluster consists of an alveolar followed by a retroflex consonants, the assimilation is consistently progressive instead ($C_1 > C_2$) (Steriade 2001b).

These asymmetries prompt a number of questions. Broadly speaking, in what ways can the study of rare linguistic structures (of any type—not merely the phonological) test or refine theories of language change? What can we learn about the evolution of sound patterns by studying such patterns—especially in comparison to more abundant ones? Specifically, how can we account for the sharp disparities noted above? Are there cognitive, articulatory, and/or sociohistorical factors that favor the proliferation of certain segments types, while inhibiting others? If so, what precisely are these factors? How do they operate and interact?

This dissertation seeks to address these and related questions through a study of the natural history of preaspirated stops. By *preaspirated stops* is meant voiceless stops which are preceded by a period of glottal frication [hp ht hk], as in the Scottish Gaelic words *bata* [pahta] 'stick' or *put* [pʰuht] 'buoy,' or the Icelandic words *kappi* [kʰahpi] 'contest' or *epli* [ɛhpl̥i] 'apple' (see §1.1 for a full definition of the term). By *natural history* is meant the origins of preaspirated stops, their phonological and phonetic characteristics, and the processes leading to their elimination from individual languages. No such account of preaspirated stops is currently available. While several studies of preaspirated stops have previously been conducted, these fall short of providing a full account of the phenomenon. Most have almost exclusively concentrated their attention on the languages of northern Europe: Scottish Gaelic (Ní Chasaide 1985, Ní Chasaide & Ó Dochartaigh 1984), the Nordic languages (Helgason 2002, Hansson 1997), and Sami (McRobbie-Utasi 1991, Engstrand 1987). Silverman (2003) offers a survey of preaspirating languages worldwide, and considers their diachronic development, but at article-length is unable to offer the depth or breadth of this dissertation.

The dissertation will consider each aspect of development of preaspirated stops, including their origin, typology, phonetic variation, and phonological behavior. In doing so, the dissertation will employ two theoretical models of linguistic typology. The first is the State-Process Model (Greenberg 1978, 1969, 1966). According to this model, the diachronic factors governing the development of some linguistic feature can be placed into two categories: those that impact the innovation rate of the feature, and those that impact its rate of intergenerational transmission once innovated. Moreover, the model proposes that the synchronic, typological distribution of the feature is a product of tension between these two rates. For instance, if a feature tends to cluster tightly among related languages and within language areas, this suggests that the feature is relatively diachronically robust, persisting as a parent language diversifies into daughter languages. Conversely, if the feature is fairly randomly distributed, this suggests that once innovated, the feature does not survive long enough to ramify into descendents of the innovating language, nor to be readily transmitted into neighboring languages through contact.

This dissertation considers the typological rarity of preaspirated stops within the framework of the State-Process model. The prevailing explanation in the existing literature is that preaspiration is simply difficult to hear, or at least to hear accurately, and consequently diachronically unstable (Silverman 2003, Kingston 1990, Bladon 1986). Chapter 3 describes a perception experiment which tests the rate at which both preaspirated and postaspirated stops are confused with their unaspirated counterparts. The experiment finds that neither type of aspirated stop is more likely to be confused with unaspirated stops, strongly suggested that the standard hypothesis is untenable. The chapter argues instead that based on their typological distribution, preaspirated stops are in fact diachronically relatively stable, but are rare because they are difficult to innovate.

The second theoretical model the dissertation will test is the P-map hypothesis (Steriade 2001a, 2001b). The P-map is a component of the phonological grammar which incorporates the speaker's knowledge of the "relative perceptibility of different contrasts, across the different contexts where they might occur" (Steriade 2001a, p. 1). The P-map stipulates that the preferred repair for a constraint violation be that which involves the minimal perceptual departure from the underlying target form. For instance, though a number of strategies would satisfy a phonological constraint against voiced codas, such as deletion, epenthesis, or metathesis, these repair strategies are unattested in favor of devoicing. The P-map hypothesis claims that this is because devoicing is a less costly perceptual departure from the underlying form than the unattested strategies; accordingly, faith constraints are invariably ranked in such a way as to prohibit unattested strategies, but permitting devoicing.

The dissertation employs the P-map to resolve two positional asymmetries in the form of preaspirated stops in Scottish Gaelic. Preaspirated stops in Gaelic are subject to two diachronic processes, deaspiration (loss of preaspiration) and buccalization (or the development of preaspiration from a glottal form [h] to an oral form [x]). Deaspiration applies preferentially to labial stops and then spreads to more posterior stops, while buccalization applies in the opposite direction, targeting velar stops initially and then extending to more anterior stops. A standard Optimality Theoretic analysis of the two asymmetries overgenerates, predicting a range of configurations that are not only unattested, but violate the observed hierarchies. However, the P-map analysis predicts that there should be perceptual scales driving these asymmetries. Data from the perception study in Chapter 3 confirms a perceptual scale consistent with the deaspiration asymmetry, while data from production studies described in chapter 4 strongly suggest that there is also a clear phonetic basis to both asymmetries.

Based on both empirical and theoretical evidence, the dissertation draws the following key conclusions. First, the category of preaspirated stops is non-arbitrary: such stops have similar origins, phonetic realizations, phonological functions, and phonotactic distributions, which distinguish them from other structures that have been described as preaspirated, e.g. preaspirated fricatives, sonorants, or consonants generally. Second, where the origins of preaspirated stops can be identified with some confidence, these origins are surprisingly uniform. Preaspirated stops tend to develop from two types of antecedent structures: geminate voiceless stops (the majority); and nasal-voiceless stop clusters (two possible cases). Third, experimental and typological evidence demonstrates that preaspirated stops are no more difficult for listeners to distinguish than postaspirated stops; therefore, the relative scarcity of preaspirated stops should not be attributed to poor perceptibility leading in turn to low diachronic stability (contra Bladon 1986, Silverman 2003, and others), but rather to a low innovation rate.

In the remainder of the introductory chapter, I provide a working definition of preaspirated stops, briefly review the key previous works on the topic, and describe the theoretical framework supporting my investigation. I also summarize the contents of the remaining components of the dissertation.

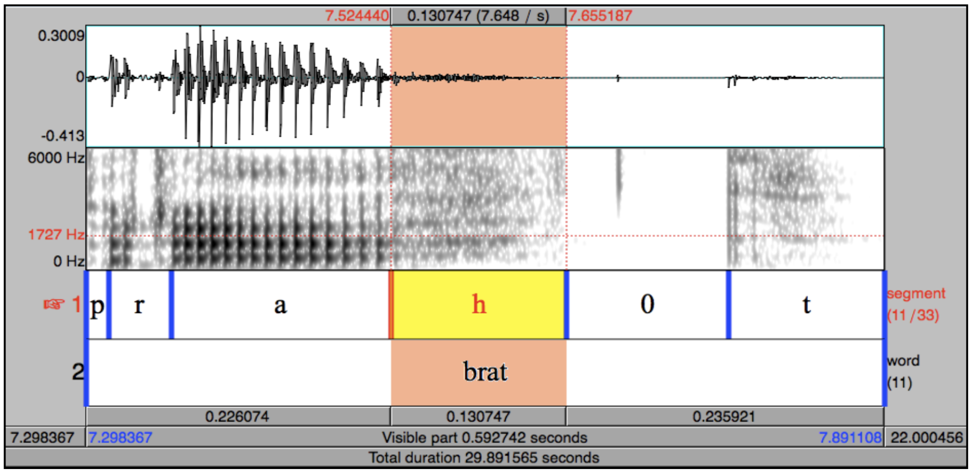


Figure 1.1. Scottish Gaelic *brat* [prahṭ] 'apron'

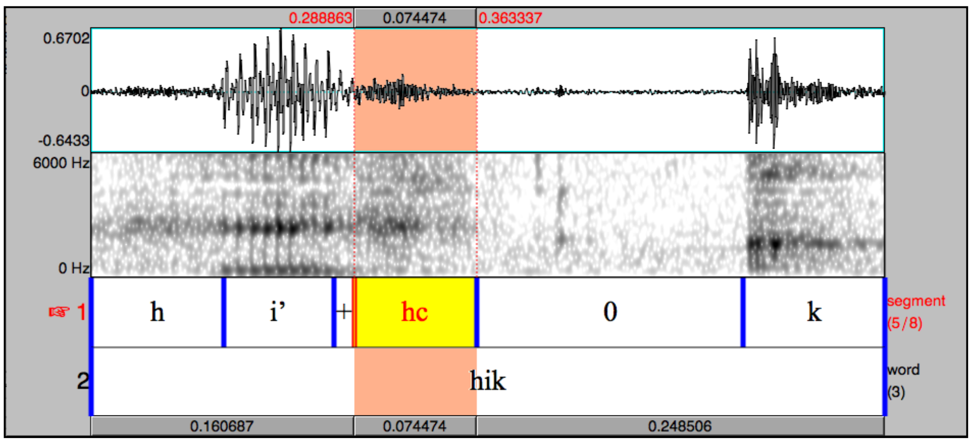


Figure 1.2. Icelandic *flakk* [flahk] 'migration,' with breathy voice (+)

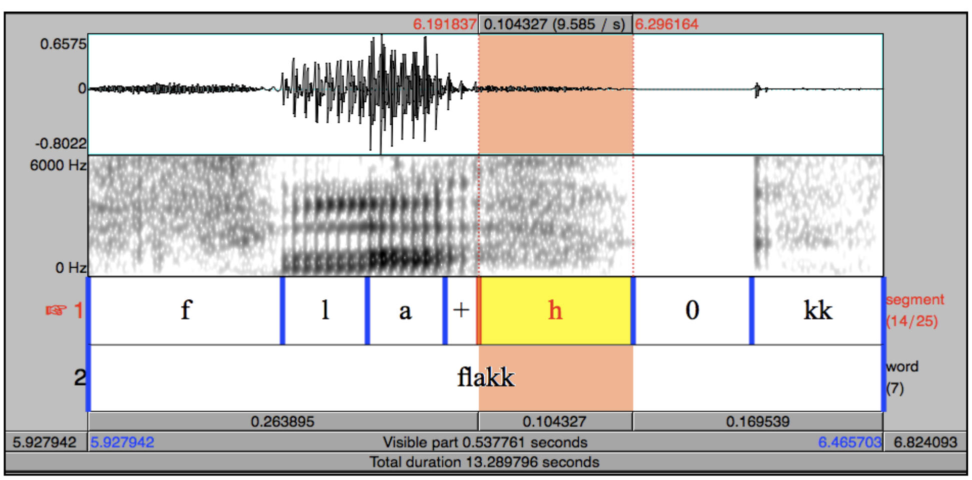


Figure 1.3. Tohono O'odham *hik* [hihk] 'navel'

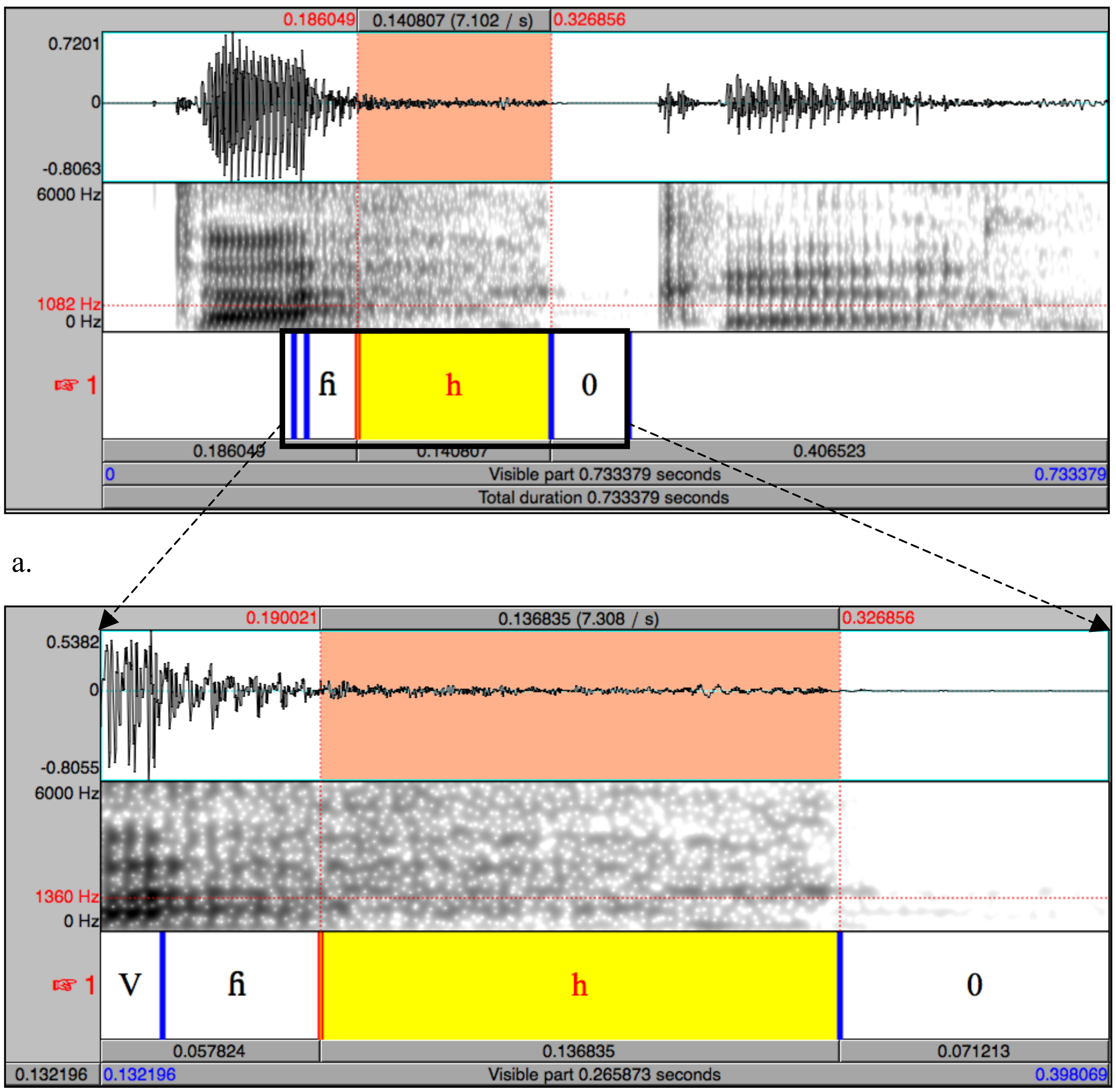
1.1 What are preaspirated stops?

Prototypically, the term “preaspiration” refers to a period of glottal frication, usually represented as [h], that intercedes after a vowel and preceding a consonant. Preaspiration has been referred to as *Voice Offset Time* (VOffT) (Steriade 1997, Pind 1999, Catford 1977), a term modeled on the familiar term *Voice Onset Time* (VOT) used to characterize the voicing and *post*aspiration contrasts abundantly found in the world’s languages (Lisker & Abramson 1964). As examples, consider Scottish Gaelic *brat* ‘apron,’ phonemically /prat^{h}/, phonetically [pr̥aht] (in most preaspirating dialects), Icelandic *flakk* ‘migration,’ /flak^{h}k^{h}/,[1] phonetically [fl̥ahk], and Tohono O’odham *hik* ‘navel,’ /hik^{h}/ [hihk^{j}] (Figure 1.3) (see §1.2 for a discussion of the phonological analysis of preaspirated stops). While usually glottal, this frication may sporadically be realized with a supralaryngeal component, even by the same speaker in different tokens of the same word; for instance, Helgason (2002) recorded a Faroese speaker producing the word *vatn* ‘lake’ on separate occasions, once with a purely glottal fricative [ve̝ht̪n̥n̪] and a second time with a voiceless uvular trill added [ve̝hʀ̥t̪n̥n̪] (Helgason’s transcriptions).

In spectrographic analysis, preaspiration is plainly visible as a period of aperiodic noise distributed fairly evenly across the spectrum, much like a normal glottal fricative [h] (Figure 1.4). The noise may range in duration from a few milliseconds to over 200ms, depending on language, context, and speaker. The preaspiration commences at the conclusion of the preceding vowel; the transition between the two may be marked by a period of breathy voice, which may be extend only over two or three glottal pulses (i.e. a few milliseconds), or

[1] By the analysis of Icelandic preaspiration offered in Suh (2001).

be considerably longer, in some cases longer in duration than the preaspiration itself. The end point of the preaspiration is typically quite gradual, its amplitude diminishing as the articulators approach total occlusion; usually, however, a discernible endpoint can be located.



a.

b.

Figure 1.4. (a) spectrogram of the nonsense word [tahka] as pronounced by a Lewis Gaelic speaker. (b) expanded view of the preaspiration component. V = preceding vowel, [ɦ] = breathy voice transition, [h] = preaspiration, and 0 = stop closure.

It is reasonable to ask why such stops should not simply be considered clusters of [h] plus some consonant. By the criterion used in this dissertation, in order for a segment to be counted as *preaspirated*, rather than simply an [hC] cluster, there should be a tight distributional relationship between the aspiration and a set of consonants X, such that the aspiration precedes those consonants, and no others. Assume that the set X consists of voiceless stops (though other consonant types could be involved instead, such as liquids or voiceless fricatives). If aspiration only occurs before voiceless stops (alternatively, before voiceless non-continuants, inasmuch as some languages group affricates and stops together), producing such sequences as [hp ht hk], then these stops should be treated as preaspirated. If on the other hand, the aspiration is relatively indiscriminate in its distribution, appearing before not only voiceless stops, but also before voiced stops, fricatives of all persuasions, liquids, glides, and even alone in a post-vocalic coda position, such [hC] sequences are better treated as clusters than as preaspiration, since the [h]-like segment is displaying no special affinity for voiceless stops. Thus excluded from the present investigation are those languages featuring consonants that might be regarded as preaspirated, insofar as they can be preceded by an [h]-like period of glottal frication, or by some allophone of an /h/ phoneme, such as Finnish (Suomi, Toivanen & Ylitalo 2008), numerous dialects of Spanish (Gerfen 2001, Morris 2000, Hualde 1987), Chamicuro (Parker 1994, Payne 1991), or Huatla Mazatec (Pike and Pike 1947).[2] However, I have included Tohono O'odham stops as truly preaspirated, though the sibilant [s] is also preaspirated in that language, simply because the preaspiration

[2] Huatla Mazatec and Chamicuro have been included in other inventories of preaspirating languages (e.g. Silverman 2003).

is still tightly restricted in its distribution, rather than more or less freely clustering with any coda segment.

Phonological systems in which supralaryngeal variants of preaspiration sporadically appear as a product of phonetic context should be distinguished from those in which a non-glottal form is obligatory before some or all stops, i.e. where a glottal realization would be perceived as aberrant by native speakers of the language or dialect. For example, in the Lewis dialect of Scottish Gaelic, glottal preaspiration is found across the board [hp ht hk]. But most other preaspirating dialects of Gaelic have oral friction at least before dorsal stops (e.g. Skye and Harris), and may have it also before coronal and even labial stops [xp xt xk] (e.g. Perthshire). Consider also the language Bora, which has been described as "preaspirating" (Aschmann 1993), but in which the so-called preaspiration is characterized as velar. In these examples, the "preaspirated" segment is somewhat like the mirror image of an affricate, just as a preaspirated segment resembles a mirror image of a postaspirated segment. Consequently, I will describe segments of this type as *preaffricated*, when it is necessary to distinguish them from preaspirated segments proper. The term is imperfect to the extent that not all examples of preaffrication may be homorganic with the following occlusion, but given similar usage in, e.g., Helgason (2002), Trask (1996), Hansson (1999), and Laver (1994), I maintain it here. The dissertation will include discussion of preaffricated stops where they are relevant to preaspiration, as when they appear to have been derived from earlier preaspirates (as in Bora) and/or pattern with them as tokens of an underlying aspiration contrast (as in dialects of Scottish Gaelic).

The phonological behavior of preaspirated stops is fairly uniform, and a range of generalizations can be made about this behavior. First, in their distribution, preaspirated stops closely resemble the geminate stops and nasal-stop clusters from which many preaspirates have evolved (see chapter 2): typically, preaspirated stops are confined to medial and to a lesser extent final position; only rarely do they occur word-initially. Second, most languages featuring phonemically preaspirated stops possess two contrasting sets of stops: voiceless plain stops versus voiceless aspirated stops. Preaspirated stops are typically allophones of the aspirated stop phonemes: these stops are realized as postaspirated in initial position, as preaspirated in medial and final position. Usually the aspiration contrast is only fully realized in stressed environments. (See Steriade 1997 for a discussion of possible phonological motivations for this allophony.) It is not the case that other so-called preaspirated segments are realizations of contrastively aspirated phonemes, whether the affected segments are preaspirated liquids and glides, as in Old and Middle English (Schreier 2005) or preaspirated fricatives, like those of Scottish English (Gordeeva & Scobbie 2004).

There are languages in which preaspiration frequently accompanies voiceless stops, but has not become the primary cue to a phonological contrast. That is, the preaspiration is not a "normal" or obligatory component of the production of voiceless stops in the affected language, but only a possible realization. Hence Helgason's (2002) opposition between "non-normative" or non-phonologized preaspiration and "normative" preaspiration, in which the preaspiration cue is an essential feature of the production of the stop. The contribution of non-normative preaspiration to the expression of phonological contrast is variable in these languages. For instance, in Central Standard Swedish, preaspiration is non-normative: preaspiration occurs in the speech of only some speakers of the dialect, but when it is employed, it constitutes an important perceptual cue (Helgason 2002, 2004). Other languages with non-normative preaspiration of stops include Goajiro (Holmers 1949) and Sienese

Italian (Stevens 2007; Stevens and Hajek 2004); the role of preaspiration as a perceptual cue in these two languages is not clearly established. It is possible, even likely, that preaspiration appears first in a language as a non-phonologized, possibly sporadic feature of some existing set of phonemes, like geminate stops (see further discussion in sections §2.9 and §3.1.1). If the circumstances are favorable, this preaspiration could then serve as the precursor to a fully phonologized set of preaspirated segments (see Helgason 1999 for a related discussion in the context of Swedish).

Where their origins can be determined with reasonable confidence, preaspirated stops seem to evolve from a narrow set of antecedents: confirmed cases involve geminate voiceless stops and perhaps also nasal-voiceless stop clusters. Other types of preaspiration evolve from distinct antecedents, typically via lenition, whether it be /s/ as in Spanish (Gerfen 2001), */k^h/ as in early English preaspirated sonorants (Schreier 2005), or through adjustments in glottal timing relationships (which appear spontaneous, whether they are or not), as in certain dialects of British English (Gordeeva & Scobbie 2004, Gobl & Ní Chasaide 1988).

1.2 The segmental status of preaspiration

Without proceeding further, it is necessary to justify the phonemic and phonetic representations assumed by this dissertation and presented without discussion up to this point, concerning the segmental status of preaspiration, and its phonological function as a marker of contrast.

The phonological analysis of preaspiration is a little tricky, in the sense that it displays phonological behaviors which are somewhat contradictory. Prosodically, preaspiration frequently behaves as a segment in its own right. However, preaspiration may simultaneously function as a contrastive feature of the stop itself, as a positionally conditioned allophone of an underlying aspiration contrast.

Prosodically, preaspirated stops are may act like heavy elements in the same way that geminate consonants or long vowels do, in contrast with postaspirated or unaspirated stops, which do not usually behave as heavy segments. For instance, in Icelandic, stressed vowels are obligatorily lengthened in open syllables (1), or in closed syllables before singleton consonants (2). This lengthening rule does not apply before geminate consonants or clusters of obstruent plus nasal or obstruent + /l/ (3), or before preaspirated stops (4) (which are usually analyzed as underlying geminate voiceless aspirated stops in Icelandic for this reason) (Helgason 2002, Suh 2001, inter alia) (examples cited in Suh 2001).

(1) /CV/ > [CV:]

a. /$t^ha k^h a$/ > [$t^h a{:}k^h a$] 'take'

b. /$vit^h ja$/ > [$vi{:}t^h ja$] 'to call on'

(2) /CVC/ > [CV:C]

a. /ut^h/ > [$u{:}t^h$] 'out'

b. /sem/ > [se:m] 'as, like'

(3) /CVCC(V)/ > [CVCC(V)]

a. /flakk/ > [flakk] 'flag'

b. /flippi/ > [flippi] 'collar'

c. /$vak^h na$/ > [vahk.na] 'wake up'

(4) /$CVC^h C^h(V)$/ > [CVhC(V)]

a. /$tak^h k^h$/ > [$t^h ahk$] 'thanks'

b. /$t^h ap^h p^h i$/ > [$t^h ah.pi$] 'cork'

A similar though less categorical effect is observed in Scottish Gaelic, where the preaspiration cue is shorter after phonologically long vowels, longer after short vowels (see §4.6). The effect is not universal, however: preaspiration in Tohono O'odham lengthens as the vowel lengthens, and shortens as the vowel shortens (§4.6.5). This may be because in O'odham, the preaspiration cue is analyzed as part of the vowel nucleus, rather than the coda as must be the case in Icelandic or Gaelic.

Preaspiration may also display segment-like behavior of a second kind: its omission or loss may trigger compensatory lengthening in the preceding vowel in at least two languages (see further discussion in §4.2.2). In Tarascan, some speakers may produce voiceless unaspirated stops in place of preaspirated stops (Foster 1969); in Goajiro, preaspirated stops may vary more or less freely with unaspirated stops (Holmers 1949). In both languages, short vowels precede preaspirated stops, but phonetically lengthened vowels precede the unaspirated versions that result from the omission of preaspiration; such lengthening does not occur before underlyingly unaspirated stops. A similar process can be observed in Scottish Gaelic, where unaspirated stops frequently are produced by Gaelic speakers in place of preaspirated tokens; this substitution (or deaspiration) is most common after phonemically long vowels (§4.6).

In terms of its phonetic character, preaspiration seems very segment-like. Laver's (1994) definition of "segment" applies: "a short stretch of speech of relatively unchanging feature values" (227). In terms of its phonetic structure, as opposed to its distribution, preaspiration is indistinguishable from a phonetic [h]: a period of aperiodic glottal noise, broadly distributed across the spectrum. Duration is very little use as an indicator: within

Scottish Gaelic, for instance, preaspiration may vary from around 20 milliseconds to more than 200, depending on speaker, phonological context, and speech rate.

Functionally, by contrast, preaspirated stops can usually be analyzed as allophones of an underlyingly aspirated stop series: postaspirated allophones appear initially, preaspirated allophones medially and finally (and hence in complementary distribution) (see Table 2.3). In such systems, the aspirated series contrasts with a voiceless unaspirated series (e.g. Scottish Gaelic, Icelandic, Tarascan, Mongolian, and Sami). Thus, preaspiration appears to behave phonologically as an expression of a [+Spread] feature in exactly the same way that postaspiration does. Since postaspiration is not customarily analyzed as a separate segment, why should preaspiration be so analyzed?

The solution to this apparent contradiction must vary according to the specific facts in each language. In Icelandic, the solution (as indicated earlier) is to treat preaspirated segments as realizations of underlyingly geminate aspirated stops (Helgason 2002, Suh 2001, Gibson 1997); singleton aspirated stops (which may appear in initial, medial, or final position) are realized as postaspirated or unaspirated (in final position); geminates (which may appear in medial or final position) are realized as preaspirated (Figure 1.5). Steriade (1997) offers a persuasive cue-based argument for such alternations. In final position, and in medial position in unstressed syllables or before obstruents, postaspiration cues are difficult to realize reliably. A practical alternative is for the aspiration to be realized as preaspiration. (Steriade provides no satisfactory answer for the question why such alternation is not seen more abundantly, instead of simple neutralization in medial and final positions.)

Unaspirated		Postaspirated		Preaspirated	
Short	Long	Short	Long	Short	Long
[p]	[pp]	[p^h]	*[p^hp^h]	[hp]	*[hphp]
[t]	[tt]	[t^h]	*[t^ht^h]	[ht]	*[htht]
[k]	[kk]	[k^h]	*[k^hk^h]	[hk]	*[hkhk]

Figure 1.5. Realizations of Icelandic stops (from Suh 2001)

Scottish Gaelic has no independently motivated set of geminate consonants, so the Icelandic solution is inappropriate in this case. The alternative I have used (in e.g. the discussion in §4.4) is to assume that preaspirated segments are underlyingly singleton aspirated stops in Gaelic; such stops are realized as postaspirated singletons in initial position, as [h]-stop sequences in medial and final position (or as [x]-stop sequences in buccalized variants).

A final possibility to consider is that preaspiration serves no phonological function at all, but is a matter of voice-quality setting, that is, a predisposition toward a particular articulatory resting state; see e.g. Laver (1994).[3] It may be, for instance, that the speakers of preaspirating languages are laryngeally predisposed toward the voiceless state (a natural tendency, one might suppose), and so anticipate the devoicing associated with a voiceless obstruent by devoicing any preceding sonorant, even before the articulatory gesture associated with the obstruent has commenced. If this is in fact the correct analysis, it follows that such anticipatory devoicing should characterize all voiceless obstruents in the language, making it impossible for it to be a cue to any phonological contrast (as per Laver's definition).

[3] Thanks to Erik Thomas for this suggestion.

While it is impossible to assess this suggestion for even the majority of preaspirating languages, given the data available to me as of this writing, it is possible for a limited number of cases. In the case of Guajiro, for instance, the voice-quality setting hypothesis may indeed hold; preaspiration is non-contrastive in Guajiro (the language having only a single stop series), and moreover is “not used by many speakers” (Holmer 1949, p. 49), and so would be an unreliable phonological cue. Holmer provides no indication that voiceless fricatives are also preaspirated in Goajiro, which would be telling, but neither does he rule it out. I conclude that there is a real possibility that preaspiration in Goajiro is a matter of voice-quality setting.

In Scottish Gaelic, by contrast, I think it very unlikely that preaspiration is a product of voice-quality setting. First, preaspiration serves a clear phonological function as a marker of contrast in Gaelic; consider such (near) minimal pairs as *boc* [pohk] ‘buck’ < > *pog* [p^{h}ok] ‘kiss’ (in the Lewis dialect), *cop* [k^{h}ohp] ‘foam’ < > *gob* [kop] ‘beak’, and *bàta* [ˈpa:hta] ‘boat’ < > *fàdadh* [ˈfa:tax] ‘kindling’. Second, preaspiration is highly restricted in its distribution: it does not occur with just any voiceless obstruent, but only before a select few. Fricatives, for instance, seem to be unaffected; to the extent that anything like preaspiration occurs with fricatives, it is very short in duration (see Figure 1.6) and difficult to distinguish by ear from the fricative proper; such “preaspiration” may indeed be an articulatory artifact, but is quantitatively different from the preaspiration seen with stops, and should thus probably not be placed in the same category.

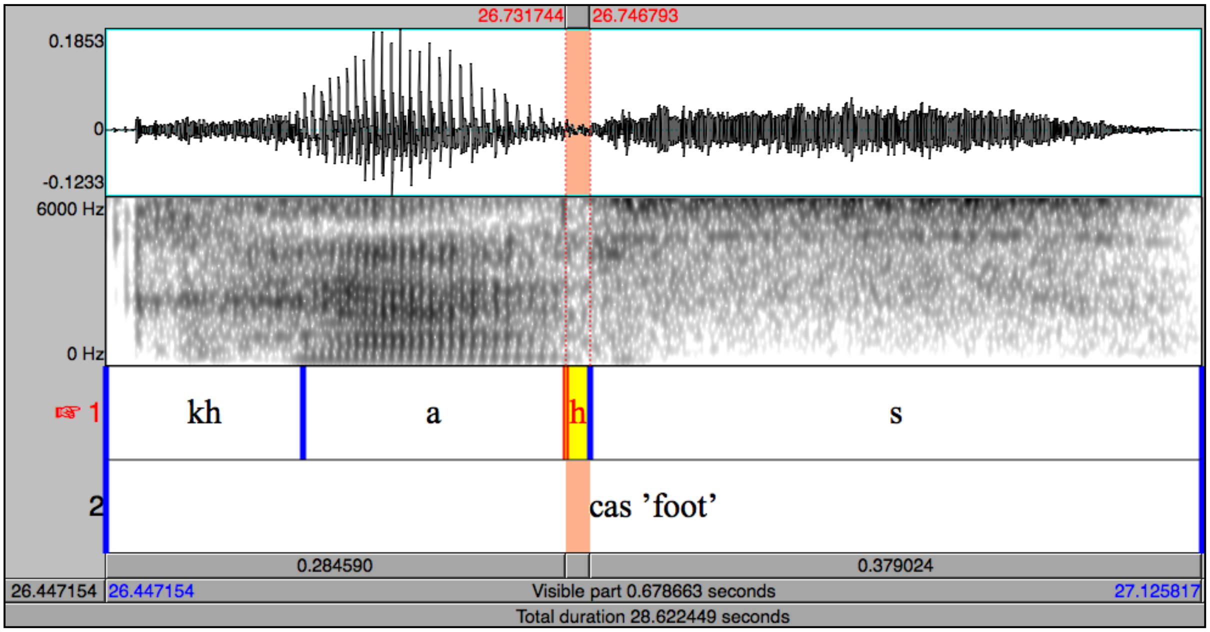


Figure 1.6. Aspiration preceding [s] in the Gaelic word *cas* [kʰas] 'foot'. Highlighted section is 15ms in duration

1.3 Previous works

Here I will describe those existing works on the subject of preaspirated stops that I principally drew upon in this dissertation. While there are many other excellent works on the subject, these four are notable for their depth and/or breadth.

1.3.1 Silverman (2003)

The only previous typological study of preaspirated stops worldwide is Silverman (2003). The article catalogs most known or suspected examples of the phenomenon, and describes in detail the acoustic and articulatory features of preaspiration in each language or dialect. In cases where the primary literature is vague, contradictory, or confusing, Silverman is often able to sift out useful information. Beyond his nearly comprehensive survey of systems, Silverman’s principal contribution is his explanation for the rarity of preaspirated stops, which is in part a development of similar arguments presented in Bladon (1986). The crucial claim is that purely glottal preaspiration [hT] is a perceptually inferior (or "suboptimal") realization of an aspiration contrast; postaspiration is the optimal form (the "suboptimal" interpretation is introduced in Silverman 1997). The key claim here is that postaspiration benefits from the high-pressure, high-volume airstream conditions of a stop release, while preaspiration enjoys no such benefits, occurring as it does before the stop closure. Moreover, Bladon (echoed by Silverman) claim that since the closure intercedes between a postaspiration cue and the preceding vowel, essentially producing a period of silence, the auditory apparatus has a brief recovery period. This recovery makes the listener more sensitive (it is hypothesized) to the aspiration cue. Preaspiration, on the other hand, follows no such rest period, meaning that, in effect, the auditory nerve is "tired" when the preaspiration cue comes along, and is therefore less sensitive to it.

Over time, two important outcomes result from this perceptual inferiority, Silverman hypothesizes. It may be that the preaspiration cue is simply dispensed with, perhaps with compensatory lengthening of the preceding vowel. Alternatively, it may undergo fortification: if some oral component supplants the glottal aspiration component of the preaspirated stop (which as we have seen is not uncommon among preaspirated stops), that oral realization sufficiently reinforces the stop's perceptibility to prevent its elimination from the system, and ultimately is phonologized as a "new, improved" version of preaspiration (if you will). In other words, the preaspirated stop in its prototypical [hT] form is a kind of "audio-phonetic dinosaur" which "suffers from an accumulation of auditory handicaps" (Bladon 1986, p. 7) and is doomed to rapid extinction whenever innovated, unless it succeeds in making itself more perceptually prominent.

Nevertheless, this hypothesis of perceptual inferiority is tested experimentally in chapter 3. The results of the experiment are not favorable to the hypothesis: the subjects in that experiment (which included native speakers of Polish, Gaelic, and English) found preaspirated stops to be no harder to detect than postaspirated stops, placing Bladon's hypothesis, and by extension Silverman's, in doubt.

1.3.2 Helgason (2002)

Preaspirated stops occur in all of the Nordic languages except Danish, in at least certain dialects if not the standard languages. Helgason (2002) is an in-depth study of the phonetics and phonology of preaspirated stops in each of these languages, with special emphasis on dialects of Swedish. Examples, phonetic analysis, and detailed discussion are provided in each case.

Helgason employs an useful distinction between languages or dialects that feature "normalized" preaspiration, and those that feature a "non-normalized" version, which I have incorporated in my own definition of preaspiration (§1.1 above). In the former case, preaspiration is essentially obligatory, and articulations that omit preaspiration would be regarded as aberrant by speakers of the language. In the latter case, preaspiration is produced only by some speakers of the language community, while others omit preaspiration; either type of articulation is "normal" or acceptable. This distinction is similar to the distinction made in the phonological literature between "phonologized" and "non-phonologized" articulatory features (e.g. Kirchner 1999, Barnes 2002, Moreton & Thomas 2007).

Based on its phonetic characteristics, phonological function, and areal distribution, Helgason argues that preaspiration in the Nordic languages must be an archaic feature inherited from Proto-Nordic, a position shared by Hansson (2001), Thraínsson (1978), and others. This argument provides a *terminus ante quem* for the development of preaspirated stops in these languages; if the phenomenon dates from the Proto-Scandinavian era, it must be at least one thousand years old.

1.3.3 Ní Chasaide (1985)

Ní Chasaide's (1985) laboratory study of preaspiration in Icelandic, Scottish Gaelic, and Irish is groundbreaking in several ways. First, it was the first study to report the existence of non-normative preaspiration in Irish, and moreover, to provide any phonetic data about it. Previously, the only Celtic language known to have preaspirated stops was Scottish Gaelic. The dissertation seems also to have been the first study to systematically compare the phonetics of preaspiration in these three languages, showing that they exist on a kind of durational continuum, with Icelandic and the Harris dialect of Gaelic at the upper limit, Lewis Gaelic occupying an intermediate position, and the non-normative preaspiration in Irish the lower end of the durational spectrum, a conclusion reaffirmed for Gaelic and Icelandic by my own production studies (see chapter 4).

Ní Chasaide (1985) also established experimentally that the duration of preaspiration is heavily context-dependent. Place of articulation is a significant factor, with the duration of the preaspiration cue generally increasing as one moves from labial to dorsal; in addition, Ní Chasaide showed that these generalizations hold across three languages, suggesting that they are physiological or aerodynamic in origin, not language-specific. The study also found that preaspiration is shorter in medial position and after phonemically long vowels (in Gaelic and Irish), longer in final position and after short vowels, and greatly reduced in non-stressed environments. In general, my own findings support Ní Chasaide's conclusions regarding Scottish Gaelic, Irish, and Iceland, whereas my preliminary data suggest that in Tohono O'odham, preaspiration in fact *increases* with the length of the preceding vowel, instead of decreasing as in Gaelic, Irish, and Icelandic; see section §4.6 for further discussion.

Ní Chasaide also conducted a series of perception studies, concluding the breathy voice transition often found associated with preaspiration (or in place of it) is a useful cue for listeners to a preaspiration contrast, as was the amplitude of the aspirated component.

Finally, Ní Chasaide proposed a diachronic account of the development of preaspiration in both the Nordic and Celtic languages which is similar in outline to that argued for in this dissertation (see discussion in chapter §3.1.2.1).

1.4 Theoretical underpinnings

This dissertation addresses a long-standing and vigorously debated issue: that of typological asymmetries in language. In general terms, there are two types of asymmetries: those that concern the cross-linguistic abundance of linguistic structures and patterns; and language-internal asymmetries in the distribution of structures and patterns (which frequently hold cross-linguistically).

For the first: Certain types of phonological segments are commonplace, while others are much more rare. For example, front unrounded vowels are effectively universal, while front *rounded* vowels are restricted to perhaps six or seven percent of the world's languages (Maddieson 2008a). Similarly, clicks are present in fewer than one percent of languages, and interdental fricatives in about eight percent (Maddieson 2008b). To this list of rare phonological structures can be added preaspirated stops, which are probably present in fewer than one percent of languages.

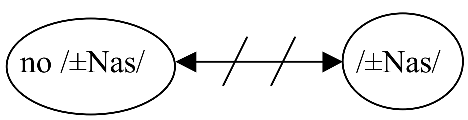
For the second: languages generally feature licensing asymmetries, allowing certain segment types only in specific positions, or prohibiting certain sequences of segments while licensing others. This type of asymmetry differs from the first in that the affected segment types might not themselves be rare; instead, their occurrence in particular environments is sharply restricted, and that these restrictions tend to hold cross-linguistically. For example, many languages license only voiceless obstruents in syllable codas, while permitting both voiced and voiceless obstruents in syllable onsets. German, Russian, and Dutch are examples. Languages with the opposite pattern, synchronically voicing underlying voiceless coda obstruents, are at best rare (Blevins 2004, Kiparsky 2006). Another example: Nasal-voiceless obstruent sequences are prohibited in many languages. These languages display a variety of strategies to avoid such sequences, which include voicing the obstruent, deleting the nasal, deleting the obstruent, or replacing the nasal with its oral counterpart, but exclude metathesis and epenthesis, though both of these strategies would also eliminate the offending cluster (Pater 1996, Myers 2002).

In this dissertation, I test two theoretical models that directly address these questions: the State-Process Model (Greenberg 1978, 1969, 1966), and Steriade's P-map Hypothesis (Steriade 2001a, 2001b).

1.4.1 The State-Process Model

The central insight behind the State-Process model (Greenberg 1978, 1969, 1966) is this: for any state occupied by at least one language, there must be (a) at least one process leading to that state, and (b) at least one process leading from it. Were it not for (a), no language could ever achieve the state (unless spontaneously generated within it); were it not for (b), every language would eventually end up in a terminal state, from which it could never exit. As an example, consider contrastive nasalization in vowels: unless by some means a language can move from the state of not having such vowels to the state of having them, or vice-versa, there would exist two eternal and invariant sets of languages, those with nasal vowels and those without , as in (1) (adapted from Greenberg 1978). It must also be true that languages can not only move into a state, but out of it again. Otherwise, all languages would eventually end up in a universal and terminal state, a so-called "sink," as in (2). A more probable situation is illustrated in (3), whereby languages can enter a state and leave it again, even if they do so by some intermediate state (perhaps via a precursor like phonetic nasalization).

(1)



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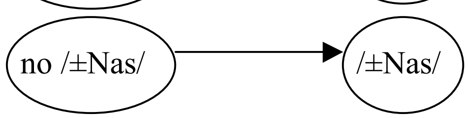

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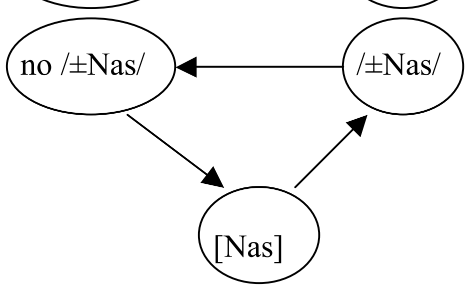


It follows from Greenberg's insight that the relative abundance of phonological patterns is a probabilistic function. If state A is more abundant than state B, it must be the case that languages enter state A more frequently than B, or else tend to remain in A longer than they remain in B. Put another way, it must be that A is innovated more frequently than B, or else A is diachronically more stable than B (or some combination of the two, since both factors must be gradient).

Moreover, Greenberg argues, it is possible to make inferences about innovation and transmission rates from synchronic evidence: the global distribution of states provides important information about the processes leading to those states. If some structure is abundant and more or less universal, then the probability of a language entering that state must be high, and the probability of its remaining there, must both be high. Front unrounded vowels might be of this type (this and following examples are Greenberg's[4]). If some structure is of lower abundance, but nevertheless fairly randomly distributed across language families, then it must be readily innovated, but unlikely to remain in that state for very long. Greenberg suggests that nasalized vowels might be of this type. If the structure is infrequent, and restricted to a few language families, then it must be relative hard to innovate, but stable once innovated, like vowel harmony. Structures that are neither abundant nor clustered within genetic groups (or linguistic areas) must be both hard to innovate and unstable once innovated (like velar implosives).

Chapter 3 of this dissertation applies the State-Process model to the case of preaspirated stops, arguing that their abundance and areal distribution indicate not that they are short-lived (as argued by Silverman 2003, Bladon 1986, and others), but rather long-lived

[4] It should be pointed out that some of Greenberg's examples have turned out to be somewhat less *a propos* than he might have guessed at the time, now that more information has become available. Nasal vowels, for instance, do in fact tend to cluster to some extent in equatorial Africa and South America, the northern region of the Indian subcontinent, and in parts of North America (Hajek 2008). Nevertheless, Greenberg's fundamental logic remains sound.

but hard to innovate. Like vowel harmony, preaspirated stops tend to cluster within a few linguistic stocks and language areas, notably the Germanic, Celtic, and Finno-Ugric languages of northern Europe, and the Central Algonquian languages of North America, suggesting that they are sufficiently robust to survive the differentiation of a parent language into numerous daughter languages, and/or transfer via language contact. Moreover, the evidence from the Nordic languages (Helgason 2002, Hansson 2001, Thraínsson 1978) suggests that in those languages, preaspirated stops have survived in a fairly stable state for at least a millennium.

1.4.2 The P-map

The second model employed in this dissertation is the P-map hypothesis (Steriade 2001a, 2001b). According to Steriade (2001a), the P-map is a component of the phonological grammar which incorporates speakers' knowledge of the "relative perceptibility of different contrasts, across the different contexts where they might occur" (p. 1) which stipulates that any modifications speakers may make to underlying forms in their spoken forms will be those the entail the smallest possible perceptual departure from that underlying form. Consider, for instance, the tendency toward word-final obstruent devoicing noted above. In Optimality Theoretic terms, this tendency is interpreted as evidence for a phonological constraint against voiced obstruents in word-final position, i.e. *[+VOICE]/_]$_{\text{word}}$ or a similar constraint. If the prohibition is simply against voiced obstruents in this position, there are a numerous possible ways to resolve potential violations of the constraint. Given an underlying form /tæb/, the alternative realizations [tæm] (nasalization), [tæw] (gliding), or [bæt] (metathesis) would all satisfy the constraint as well as [tæp], but are seldom or never attested.

Steriade argues that the latter repair is favored because other alternatives are perceptually farther removed from the target than devoicing (2001a).

Two processes obtain in Scottish Gaelic preaspiration, as illustrated in Figure 1.7. First, in two dialects, preaspiration has been lost before certain stops; second, in four dialects, preaspiration shows a velar instead of glottal realization in at least some stops (Clayton to appear, Oftedal 1956, Borgstrøm 1974, Ó Baoill 1980, Ó Murchú 1985, Ó Maolalaigh 2007). Each process observes a distinct place hierarchy. First, loss of preaspiration preferentially targets bilabial stops (dialects 2, 3), affecting dental stops only if bilabials are also included, while leaving velar stops unaffected. This yields the implicational asymmetry p » t » k. By contrast, the velar form of preaspiration preferentially targets in velar stops, only then extending to dental and perhaps bilabial stops (dialects 3-6): k » t » p. Finally, neither process obtains in the conservative Lewis dialect (1).

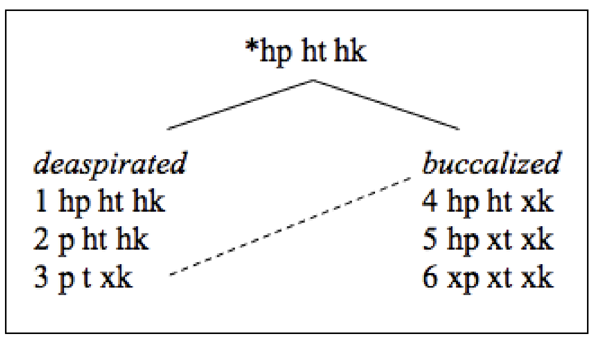


Figure 1.7. Deaspiration and buccalization in six Scottish Gaelic dialects

There is no clear reason for this curious state of affairs to obtain in Gaelic. Are there certain features of the articulation of preaspiration that might act as phonetic precursors for each asymmetry (a so-called *channel bias*)? Or is there instead a cognitive bias, perhaps originating with a P-map-like phonological module, such that perceptual scales favor certain rankings of faith constraints while discouraging others (an *analytic bias*)? Chapter 4 of the dissertation tests the ability of the P-map to resolve these two asymmetries in Scottish Gaelic preaspiration. It finds that the P-map is capable of explaining in the abstract why such asymmetries should occur, and predicts moreover that there should be perceptual scales congruent with these asymmetries, as measured by confusion studies comparing preaspirated with unaspirated stops. A review of the data from the perception study in Chapter 3 reveals just such perceptual scales which hold moreover across multiple native-speaker populations.

1.4.3 The diachronic/channel bias model

By contrast, other scholars assert that it is unnecessary to modify phonological theory to allow it to systematically distinguish attested from unattested patterns, maintaining that typological gaps occur because the phonetic precursors for the unattested constraint rankings rarely or never occur, not because of some inherent cognitive bias against them. If typological gaps can be accounted for through the diachronic operation of phonetic factors (sometimes referred to as *phonetic precursors*), it is unnecessary—indeed, undesirable—to attempt to account for these gaps synchronically: "gaps in factorial typology do not constitute a problem for the formal theory of OT, but rather represent a manageable challenge for the theory of phonologization" (Myers 2002: 2). This position is echoed in Barnes (2002: 353) ("We should not simply assume a priori that the phonological grammar contains such information [concerning phonetic patterns] because it is possible to model it in such a way"), and is perhaps articulated most clearly in Ohala (2005): "[t]he 'phonetic naturalness' requirement in phonological grammars should be re-examined and probably abandoned" (p. 1).

The theory of phonologization claims that sound change is in the main driven by misperception. Thus, attested grammars illustrate not only what phonological configurations are likely to be misheard (marked configurations), but what they are likely to be misheard as (attested repairs): “attested cases are ones that arise out of a perceptual reinterpretation of a phonetic pattern, while the unattested cases are ones that do not correspond to a natural phonologization of a phonetic pattern” (Myers 2002, p. 28). According to Myers, Ohala (2005, 1993), Blevins (2004), Barnes (2002), and others, to ask that phonological theory account formally for these phonetic tendencies is unnecessary, undesirable, and redundant.

1.5 Preview of dissertation

The balance of the dissertation is organized as follows. In chapter 2, I review the principal literature concerning preaspirated stops, and construct a census of those languages featuring preaspirated stops. I also identify patterns of variation, and isolate the probable antecedent structures that have given rise to preaspirated stops in several languages. These antecedents include geminate voiceless stops and nasal-voiceless stop clusters.

In chapter 3, I consider the prevailing explanation for the rarity of preaspirated stops, which rests on the crucial assumption that the aspiration cue in such stops is difficult to perceive, and argues that they are therefore short-lived (Silverman 2003, 1997; Bladon 1986). I conduct a perception experiment comparing preaspirated stops with postaspirated stops, which shows that in fact preaspiration is no harder for listeners to detect than postaspiration. I then explore an alternative hypothesis within the framework of Greenberg’s State-Process Model, arguing that preaspirated stops are in fact diachronically robust, but are probably difficult to innovate, and are thus part of a larger set of phonological structures, whose likely members include clicks, labiovelar obstruents, and bilabial trills.

Chapter 4 considers how well the P-map and phonologization models account for the two asymmetries in buccalization and neutralization of prototypical preaspiration in Scottish Gaelic. A clear perceptual basis for the deaspiration asymmetry is detected in subject responses to the perception experiment described in Chapter 3, lending support to the P-map. Meanwhile, two production studies of Gaelic preaspiration identify patterns of variation in the duration of preaspiration which may serve as potential phonetic precursors to these asymmetries. However, the same experiments also reveal that many (though not all) speakers sporadically produce unaspirated tokens where preaspirates are expected; this deaspiration pattern roughly conforms to the perceptual scales detected by the perception experiment described in chapter 3. Such a pattern of variation is predicted by the P-map hypothesis, but not by the diachronic/channel bias account.

Finally, chapter 5 summarizes the dissertation's contents and principal findings.

Chapter Two

The typology of preaspirated stops

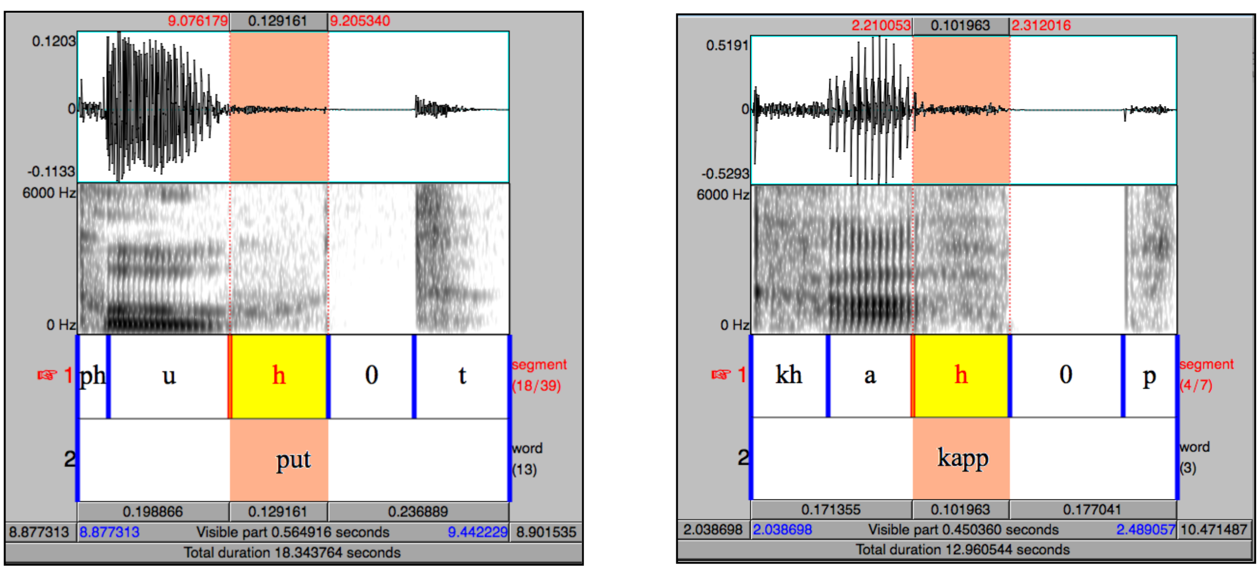
2.1 Introduction

This chapter sets out to construct as complete an inventory of preaspirating stop systems worldwide as the current literature permits. The result may be described as both more complete and more selective than previous surveys (notably Silverman 2003 and Helgason 2002), since it adds examples not included in those surveys, while excluding others (though not without comment). In constructing this inventory, the chapter addresses the second and more important goal: to assess the geographic and genetic distribution of preaspirated stops, variation in their phonetic form, the range of their phonological function, and where possible, their origin, i.e. what phonological structures and patterns favor their innovation.

In constructing the census, a clear definition of "preaspirated stop" was essential; I employed that offered in Chapter 1, which I will summarize here. Prototypically, the "preaspiration" component refers to a period of glottal [h], that intercedes after a vowel and preceding a consonant. As examples, consider Scottish Gaelic *put* 'buoy', phonemically /p^hut^h/, phonetically [p^huht], or Icelandic *kapp* 'contest' /$k^hap^hp^h$/,[1] phonetically [k^hahp] (Figure 2.1). While primarily glottal, this frication may sporadically be realized with a

[1] By the analysis of Icelandic preaspiration offered in Suh (2001).

supralaryngeal component, even by the same speaker in the same word; for instance, Helgason (2002) reports that he has recorded a Faroese speaker producing the word *vatn* ‘lake’ on separate occasions, once with a purely glottal fricative [vɐ̝ht̪n̥n̪] and a second time with a uvular trill [vɐ̝hʀ̥t̪n̥n̪] (Helgason’s transcriptions). However, these variant productions in which phonetic context exerts some influence on the form of frication should be distinguished from those situations in which the non-glottal form is obligatory—in which a glottal realization would be perceived as aberrant by native speakers of the language or dialect, a circumstance indicating that the non-glottal form has most likely undergone phonologization (i.e. become grammatically required). As a clarificatory term, I will refer to “prototypical preaspiration” when it is necessary to distinguish the first or more “basic” form of preaspiration from other phenomena which may be more loosely placed under the rubric of “preaspiration” for the sake of convenience.



a. **b.**

Figure 2.1. Spectrograms of (a) Gaelic *put* ‘buoy’ and (b) Icelandic *kapp* ‘contest’

The second stipulation employed here is that any preaspiration should be phonotactically associated with stops to the (near) exclusion of other types of consonants. In other words, [h] should not freely cluster with a wide range of consonants beyond the class of stops. Thus excluded from the survey are those languages featuring stops that might be regarded as preaspirated, insofar as they can be preceded by an [h]-like period of glottal frication, or by some allophone of an /h/ phoneme; examples include Finnish (Suomi, Toivanen & Ylitalo 2008), numerous dialects of Spanish (Gerfen 2001, Morris 2000, Hualde 1987), Chamicuro (Parker 1994, Payne 1991), or Huatla Mazatec (Pike and Pike 1947). Note that though the last two examples have been included in other inventories of preaspirating languages (e.g. Silverman 2003), I am thus excluding them here. In these excluded instances, though aspiration or allophones of /h/ can appear before voiceless stops, they can also appear before a range of consonants besides, or even alone in coda position, and therefore should probably not be regarded as any special property of the stops themselves. I have, however, included several languages in which preaspiration can appear before only one or perhaps two other segments in addition to stops, for instance [s] (like Tohono O'odham), [ts] (Bora), or [tʃ] (Goajiro). These examples are included (albeit guardedly), because the aspiration is still tightly restricted in its distribution, rather than more or less freely clustering with any segment. Again, this decision is in keeping with previous literature, including Helgason (2002), and I have seen no reason to depart from existing practice in this regard. The example offered above reflect the common analysis for many languages that preaspiration is an allophone of a phonemically aspirated stop, as well as the widespread practice of using a normally sized [h] to represent the preaspiration, in contrast to the superscript version used for postaspiration. A common justification for this practice is that preaspiration is generally quite a bit longer in duration than postaspiration

Finally, it should also be mentioned that I have included in the survey three languages which have been described as preaspirating, Bora, Hopi, and Scottish Gaelic, but which in fact (at least partially, or in some dialects) exhibit phonological patterns which can be considered derivative of preaspiration. In the case of Bora, so-called preaspiration is phonetically not glottal [h], but rather velar [x] (Aschmann 1993), and is therefore most likely an evolutionary step beyond the prototypically preaspirating state described in the definition above (see chapter 4 for more on such buccalization processes). The Toreva dialect of Hopi was described by Whorf (1935) as having preaspiration, but subsequently, preaspiration in this language seems to have developed into a tonal contrast (Manaster-Ramer 1986). However, I have included Whorf's description of preaspiration in Hopi, as it constitutes nevertheless a valuable synchronic description of the phenomenon. (See chapter 4 for a more detailed description of the Hopi situation.) Finally, Scottish Gaelic, while certainly featuring prototypical preaspiration in many dialects, also exhibits a phonologized buccalized variant in some dialects, either before all stops or a subset of them (more on this in chapter 4).

Several useful generalizations or patterns emerge from the survey of preaspirating systems, some phonological, some historical, which I will preview here:

A. Preaspiration tends to occur in languages featuring two stop series that contrast through aspiration, not voicing. Exceptions include Sienese Italian and Tyneside English (with a ± voice contrast) and Goajiro (only 1 stop series). In each of the exceptions, preaspiration has not been phonologized (that is, preaspiration occurs sporadically, and may only be employed by a subset of the speaker population), whereas in most of those languages conforming to the generalizations, preaspiration is a phonological, contrastive property of underlyingly aspirated stops.

B. Where it is possible to identify or productively speculate about their origin, two antecedents to preaspirated stops ca be identified: 1) geminate voiceless stops (most examples, including Icelandic and the other Nordic languages, Scottish Gaelic, Sami, Forest Nenets, and Bora), and 2) nasal-stop clusters (a few examples, including the Central Algonquian languages, possibly some tokens within the Nordic languages, and Hopi).

C. The phonologization of preaspirated stops (that is, preaspiration as a normative component of the speaker community's phonological grammar) seems to correlate with the transition from a two-way phonological contrast in stops based on voicing to a contrast based on aspiration; in these cases, preaspirated stops are allophonic realizations of phonologically aspirated stops.

D. Preaspirated stops are usually limited to medial and final position. Two putative exceptions, Huatla Mazatec (Pike and Pike 1947) and Chamicuro (Parker 1994), are better analyzed as [hC] clusters than as preaspirated stops *per se*. In Sienese Italian, both underlying geminates (medial) and derived geminates (initial, through *raddoppiamento sintattico*) may be realized as phonetic preaspirates (Stevens 2007, Stevens and Hajek 2007, 2004). Bora allows preaspirates in initial position postvocalically (Aschmann 1993).

E. Various allophonic or (less commonly) phonologized modifications to the prototypical glottal [h] realization are commonplace; these include breathy voice [ɦ], and buccal variants such as [x] and [ç] (see comments above). Frequently, the form of a buccal variant is context-dependent: e.g. palatal [ç] may occur in palatal environments (i.e. after high front vowels or before palatal stops; multiple examples), [x] before velar stops (as in certain dialects of Scottish Gaelic). Only in a small number of cases are these buccal forms phonologized (i.e. obligatory), including certain dialects of Scottish Gaelic (only before certain stops in most affected dialects, [h] being retained before the remaining stops) and Bora.

F. Several geographic and genetic clusters of preaspirating languages can be identified. The greatest geographic and genetic hotspot for preaspirated stops is northern Europe, where the Nordic languages (excepting Danish), Scottish Gaelic, and many of the Sami dialects all feature preaspirated stops in some degree. Other genetic clusters can be identified in North America among the Algonquian and Uto-Aztecan languages.

As an inevitable consequence of the state of our knowledge, certain languages will receive far more attention than others in this discussion; this is especially true of Scottish Gaelic and the Nordic languages, simply because far more is known about preaspiration in these languages than in any of the others.

The following discussion is organized first by language family and then individual language. The chapter concludes with a table summarizing key facts about each of the languages discussed.

2.2 Celtic

Unlike the Germanic languages, preaspiration in the Celtic languages is not widespread, being effectively limited to certain dialects of Scottish Gaelic, and to a very limited extent Irish (Ní Chasaide 1985, Ní Chasaide & Ó Dochartaigh 1984). Preaspiration has not been reported in the other Celtic languages, Welsh, Breton, Manx and Cornish.

2.2.1 Scottish Gaelic

Preaspiration in Scottish Gaelic is better documented than in any other language save perhaps Icelandic. Principal works discussing the form and distribution of Gaelic preaspiration in specific dialects include Borgstrøm (1940, the Outer Isles), Oftedal (1956, Leurbost, Lewis), and Ternes (1973, Applecross). Particularly valuable is Ó Dochartaigh (1994-1997), a five-volume compendium of the data accumulated during the Scottish Gaelic Dialect Survey of the 1950's and 1960's. This study is remarkable for the variety of phonological and morphophonological structures investigated, and invaluable because a very large proportion of the speakers interviewed in the survey represent dialects which are no longer spoken.

Most dialects of Scottish Gaelic feature two series of stop phonemes with an aspiration contrast: voiceless unaspirated /p t̪ t̪^{j} k^{j} k/ versus voiceless aspirated / p^{h} t̪^{h} t̪^{jh} k^{jh} k^{h}/. Aspirated stops are post-aspirated in initial position, and preaspirated in medial and final position. Both types of aspiration favor stressed environments, i.e. adjacent to stressed nuclei; in stressless contexts, the aspiration contrast is typically neutralized or greatly diminished. Since Scottish Gaelic is a stress-initial language (with a few exceptions, typically borrowed words), both postaspiration and preaspiration are thus effectively restricted to initial syllables. These facts are illustrated in the (near) minimal pairs in (1) and (2):

(1) *cop* [k^{h}ohp] 'foam' < > *gob*[kop] 'beak'

(2) *bàta* [ˈpa:hta] 'boat' < > *fàdadh* [ˈfa:tax] 'kindling'

Scottish Gaelic displays considerable dialect-related variation, and there is a commensurate degree of variation in the configuration of preaspiration in each dialect (Clayton, to appear; Ó Dochartaigh 1994-1997; Clement 1994; Ó Murchú 1985; Borgstrøm 1974, 1940; Oftedal 1956). This variation is illustrated in (3) (distributions are approximate).

(3) 1. /hp ht hk/: Lewis, the northwestern mainland

2. /p ht hk/: west Sutherland variant

3. /hp ht xk/: western Inverness-shire, Skye, outer Hebrides except Lewis

4. /xp xt xk/: north Argyll, central Highlands

5. /hp xt xk/: southwest mainland (Ó Maolalaigh 2007).

6. /p t xk/: southern Argyll; portions of south-central Highlands

Two distinct patterns can be discerned in the form and phonological distribution of preaspiration (Figure 2.2). First, note that in two dialects (west Sutherland, southern Argyll), labial stops are never preaspirated; in one dialect (Skye), coronal stops are also never preaspirated. In these dialects, the affected stops remain postaspirated in initial position; the result is a partial merger with unaspirated stops in medial and final position. This pattern of implies a hierarchy of deaspiration *labial* >> *coronal* >> *dorsal*. The second pattern concerns the phonetic form taken by preaspiration.

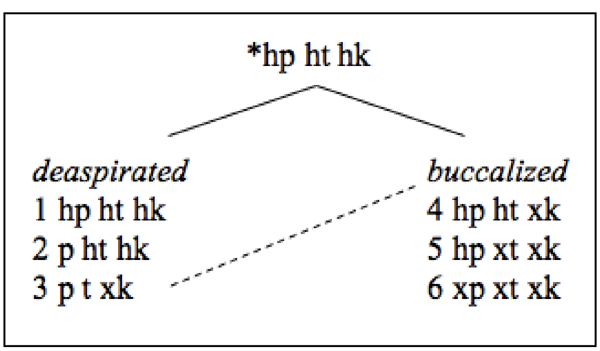


Figure 2.2. Dialect variation in SG preaspiration

In some dialects (3-6), preaspiration takes a velar form [x] as well as, or instead of, glottal [h]. Like the neutralization pattern just described, this buccalization pattern is place-sensitive: it affects dorsal stops in four dialects (3-6); also includes coronal stops in two of these dialects (southwest mainland, southern Argyll); and finally, affects all positions in dialect (southern Argyll). Thus, a place hierarchy is implied which is opposite to that for deaspiration: *dorsal* >> *coronal* >> *labial.* (See chapter 4 for a more detailed analysis of these patterns.)

Non-preaspirating Gaelic dialects have also been described. These dialects either preserve the earlier contrast between voiced and voiceless stops from the parent language, as in East Sutherland (Dorian 1965), or have neutralized the earlier contrast altogether and now feature only a single set of voiceless stops, as in East Perthshire and the Isle of Arran (Ó Baoill 1980, Ó Dochartaigh 1994-1997).

The origin of Scottish Gaelic preaspiration is much discussed in the literature. There are two principal schools of thought. The first maintains that preaspiration was borrowed from preaspirating dialects of Old Norse during the extensive period of contact between the two languages during the medieval period; Marstrander (1932), Oftedal (1956), and Borgstrøm (1974) are the principle exponents of this view. The proposal is that, since a large contingent of Norse speakers must have populated the affected Gaelic-speaking areas at some point (as toponymic evidence clearly indicates), it is likely that a Norse/Gaelic bilingual population arose. Such bilingual speakers, especially those whose first or dominant language was Norse, may have transferred features of the Norse system of stop contrasts to their Gaelic: those who spoke a preaspirating dialect preaspirated their Gaelic stops, while speakers of non-preaspirating Norse dialects did not. Such transfer is not unattested: similar transfer of preaspiration can be heard in the English utterances of Icelandic/English bilinguals, and in those of individuals bilingual in English and the Lewis dialect of Gaelic (though not, evidently, other Gaelic dialects) (personal observation; also Borgstrøm 1974).

The point of introduction must have been Lewis, Borgstrøm argues, because the form of preaspiration found there is closest to the Icelandic form, i.e. prototypical [hp ht hk]. The variant forms, especially those featuring [x] in place of [h], Borgstrøm continues, must have been subsequent developments, potentially explained as imperfect copying of the innovative but possibly high-prestige Lewis form by Gaelic monolinguals in adjacent regions, and/or by substitution by such speakers of [xk] for [hk] (the former but not the latter permitted by existing Gaelic phonotactics).

Objections come from several quarters. Ó Murchú (1985) argues that similar contact with Norse took place over much of the British Isles, including England and Ireland; yet, for all intents and purposes, contrastive preaspiration is not to be found outside of a small region of Scotland. Instead, Ó Murchú proposes, preaspiration should be considered a native development of Scottish Gaelic, associated with a loss of the earlier Old Irish voicing contrast: as /b d g/ become devoiced in some dialects of SG, distinctive aspiration was introduced to the originally voiceless stops /p t k/ to prevent a merger between the two sets of stops. The new system is seen in its fully developed form in Lewis Gaelic (dialect 1): [p t k] < > [hp ht hk]. Partial mergers resulted in those dialects where the new contrastive feature was incompletely adopted (west Sutherland [p ht hk] and southern Argyll [p t xk]). In the eastern Perthshire dialect, which features only a single stop series /p t k/, the devoicing of /b d g/ has completely run its course (according to Ó Murchú) without the adoption of aspiration, and there has thus been a total merger of the two stop series. Velarized realizations represent an "intensification" of preaspiration beyond that seen in dialect 1; in other words, [h] has been replaced by [x] partially or en toto.

Ó Murchú's scenario does not, however, explain how the aspiration contrast came to be expressed as *pre*aspiration in medial and final position, instead of the typologically more commonplace postaspiration. To this question, Ó Baoill (1980) offers an interesting solution: he suggests that preaspirated stops developed from earlier Old Irish geminate stops. When the length contrast in Old Irish stops was lost, Ó Baoill argues, preaspiration was introduced as a strategy to maintain optimal syllable length: together, preaspiration + singleton stop offer the same prosodic length as the earlier geminate, he argues. As evidence that the Old Irish antecedents of modern SG preaspirated stops were in fact geminates (a point not universally accepted, e.g. by Greene 1956), Ó Baoill shows that stops (both voiced and unvoiced) in modern Donegal Irish continue to be pronounced as long in just those words where they are described as geminates in the standard Old Irish handbook, Thurneysen (1949). For instance, since the final stops in the Modern Irish forms *mac* "son" and *brat* "cloak" were frequently written *macc, bratt* in Old Irish, Thurneysen concluded that their final stops must have been geminates. Likewise, in the Modern Irish of Donegal, Ó Baoill found that speakers continue to pronounce these final stops long, though consonant length is no longer phonemic in that dialect; Ó Baoill argues that this pronunciation is thus an archaism.

Interestingly, Ó Baoill also mentions that such lengthening of final stops in Donegal Irish is less prominent following phonemically long vowels (preserved in Modern Irish and Scottish Gaelic). This fits well with his hypothesis that preaspiration was introduced to maintain prosodic length: such an imperative could potentially be satisfied by either a lengthened vowel or by preaspiration. Moreover, this is reminiscent of the situation in

Icelandic: stressed vowels are predictably lengthened before singleton stops, but before preaspirated stops they remain short (see below). Furthermore, in Scottish Gaelic, the length of the preaspiration cue is, in rough terms, inversely related to the phonemic length of the preceding vowel: shorter or absent after phonemically long vowels, longer after phonemically short vowels. Ó Baoill's argument that SG preaspirated stops are a native innovation, rather than a contact feature, is thus fairly convincing on comparative grounds.

To Ó Baoill's arguments, I will add another. An account like Ó Baoill's, in which preaspiration is posited to have originally taken a form like [hp ht hk], subsequently developing buccal forms in some dialects, avoids the serious problem with relative chronology incurred by e.g. Kenneth Jackson's hypothesis that preaspiration originated in the central Highlands as [xp xt xk] and then lenited to e.g. [hp ht hk] (a personal communication reported in Oftedal 1962, p 116). Since all dialects of Gaelic retain the cluster /xk/ (derived from Old Irish /xt/), Jackson's hypothesis entails that the cluster /xk/ underwent an unmotivated split to [hk xk], an extremely unlikely scenario (see also Hansson 1999, 1997 for similar arguments).

2.2.2 Irish

While Irish is not usually described as a preaspirating language, Ní Chasaide (1985) and Ní Chasaide & Ó Dochartaigh (1984) report preaspiration of phonologically voiceless stops in the speech of a single informant from Donegal (Gaoth Dobhair). Medial and final voiceless stops following stressed vowels were investigated. According to their description, this preaspiration was a "very weak glottal fricative or period of silence" measuring, on average, approximately 35-40ms (somewhat shorter than I have found in SG; see discussion in chapter 4). The authors nevertheless do not conclude that preaspiration has been phonologized in Donegal Irish, nor have I seen such a conclusion presented anywhere else. Irish preaspiration is thus likely to be an instance of subphonemic preaspiration such as that found in certain dialects of Swedish (e.g. Helgason 2002), Tyneside English (Docherty & Foulkes 1999), or Sienese Italian (Stevens 2007); see discussion of these examples below.

2.3 North Germanic

Preaspiration is present in at least some dialects of all but one of the Nordic languages, either in a phonologized or a non-phonologized form, Danish being the exception. Even in Danish, however, some scholars have linked the West Jutland stød, or preglottalization of voiceless stops, to an earlier preaspiration pattern (Kortlandt 2003, Hansson 2001)[2]. It is this ubiquitous character that has led more than one scholar to conclude that preaspiration must be an archaic, inherited feature (Helgason 2002, Hansson 2001, Page 1998, Chapman 1962). The alternative hypothesis, that each of these closely related languages has independently innovated the feature, is improbable at best.

There is broad agreement that at least some examples of preaspiration in the modern Nordic languages can be linked to voiceless (so-called fortis) geminate stops in Proto-Scandinavian ((Helgason 2002, Hansson 2001, Árnason 1980, Thrainsson 1978). In addition, further examples can be linked to nasal-fortis stop clusters. Finally, some preaspirated stops in the modern languages can be traced to fortis singletons in Proto-Scandinavian. (See Helgason 2002, Hansson 1999, and Page 1997 for details of these reconstructions.)

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[2] This form of Danish stød (as distinct from the stød found in other dialects) patterns much like preaspiration in the other Nordic languages, being found before voiceless stops "wherever these stand in an original medial position, following a voiced sound in a stressed syllables (Ringgaard 1960, p.195, cited in Kortlandt 2003).

Alternatively, we may collapse the latter two categories into a single category: Proto-Scandinavian fortis singletons are realized as preaspirated in (some) modern Nordic languages, including when they were preceded by sonorants in the proto-language. After exhaustive consideration of previous arguments, the historical evidence, and quantities of data from the modern languages, Helgason (2002) proposes that the pattern of development in Table 2.1, arguing that "non-normative" (i.e. non-phonologized) preaspiration was present in all word-medial and final fortis stops in Proto-Scandinavian.

	Word-initial	*Word-medial & final postvocalic*	
		Singleton	*Geminate*
Fortis	p^h t^h k^h	$^{(h)}p$ $^{(h)}t$ $^{(h)}k$	$^{(h)}$pː $^{(h)}$tː $^{(h)}$kː
Lenis	b/p d/t g/k	(β/v) (ð) (ɣ)	bː dː gː

Table 2.1. Reconstruction of Proto-Scandinavian stops (after Helgason 2002). Parentheses denote non-phonologized preaspiration.

Helgason argues that both phonologized and non-phonologized preaspiration the daughter languages is essentially a shared retention from the parent language, with relatively minor permutations in individual languages. He further argues that the glottal gesture associated with preaspiration would have been carried over into any pre-stop sonorants, effectively devoicing them; similar processes can be observed in the modern Nordic languages and in Scottish Gaelic: sonorants before voiceless stops are devoiced. Since devoiced nasals sound much like aspiration (Ohala & Ohala 1993) or may be perceived as breath (Herbert 1986), Proto-Scandinavian nasal-stop clusters as a result would have merged with singleton fortis stops. Similar arguments have been presented in Chapman 1962 and

Marstrander 1936 for Proto-Scandinavian, and for Central Algonquian by Bloomfield 1925 (see below). Icelandic examples are provided in (4).

(4) a. Latin *campus* > *kapp* [k^{h}ahp] ‘contest’ (see Figure 2.1).

b. PGmc **driŋkan* > *drekka* [trɛhka] ‘to drink’

Pertinent elaborations concerning individual languages and dialects will be provided in the balance of §2.3.

2.3.1 Icelandic

The probable pattern of development between Proto-Scandinavian and modern Icelandic is outlined in (5), based on discussion in Page (1997) and Helgason (2002). In the diagram, “p” represents any voiceless stop, “b” any voiced stop, and “N” any nasal or /l/. Specifically, Proto-Scandinavian *g* is reflected as a voiced velar fricative, or even a palatal glide.

(5)

PS:	pV	Vp	Vpp	Vb/g	bV	Vbb	VNp
			⇓				
Icel:	phV	Vph	Vhp	Vp/ɣ	pV	Vpp	VNhp/VN̥p

Like the preaspirating dialects of Scottish Gaelic, Icelandic features two phonemic series of voiceless stops distinguished by an aspiration feature: /p t k/ < > /p^{h} t^{h} k^{h}/. Icelandic adds quantity contrast. Singleton aspirated stops /T^{h}/ are postaspirated in all positions, unless before the sonorants /n/ or /l/, when they are realized as preaspirated, e.g. *vatn* [vahtn̥] “water,” *epli* [ɛhpl̥ɪ] “apple.” Underlyingly geminate aspirated stops /T^{h}T^{h}/ are realized as preaspirated singletons [hT] (see e.g. Gibson 1997, Suh 2001 for arguments that these stops are indeed phonologically geminates). Preaspirated stops may occur in both medial and in final position, as in Gaelic: *brekka* [brɛhka] “slope”, *tryppi* [t^{h}rɪhpɪ] “colt”, *latt* [laht] “lazy” (examples from Silverman 2003). In sonorant + aspirated stop clusters, the sonorant is devoiced (with exceptions in northern dialects): *heilt* [hɛiːl̥t] “whole” (neut.), *fantur* [fan̥tʏr] “villain” (Árnason 1980). These facts are summarized in (6):

(6) a. CV *bakki* /pak^{h}k^{h}i/ > [pahki] “bank, shore”

pakka /p^{h}ak^{h}k^{h}i/ > [p^{h}ahka] “pack”

b. VC(V) *Adam* /atam/ > [a:tam] “Adam”

fat /fat/ > [fa:t] “basket”

c. VCV *vika* /vɪka/ > [vɪ:ka] (S. dialect), /vɪk^{h}a/ > [vɪ:k^{h}a] (N. dialect)

d. VC: *gabba* /kappa/ > [kappa] “spoof”

kapp /k^{h}ap^{h}p^{h}/ > [k^{h}ahp] “contest”

e. VC + /l, n/ *epli* /ɛpli/ > [ɛhpl̥i] “apple”

f. VC + /r/ *dapra* /tapra/ > [tapr̥a] “be sad”

g. VNC (nasal or lateral + stop clusters)

veltur /vɛlt^{h}ʏr/ > [vɛl̥tʏɹ̥] “falls”

veldur /vɛltʏr/ > [vɛltʏɹ̥] “causes”

Icelandic features a vowel lengthening rule, such that stressed vowels are predictably lengthened before singleton stops or clusters consisting of *p, t, k* + *r, j*, *v* (Árnason 1980, Helgason 2002). Such lengthening does not occur before geminates, nor before preaspirated stops (this is one argument in favor of their underlying geminate status, in fact). Compare this to other languages in this survey where preaspiration alternates either synchronically or diachronically with vowel lengthening (including Tarascan and Goajiro).

Árnason (1980) indicates only glottal realizations of preaspiration in Iceland (i.e. [h]). Liberman (1982) mentions that some researchers have reported supralaryngeal realizations, e.g. homorganic sequences like [fp, θt, xk], but objects that "this is a mischaracterization of their phonetic properties" (Liberman, p.c. in Silverman 2003).

2.3.2 Faroese

Faroese preaspiration is very similar to that found in the closely related Icelandic, with certain additional permutations (Helgason 2002, Árnason 1980). As in Icelandic, there are two stop series in Faroese: voiceless unaspirated stops contrast with voiceless aspirated stops, plus a length contrast. Underlyingly geminate aspirated stops are realized as preaspirated in medial position, and as preaspirated *and* postaspirated in final position: *glopp* [klɔhpʰ] "gap", *bakkar* [bɐ̹hˣkɐɹ] "banks (of a river)" (examples and transcriptions from Helgason 2002). In certain instances (it is not clear from the sources exactly when), preaspiration may also affect singleton aspirated stops. Moreover, preaspirated stops do not appear to block vowel lengthening as they do in Icelandic. In the northwestern dialect, preaspiration before singletons seems to be blocked by the high front vowel [i] and sometimes also the mid vowel [e], and may be realized as postaspiration instead: *bátin* [bɔɐːhtən] "the boat," but *vík* [vʊi:kʰ] "bay"; *eta* [e:ta] ~ [e:hta] "eat" (examples adapted from Helgason 2002).

A further consideration is that, depending on the dialect, the initial stops in modern reflexes of the Old Norse clusters *ks kt pt* are preaspirated, while in other Faroese dialects, those stops have instead become the corresponding fricative, e.g. *akstur* [ɐhˣks̪təɹ] ~ [ɐ̹xs̪təɹ] "driving," *seks* [sɛhks] ~ [sɛxs] "six," *keypt* [tʃʰɛhp̪t̪] ~ [tʃʰɛft̪] (transcriptions after Helgason 2002).

2.3.3 Norwegian

Preaspiration is also reported in the Jæren, Gudbrandsdalen, and Trøndelag dialects of Norwegian (Helgason 2002, Oftedal 1947). Here, as in Icelandic and Faroese, Proto-Scandinavian geminate voiceless stops may be reflected as preaspirated and long, or as singleton preaspirated stops in stop-sonorant clusters: PS *sleppa* > [sl̪ɛhpːɐ] "release," *katt* > [kʰɐht̪ː] "cat," *snikka* > [sn̥ihkrɐ] "do woodwork" (examples adapted from Helgason 2002).

2.3.4 Swedish

Several dialects of Swedish also feature preaspirated stops, among them the Härjedalen, North Dalarna, Kökar, Arjeplog, Gräsö, and Central Swedish dialects (Helgason 2002, Hansson 1999). Preaspiration in these dialects, as in Icelandic, is associated with underlyingly geminate voiceless aspirated stops (reflexes of Proto-Scandinavian geminate voiceless stops). With one exception, these dialects of Swedish share the system of stop contrasts noted for the other Nordic languages: two series, both voiceless, distinguished by an aspiration contrast in stressed environments. The exception is the Vemdalen dialect, which appears to also have a third series of voiced stops, which are reflexes of the Proto-Scandinavian geminate voiced stops (Helgason 2002).

Unlike the Nordic languages previously discussed, preaspiration in Swedish can also precede nasal-stop clusters: Westin (1897, cited in Page 1997) claims the following forms (transcriptions based on those Page provides): *inte* [ɪhnt]"not," *tänka* [tæhŋke] "think," *vanka* [vɑhŋke] "wander." Note particularly that Westin's transcriptions do not indicate that the nasals are devoiced, as one would normally expect between voiceless obstruents. Liberman (1982:115) argues on the basis of Westin's data that a following voiceless obstruent is not an essential condition for preaspiration; this claim seems highly questionable to me (Page 1997 agrees), since such a phonetic environment practically guarantees the devoicing of the nasal.

A second interesting controversy concerns evidence provided in Millardet (1911) and Rositzke (1940) (cited in Page 1997) for "epenthetic consonants" sometimes taken to be preaspiration; these consonants are voiceless oral fricatives which match the rounding of the preceding stop, e.g. *kok* [kωφk] ~ [kωβk] (where [ω] represents, I presume, a mid or high back round vowel). According to Page (1997), these epenthetic consonants are actually affiliated with a widespread diphthongization process in Swedish "and so should not be considered an example of preaspiration" (p. 173).

2.4 English

English is the only non-Nordic Germanic language reported to feature preaspiration: in Newcastle (Tyneside) and among bilingual speakers of English and the Lewis dialect of Scottish Gaelic.

Docherty and Foulkes (1999) describe what they refer to as "extended frication" (p. 62) before the closure period of prepausal /t/ in the English of Newcastle, England (otherwise known as Tyneside English). Judging both from the authors' choice of descriptor, and from the spectrogram provided, this seems to be a plausible example of genuine preaspiration. No information is offered about such frication before stops at other places of articulation in this publication, but Silverman (2003) reports a personal communication from Foulkes indicating that preaspiration occurs at least before [k] as well as [t]. Besides glottal [h], other possible realizations include breathy voice or “preaffrication,” which presumably consists of homorganic oral frication preceding the stop. “Extended frication” occurs most frequently among younger and in female speakers: among speakers 14-27 years of age, approximately 70% of females and 35% of males employ “extended frication,” while among older speakers (45-67), approximately 23% of females and 2% of males employ it (Docherty & Foulkes 1999).

The origin of preaspiration in Tyneside is not clear. Docherty and Foulkes suggest that physiologically, preaspiration results from a “relatively slow tongue tip closure” (p. 62), but do not speculate concerning reasons for the introduction of preaspiration into English at this particular time and place. Unlike preaspiration in the Nordic languages, preaspiration in Tyneside English cannot be associated with underlying or historically geminate stops. The motivation for this development must then remain unestablished for the time being, but it seems to be a spontaneous development within this form of English.

By contrast, preaspiration in Lewis English is very likely to be a transfer feature from Gaelic, since the phenomenon appears to be limited to older Gaelic/English bilingual individuals (Borgstrøm 1940, Oftedal 1956, and personal observations). Such speakers can clearly be heard to preaspirate tokens of medial and final /p t k/ in their English. While preaspiration has not been remarked in the speech of younger bilingual individuals, no systematic investigation of the phenomenon has yet been undertaken. Nor is preaspiration noticeable in the English of bilingual Gaelic/English speakers from other regions of Scotland.

It is precisely this kind of phonological transfer of preaspiration among bilingual individuals that Borgstrøm (1974) argues was the mechanism responsible for the introduction of preaspiration into Gaelic from Norse: bilingual speakers adapted the new language

(Gaelic) to the phonological demands of the old (Norse). A similar transfer can be heard in the English of native Icelandic speakers. Two important questions remain unanswered. First, why this transfer has only happened among speakers of Lewis Gaelic, and not other Gaelic dialects? Second, why does it seem to be characteristic only of older bilinguals? Both questions merit a closer look in future research.

2.5 Finno-Ugric

Preaspiration is represented in two separate families of Uralic, Sami and Samoyed. However, it is likely that two separate innovation events are represented, according to the descriptions available, in contrast with the Nordic languages, in which preaspiration is argued to be a conservative feature inherited from a single ancestor.

2.5.1 Sami

Historically, the Sami languages (or dialects—the chosen descriptor varies) featured three "grades" of voiceless stop contrast. These grades of contrast resulted from a phonological contrast between short ("weak grade") and long ("strong grade") stops, complicated by a further weak/strong distinction: long stops became "overlong" when followed by an open syllable (Helgason 2002). Precise descriptions of the stop contrasts in the modern languages are difficult to come by, those of preaspiration even harder; the most complete I have found is contained in Hasselbrink (1965), for "Central South-Lappish," i.e. Southern Sami.

According to Hasselbrink (1965), modern Southern Sami possesses two sets of phonemic stops: "weak" stops, phonemically /b d g/, phonetically [b d g p t k], and "strong" stops, phonemically /p t k/, realized as preaspirated or postaspirated voiceless stops, according to environment. Postaspirated realizations occur word-initially, or in medial and final position before another consonant (the following transcriptions are adapted from Hasselbrink's): [p^{hj}eːraː] "potato," [khaːrene] "man," [aːk^{h}ʃuo] "axe." In medial and final position, "strong" steps are preaspirated when phonologically geminate: [baːrgaːldahkke] "plait," [luhk^{h}] "read" (imper.). (Hasselbrink's transcriptions seem to indicate that in final position, underlying geminates are realized as singletons). Phonological singletons are preaspirated in medial and final position, including when preceded by a sonorant consonant: [b^{j}ejhpuo] "pipe," [gyrht^{j}ie] "loon."

According to McRobbie-Utasi (1991), preaspiration in the Skolt dialect of Eastern Sami is typically glottal, but may also be realized with oral articulations, including [f], [x], and [ç]. There is no significant difference in duration according to place of articulation, unlike Scottish Gaelic and Icelandic (see chapter 4, also Ladefoged et al 1997, Clayton to appear); preaspiration is also likely to be omitted after the vowel [u].

2.5.2 Forest Nenets[3]

According to Sammallahti (1974), Forest Nenets contrasts the voiceless unaspirated oral stops /p p^{j} t t^{j} k/ with the preaspirated stops /hp^{j} ht ht^{j} hk/, and features as well an opposition between unaspirated /ʃ/ and preaspirated /hʃ/. Preaspirated /hp/ and /hs/ are missing in this inventory, but Sammallahti attributes this absence to limitations in his data collection, rather than actual gaps in the Forest Nenets phoneme inventory. Salminen (2007) confirms Sammallahti's conjecture: preaspirated variants of /s/ and /p/ do in fact occur.

[3] Ethnologue instead refers to Forest and Tundra Enets, reserving the name Nenets for a closely related but distinct language. I have followed the practice of my principal sources in refering to these two languages with the name Nenets, however.

According to Sammallahti, intervocalic consonants are usually geminated, including preaspirates. Examples include [tʃuhppei] “all,” [tʃehttaʃ] “they were four,” [mahkna] “tent,” [ʃahtʃ] “you,” [mahkna] “tent,” and [tuhʃ].

Phonologically, Salminen (2007) argues that the preaspiration described above is actual a positional variant of an underlying glottal phoneme /ʔ/, which is realized as the glottal fricative [h] before obstruents. As to its origin, according to Hansson (1997; cited in Helgason 2002), Forest Nenets /ʔT/ corresponds with Tundra Nenets /TT/, suggesting a possible geminate origin for the preaspiration in Forest Nenets (though of course it may be that Tundra Nenets has developed geminates from earlier preaspirates).

2.6 Mongolic: Halh Mongolian

The Halh dialect of Mongolian features an unusual stop system, as described by Svantesson, Tsendina, Karlsson, & Franzén (2005): a voiceless unaspirated series /p p^{j} t̪^{j} t̪/ contrasts with a voiceless aspirated series /p^{h} p^{jh} t̪^{jh} t̪^{h}/ (postaspirated in initial position, preaspirated in medial and final position); in addition, there is a defective voiced unaspirated series consisting only of the dorsal stops /g^{j} g ɢ/. Phrase-medially, word-initial aspirated stops may be realized with both post- and preaspiration if preceded by the long vowel [iː]. Svantesson *et al.* (2005) provide the following set of minimal pairs illustrating contrasts among the dental stops:

(7)	талаа	[t^{h}alʒa] ‘steppe’ (refl)	далаа	[talʒa] ‘shoulder blade’ (refl)
	атаа	[a^{h}ta] ‘camel gelding’ (refl)	адаа	[ata] ‘demon’ (refl)
	ат	[a^{h}t] ‘camel gelding’	ад	[at] ‘demon’

The origin of preaspiration in Halh Mongolian has not been established. Svantesson *et al.* tentatively reconstruct preaspiration in Old Mongolian, Halh Mongolian's parent language, on the basis of observed patterns of deaspiration, whose effects resemble those of Grassman's Law in Indo-European: "In all dialects of Mongolian proper, except Northern Halh and Eastern Mongolian, an initial aspirated stop or affricate ($*t^h$, $*\check{c}^h$ [i.e. tʃ^h], $*k^h$) became unaspirated if the following syllable onset [was] an aspirated stop or affricate, or the voiceless fricative **s*" (p. 206), and if the two consonants in question were separated only by a short vowel. The hypothesis is that a short vowel offered too little space for both postaspiration and preaspiration to be effectively realized; therefore, the initial aspiration cue was eliminated under these circumstances in all dialects but two.

2.7 Uto-Aztecan

Several members of the Uto-Aztecan family feature or have featured preaspiration, including Hopi, Tohono O'odham, and many members of the Numic branch, including Shoshone, Southern Paiute, and Comanche. [I have only summarized the situation in Hopi and O'odham at this point, while I sort out the complex pattern reconstructed for the Numic branch.]

2.7.1 Toreva Hopi

Whorf (1946) identifies two stop series in the Toreva dialect of Hopi: unaspirated /p t tʃ c c^w k/ < > /hp ht htʃ hc hc^w hk/. (Manaster-Ramer postulates an additional preaspirated sibilant, /hs/; see further discussion below.) While in most languages, preaspirated stops are word-medial and/or final allophones of an underlying aspiration contrast which is realized as postaspirated in initial position, no postaspirated allophones of the second series are reported in Hopi. Whorf found that plain stops occurred in all positions, while the preaspirated stops "occur only syllable-initial after a firm-stressed vowel" (p. 160). However, an apparently unique and certainly very interesting development has taken place in this dialect of Hopi since Whorf's description. According to Manaster-Ramer (1986) and Jeanne (1982, cited in Manaster-Ramer 1986), the Hopi of Third Mesa has replaced preaspiration with a tonal distinction since Whorf's investigations. Where fifty years previously, Whorf reported short stressed vowels followed by preaspirated voiceless stops, Manaster-Ramer (1986), Malotki (1983, 1979), and Jeanne (1982) find long stressed vowels with a falling tone and no preaspiration. Examples are provided in (8), using notation original to the source; Malotki and Jeanne's acute accent denotes stress, not a rising tone:

(8)	<u>Earlier</u>	<u>Later</u>	
	wɨ^{h}ti	wɨ᷍ɨti	'woman'
	le^{h}pe	léèpe	'to fall'
	kɨ^{h}kɨ	kɨ᷍ɨkɨ	'foot'

Moreover, where Whorf reported devoiced sonorants before voiceless stops, the later researchers again found falling tones. Examples include the following (where Whorf used capital letters to indicate devoiced sonorants):

(9)	<u>Earlier</u>	<u>Later</u>	
	WaLpi	wa᷍lpi	(village name)
	sik^{y}aN̦pɨ	sik^{y}yáŋ̀pɨ	'yellow'
	soMta	sóm̀ta	'to tie'

Finally, Manaster-Ramer (1986) points out that where later researchers have found a falling tone on long vowels that precede /s/, Whorf found only a short vowel followed by /s/:

(10)

	Earlier	Later	
(10)	Earlier	Later	
	soso-	sóòso-	'all'
	posi	póòsi	'to fall'
	wɨsɨ	wɨ̂ɨsi	'broom'

Manaster-Ramer postulates an earlier /hs/, which would straightforwardly explain the falling tone in this environment. Moreover, Hopi would not be unique in this respect: Forest Nenets also features /hs/ in addition to a series of preaspirated stops (see also §4.2.3).

Preaspiration in Hopi has been linked to earlier nasal consonants-voiceless stop clusters (both tautomorphemic and heteromorphemic). Hopi is thus unusual in featuring preaspiration which does not seem to have derived from earlier geminate voiceless stops. Manaster-Ramer (1986, p. 159) provides the illustrative examples in (11), drawing in part on Whorf (1935).

(11) a. *po^{h}ko 'dog' < Proto-Uto-Aztecan *punku 'dog, pet' (cf. Tubatulabal *puŋgu-l* 'dog, pet')

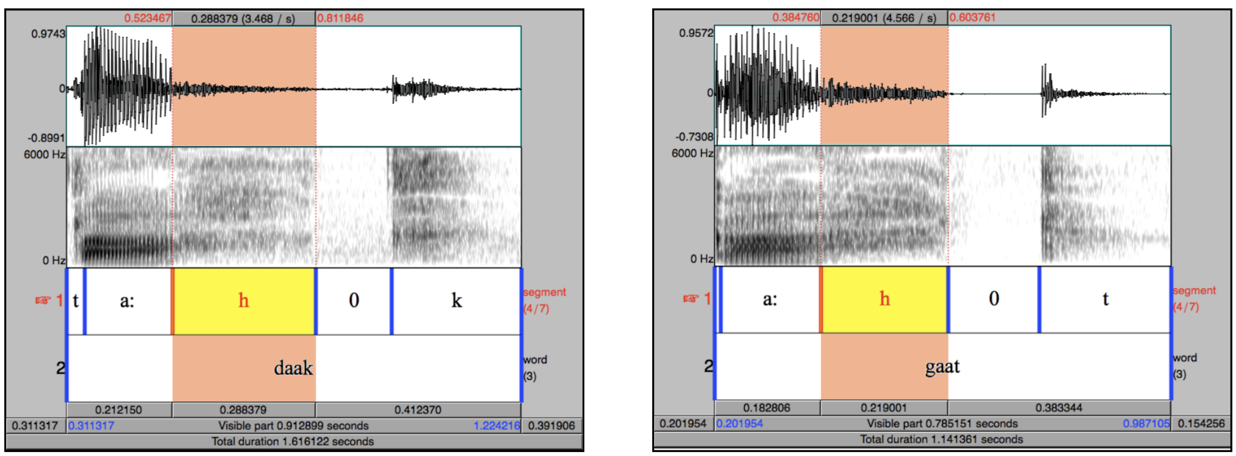
b. *na^{h}ka 'earring' < PUA *nanka 'ear' (cf. Tubatulabal *naŋha-n* '(his) ear')

c. *nɨ^{h}tɨ 'other' < PUA *nɨm 'human being' (cf. Tubatulabal *nɨm-ʔ-mɨʔɨga-* 'to kill a human being') + an element of uncertain etymology

d. *sɨ^{h}k^{y}a 'one' < PUA *sɨm 'one' (cf. Tubatulabal *šɨɨ-wa-n* 'other', Aztec *cem* 'one') + an element of uncertain etymology

2.7.2 Tohono O'odham

According to Voegelin *et al*. (1962), and Alvarez & Hale (1970), Tohono O'odham features two contrasting series of stops: a voiceless unaspirated series and a voiceless aspirated. The aspirated series is postaspirated in initial position and preaspirated in medial and final position. According to Fitzgerald (1996, cited in Helgason 2002), aspiration may also be realized as preaspiration word-initially after a preceding vowel. Two examples (final [hk] and final [ht]) are provided in Figure 2.3.[4] Preaspiration appears to favor stressed environments, and appears both after long and short vowels.



a. **b.**

Figure 2.3. Spectrograms of O'odham (a) *daak* [ta:hk] 'nose' and (b) *gaat* [ka:ht] 'a bow'

2.8 Algonquian

A number of Algonquian languages feature preaspiration. The phenomenon is widespread among members of the Central Algonquian branch, including Cree, Menominee, Fox, and Ojibwa.

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[4] Thanks are due to Mizuki Miyashita of The University of Montana for making these sound files available on her website, where I accessed them on February 6, 2010: http://www.umt.edu/ling/faculty/Miyashita/OodhamNeoki/OodhamNeokiHome.htm

2.8.1 Central Algonquian

Bloomfield (1925) posits the correspondences in Table 2.2 for the four Central Algonquian languages Fox, Cree, Menominee, and Ojibwa (table after Page 1997).

PCA	*Fox*	*Cree*	*Menominee*	*Ojibwa*
*mp	p	hp	hp	mb
*nt	t	ht	ht	nd
*nk (ŋk?)	k	hk	hk	ng
*hp	hp	hp	hp	hp
*ht	ht	ht	ht	ht
*hk	hk	hk	hk	hk

Table 2.2. Preaspiration in Proto-Central Algonquian and daughter languages

The reconstruction is based in part on the following cognate forms (Bloomfield's own transcription is preserved, which transparently represents nasals and aspiration):

(12) PCA. *mp*: **__ump__-* "up": F. ***up**āckäwi* "it flies up," C. ***uhp**inam* "he lifts it up," M. ***uhp**äʔnen*, 0. ***umb**inang* "he lifts it up."

(13) PCA. *nt*: PCA. **wāpa**nt**amwa* "he looks at it," F. *wāpa**t**amwa*, C. *wāpa**ht**am*, M. *wāpa**ht**am,* 0. *wāba**nd**ang.*

(14) PCA. nk: PCA. *ta**nk**eckawäwa "he kicks him," F. ta**g**eckawäwa, C ta**hk**iska-wäw, M. ta**hk**äskawew, 0. ta**ng**ickawād.

Two things are especially notable about these correspondences. First, Bloomfield reconstructs a set of preaspirated stops in the parent language Proto-Central Algonquian, which have been inherited by all four daughter languages. The ultimate origin of this preaspiration remains uncertain. However, Bloomfield also reconstructs a set of nasal-voiceless stop sequences in Proto-Central Algonquian. Three different developments of these clusters are reflected in the daughter languages. First, in Fox, the nasal member has been altogether deleted, apparently leaving no trace. In Ojibwa, the stop has assimilated the voicing feature of the nasal. Finally, in Cree and Menominee, nasal-voiceless stop clusters have merged with the existing set of preaspirated stops. This suggests the possibility that, at least in the last two languages, voiceless stops were preaspirated even when preceded by nasals, producing a devoicing of the nasal. Once devoiced, the nasal may have been auditorily indistinguishable from existing preaspiration (Ohala & Ohala 1993, Herbert 1986), leading to the effective neutralization of nasals in this pre-stop environment. This is much the same as Helgason (2002) posits for the Nordic languages (see above).

2.8.2 Homorganic preaspiration in Fox

Though Bloomfield (1925) indicates only that preaspiration in Fox has the glottal realization [h], a substantially different description is provided in Jones (1904, revised by Michelson 1910). According to Jones, there is "a whispered continuant before the articulation of *k, t,* and *p*" (p. 743). On the same page, Michelson adds this note: "The closure is so gradual that the corresponding spirant is heard faintly before the stop, so that the combination is the reverse of the fricative. Thus *ä'pyātc*^{i} WHEN HE CAME is to be pronounced nearly as *äfpyātc*^{i} with bilabial *f*." Michelson's note seems to indicate that /p t k/ are realized with preceding frication homorganic to the stop—not by glottal frication. As Silverman (2003) points out, Michelson's "reverse of the *fricative*" should be probably be interpreted as “reverse of the *affricative*,” since both Jones and Michelson refer to continuant obstruents exclusively as “spirants,” but use the term “affricative” to refer to [+delayed release] segments. This interpretation is consistent with Michelson’s own description of the phenomenon. While oral realizations of preaspiration are not unusual, they typically are restricted to dorsal gestures yielding velar [x] or palatal [ç], as in Scottish Gaelic, Sami, or Goajiro. If accurate, Fox is thus a unique example of a language in which preaspiration has taken on homorganic buccal forms across the board, including coronal and labial forms.

The following examples from Jones (1910) are illustrative. Transcriptions in italics are Jones’, followed by my own tentative adaptations in IPA: *ä´’pyātc*^{i} ([ˈæfpjatʃĭ]) “when he came,” *me´’tä*^{i} [ˈmɛstæĭ] “bow,” *i´’kwä`w*^{a} [ˈɪxkwæˌwă] “woman.”

2.9 Tarascan

Tarascan is an isolate spoken in Michoacán, Mexico. According to Foster (1969), an aspirated stop/affricate series /pʰ t̪ʰ tsʰ tʃʰ kʰ/ contrasts with an unaspirated series /p t̪ ts tʃ k/. As transcribed by Foster, both series are apparently unvoiced. Foster further notes, “after [stressed] medial vowels, aspirated segments occur as pre-aspirated allophones” (p. 15), but as postaspirated word-initially. Preaspiration may be realized as a sibilant fricative in coronals, thus [st sts stʃ]. After the vowel [ɨ], preaspiration sporadically alternates with a half-long (i.e. “slightly lengthened,” p. 17) form of the vowel. Foster provides the following examples (which I have approximated in IPA): [atahpɛni̥] “to kill,” [imápʰarákuhti̥] “he rolls it up,” [ˈtʃ̥ɨhkuni̥] ~ [ˈtʃ̥ɨˑkuni̥] “to drop from one’s hand.”

2.10 Romance: Sienese Italian

Italian is conventionally described as having two sets of stops, in which voiceless /p t̪ k/ contrast with voiced /b d̪ g/ (e.g. Krämer 2009), without an aspiration contrast, much less any preaspiration. However, Stevens (2007) and Stevens and Hajek (2007, 2004) have found experimental evidence that phonemically geminate medial voiceless stops in the Sienese dialect of Italian are sporadically realized with preaspiration. In addition, numerous initial voiceless stops, which are characteristically geminated phonetically through *raddoppiamento sintattico* ("syntactic doubling," essentially a lengthening of word-initial consonants after a preceding stressed monosyllable), are also affected. Approximately 29% of 380 such tokens they examined were realized not as phonetic geminates, but as singletons preceded by some glottal segment or oral fricative, especially [h]. Of the 111 aberrant tokens they collected, 42% were preaspirated [hC], while others were realized with preglottalization [ʔC], breathy voice [ɦC], creaky voice [V̰C], or oral fricatives like [çC] or [θ̪C].

Preaspiration in Italian is remarkable for two reasons. First, the discovery is the first indication that preaspirated stops *per se* exist in Romance (debuccalized /s/ excluded). Second, and more importantly (in my view) is that Italian provides what may well be an example of preaspiration a-birthing: it may be the very kind of phonetic instability displayed in the Sienese dialect that provides an opportunity for the eventual phonologization of preaspiration. Chapter 3 will consider this idea in greater detail.

2.11 Arawakan

Two Arawakan languages have been described as having preaspiration: Chamicuro and Goajiro. However, Chamicuro is probably not a bona fide example (see below), whereas Goajiro certainly is, and a unique one at that.

2.11.1 Chamicuro

Though Chamicuro is often mentioned as a preaspirating language (e.g. Silverman 2003, Helgason 2002), I reject hC clusters in Chamicuro as bona fide examples of preaspirated stops, since it appears that most if not all consonants in that language can fill the C position, including fricatives /ahsi/ "tooth", /kihʃeti/ "cotton," affricates /kahtʃi/ "fire (noun)," nasals /pahna/ "another," laterals /ihlapi/ "shore," and glides /mepolahjaka/ "never," as well as voiceless stops /ukohka/ "my uncle," /nihpa/ "louse," /ikehta/ "sky" (Payne 1991, Parker 1994; all examples from Parker 1994).

2.11.2 Goajiro

The Goajiro language, spoken in Colombia and Venezuela, possesses the single stop series /p t tʃ k/ (Holmer 1949). These stops are subject to preaspiration, but Holmer does not specify exactly under what conditions. Preaspiration does not appear to be contrastive, and is not employed by a great many speakers, for whom "the preceding vowel is then somewhat lengthened" (p. 49). According to Holmer, the preaspiration sounds "like a rough h (or sometimes like a weak Spanish jota)" (p. 47), i.e. [h] ~ [x] (Hualde 2005). The distribution of preaspiration in Goajiro seems to be at variance with what we've seen in most other preaspirating languages e.g. Icelandic and Gaelic. In the latter two languages, preaspiration is attracted to stress, but in Goajiro, preaspiration is prone to appear adjacent to unstressed nuclei. This is illustrated by the examples [tehki:] “my head” and [ihtʃi:] “salt,” which Holmer says receive final stress. Stress in Goajiro is attracted to heavy syllables, i.e. those with long or nasalized medial vowels, diphthongs, or geminate or complex codas. (In the absence of a heavy syllable, “there is a marked tendency to stress the second vowel” in a word (p. 50).) Like Tohono O’odham, initial plain stops can be preaspirated if they follow a vowel: utterance-initial [pana] ‘leaf’ ~ utterance-medial post-vocalic [nu^{h}pana] ‘its leaf.’

In sum, preaspiration in Goajiro appears to be a sub-phonemic phenomenon employed sporadically by a subset of the speaker population.

2.12 Witotoan: Bora

According to Aschmann (1993), there are two contrasting series of oral stops in Bora, a Witotoan language spoken in Colombia and Peru: voiceless unaspirated /p t ts k k^{w}/ and voiceless aspirated /p^{h} t^{h} ts^{h} k^{h}/. Stops may appear only in syllable onsets, never in codas; in fact, this is true of consonants generally, except for /ʔ/ and /x/. In word-medial position, and in word-initial, phrase-medial position, aspirated stops are preceded by /x/, yielding what Aschmann terms preaspirated stops (which retain their phonetic postaspiration); this distribution is thus similar to Goajiro and O’odham. Aschmann links unaspirated, aspirated, and preaspirated stops to distinct protoforms, tracing voiceless unaspirated stops to earlier voiced stops in the proto-language (Proto Bora-Muinane), voiceless aspirated stops to earlier voiceless stops, and preaspirated stops to earlier geminate voiceless stops (to which they usually correspond in Bora’s sister language, Muinane) (Aschmann §2.2). Examples include the following:

(15)	*PBM*	*Bora*	*Muinane*	
	a. *gai-ppi	k^{w}a-xp^{h}i	gai-ɸi	‘man’
	b. *íttáko-gííxï	íxt^{hy}ák^{h}o-číx^{y}ï	íttáku	‘cassava flour’
	c. *xḯkk(e)ʔ(ai)	ḯxk^{h}aʔe	xɨ́kkoʔai	‘beard’

2.13 Conclusions

The foregoing discussion allows us to draw a number of generalizations regarding the distribution and more tentatively the antecedent structures of preaspirated stops.

2.13.1 Distribution

When present, preaspirated stops are typically restricted to medial and final position, or even medial only; where initial preaspiration is found, it is typically utterance-medial (Sienese Italian, Tohono O’odham, Goajiro, Bora). This distribution is quite similar to that of geminates crosslinguistically, which are typically restricted to medial and in some cases final position, rarely occurring in initial position (a similar observation is offered in Blevins 2004). This congruence is favorable to a hypothesis linking preaspiration to earlier geminates. Three of the counterexamples can be attributed to prosodic conditioning: in Italian, initial preaspirates are the product of a sandhi process lengthening initial stops after a preceding stress; in Tohono O’odham and Goajiro, initial preaspirates occur only after a preceding vowel. In the final example, Bora, initial preaspirates do in fact appear to be etymologically linked to initial geminates. I have not included the commonly cited example, Huatla Mazatec, because so-called preaspirates in that language are better treated as hC clusters, insofar as h can appear initially before any obstruent, nasal, or glide (Pike and Pike 1947).

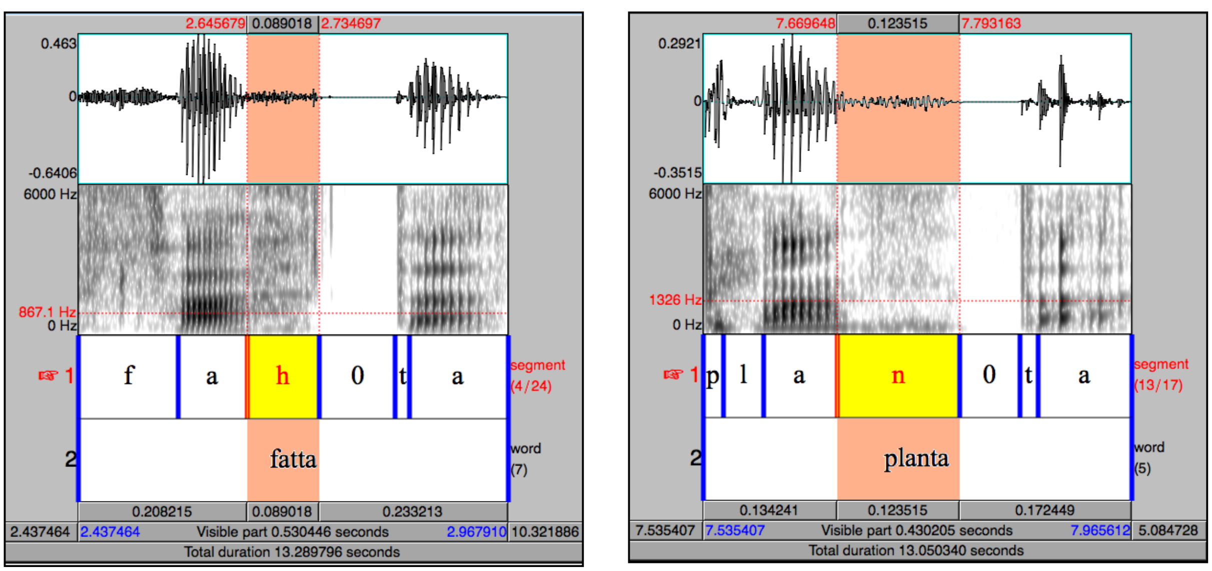
Preaspiration, when phonologized in a given language, typically (though not always) functions as a positional variant of an underlying aspiration contrast. When postaspiration occurs in a preaspirating language, it is generally in initial position; postaspirated stops are thus usually in (near) complimentary distribution with preaspirated stops. Both types of stops are thus frequently viewed as positionally conditioned allophones of underlyingly aspirated stops (Silverman 2003, Steriade 1997, Pind 1999, Suh 2001). It may even be said that an aspiration contrast is a (near) prerequisite (or at least a correlate) for the phonologization of preaspiration. There appear to be no instances where a voicing contrast co-occurs with phonologized preaspiration (English and Italian, usually described as having a voicing contrast in stops, have not yet phonologized preaspiration). There are, however, a small number of instances where preaspiration has been phonologized without the presence of postaspiration (Nenets, Hopi).

Nor, as a corollary, does postaspiration contrast with preaspiration in any language. In Icelandic, both preaspirated and postaspirated stops may appear medially. However, they are not strictly contrastive in this environment (contra Silverman 2003), because the postaspirated stop does not block the obligatory vowel lengthening that occurs before singleton consonants in Icelandic, while the preaspirated stop will; they are thus in complementary distribution in medial position. In Southern Sami, again both preaspirated and postaspirated stops may appear in medial position, but the postaspirated forms occur in CC clusters, while the preaspirates appear alone; the two types are thus once again in complementary distribution. The two oddities appear to be Tyneside English and Sienese Italian: in the first preaspiration is restricted to prepausal position; while in Italian, the phonological opposition in stops is conventionally described as one of voicing, rather than aspiration. However, as we have seen, in neither English nor Italian has preaspiration been phonologized; it may be that phonologization of preaspirates is correlated with a reorganization of the language's stop system (as hypothesized for Scottish Gaelic (Borgstrøm 1974) and Bora (Aschmann 1993)). Whether that correlation is causative or resultative cannot be said at this point.

2.13.2 Antecedents

For only a minority of the preaspirating systems discussed here are the origins of the preaspiration known or suspected. There is, however, a remarkable degree of consistency among these examples. Among the Nordic languages, preaspiration is traced with some confidence to earlier geminate stops in Proto-Scandivian: Page (1997) and Helgason (2002) make this assumption, as do Borgstrøm (1974) and Thrainson (1978). Among those who propose that preaspiration in Gaelic is of internal origin (rather than a Norse borrowing), both Ó Baoill (1980) and Ní Chasaide & Ó Dochartaigh (1984) link preaspirated stops to earlier Old Irish geminate stops. Again, in Sami, preaspirated stops are linked to earlier long and/or overlong stops (Helgason 2002). Preaspirated stops in Forest Nenets apparently correspond with geminate stops in that language's close relative Tundra Nenets (Hansson 1997), though it cannot be said at this point whether the geminates in Tundra Nenets represent an archaism from which the preaspirated stops in Forest Nenets have developed. Similarly, preaspirates in Bora correspond to geminates in its sister language Muinane; Aschmann considers geminates to be conservative (1993). Finally, it is underlyingly geminate voiceless stops which exhibit preaspirated variants in Sienese Italian (Stevens 2007). Geminate voiceless stops, then, are a strong candidate for an antecedent structure to preaspiration.

They are not, however, our only candidate. Also noteworthy are nasal-voiceless stop sequences: a devoiced nasal, perhaps, is prone to reanalysis as aspiration. Bloomfield (1925, 1946) traces preaspirated stops in Cree and Menominee to NT clusters in Proto-Central Algonquian. Page (1997) and Chapman (1962) have considered a similar line of development for at least some of the examples of preaspirated stops in the Nordic languages. Page cites Herbert (1986:243-46), who found that devoiced nasals are often "perceived as breath." My own experience with devoiced nasals in Icelandic agrees with Herbert's: such nasals are indeed very aspiration-like perceptually; on a spectrogram, a devoiced nasal is practically indistinguishable from preaspiration (Figure 2.4) (the lower intensity of the devoiced nasal is the main visible difference). We should thus consider there are two strong suspects for antecedent structures for preaspirated stops: the first is geminate voiceless stops; the second is nasal-voiceless stop clusters.



a. b.

Figure 2.4. Spectrograms of Icelandic (a) *fatta* 'figure out' and (b) *planta* 'plant.'

Table 2.3. Summary of preaspirating systems and key features.

Language	Family	Dialect	Contrast type	Inventory	Phonologized?	Sonorant Devoicing	Distribution	Likes stress?	Variants	Origins?
Scottish Gaelic	IE-Celtic	Various	± spread	p t t^j k^j k p^h t^h t^{jh} k^{jh} k^h	Yes	Yes	M F	Yes	h ç ɦ x	TT *or* borrowed
Irish	IE-Celtic	Gaoth Dobhair	± voice	p p^j t t^j k k^j b b^j d d^j g g^j	No	?	M F	Yes	h	TT *or* borrowed
Icelandic	IE-Germanic	All	± spread ± long	p t c k < > p^h t^h c^h k^h	Yes	Yes	M F	Yes	h ɦ	TT, *mp, nt, ŋk
Faroese	IE-Germanic	All	± spread ± long	p t tʃ k < > p^h t^h tʃ^h k^h	Yes	Yes	M F	Yes	h	TT, *mp, nt, ŋk
Norwegian	IE-Germanic	Jæren Gudbrandsdalen Trøndelag	± voice ± long	b d ɖ g < > p t ʈ k *or* p t ʈ k < > p^h t^h ʈ^h k^h	No	?	M F	Yes	h	TT, *mp, nt, ŋk
Swedish	IE-Germanic	Härjedalen, N. Dalarna, Kökar, Arjeplog, Gräsö, Central Swedish	varies, but seems ± spread	b d ɖ g < > p t ʈ k *or* p t ʈ k < > p^h t^h ʈ^h k^h	No	?	M F	Yes	h, β, ç	TT, *mp, nt, ŋk
English	IE-Germanic	Tyneside	± voice	/t/ only?	No	?	Prepausal, PA affects /t k/ only?	?	h	?
English	IE-Germanic	Lewis	± voice	all –voi	No	?	M F	?	h	L1 transfer
Italian	IE-Romance	Sienese	± voice ± long	p t k < > b d g	No	?	I M		h ɦ ʔ V̰	TT (variant only)
Sami	Finno-Ugric	Eight of nine, excluding Inari	± long *or* ± spread	p t k < > p^h t^h k^h	Yes	Yes	M F	Yes	h, f, x, ç	TT

Table 2.3 (continued)

Language	Family	Dialect	Contrast type	Inventory	Phonologized?	Sonorant Devoicing	Distribution	Likes stress?	Variants	Origins?
Forest Nenets	Finno-Ugric	all	± preasp	p p^{j} t t^{j} k s ʃ < > hp hp^{j} ht ht^{j} hk hs hʃ	Yes	?	M F	?	h	TT?
Mongolian	Mongolic	Halh	± spread	p p^{j} t̪^{j} t̪ < > p^{h} p^{jh} t̪^{jh} t̪^{h}	Yes	?	M F	?	h	?
Hopi	Uto-Aztecan	Toreva	± preasp	p t tʃ c c^{w} k < > hp ht htʃ hc hc^{w} hk	Yes	?	M	Yes	h	NT
Tohono O'odham	Uto-Aztecan		± spread	p t tʃ k < > p^{h} t^{h} tʃ^{h} k^{h}	Yes	?	I post-V M F	Yes	h	?
Cree	Algonquian	Swampy		p t tʃ k	Yes	?	M	?	h	hT NT
Ojibwa	Algonquian	Eastern		p t tʃ k < > p^{h} t^{h} tʃ^{h} k^{h}	Yes	?	M	?	h	hT NT
Fox	Algonquian			p t tʃ k < > hp ht tʃ^{h} hk	Yes	?	M	?	h; f s x	hT NT
Menominee	Algonquian			p t k < > hp ht hk	Yes	?	M	?	h	hT NT
Tarascan	Tarascan (isolate)		± spread	/p t̪ ts tʃ k/ < > /p^{h} t̪^{h} ts^{h} tʃ^{h} k^{h}/	yes	?	M	Yes	h [V:] st	?
Goajiro	Arawakan		N/A	/p t tʃ k/	no	?	M	N; precedes stressed syllables	h x [V:]	?
Bora	Witotoan		± spread	/p t ts k k^{w}/ < > /p^{h} t^{h} ts^{h} k^{h}/	yes	?	I post-V M	?	x	TT

Chapter Three

Innovation, perception, and the frequency of preaspirated stops

3.1 Rates of innovation and transmission determine frequency

The frequency of a given phonological structure is a function of its rate of innovation and its rate of transmission between generations of speakers (Greenberg 1978, 1969, 1966; Bell 1971, 1970; Harris 2007; Moreton 2008). If preaspirated stops are rare crosslinguistically, then they must in some proportion be (a) hard to innovate, or (b) difficult to transmit between generations. This chapter addresses both hypotheses with respect to preaspirated stops. The first two sections of this chapter are concerned with the low-innovation rate hypothesis. The first section considers the key factors which govern innovation rates and transmission rates, and explores the possible antecedents to preaspirated stops, which include voiceless geminate stops and nasal-voiceless stop clusters. In the second section, I consider how the interaction of innovation and transmission rates may yield synchronic patterns of distribution of phonological features, within the framework of Greenberg's (1978) State-Process model. The State-Process model predicts that phonological patterns with a low transmission rate but high innovation rate should be widespread and fairly randomly distributed genetically and geographically, whereas patterns with a low innovation rate but high transmission rate should be clustered both areally and genetically. I show that the typological distribution of preaspirated stops is much more consistent with the latter scenario, suggesting that they are rarely innovated but easily transmitted.

In the third and fourth sections of the chapter, I turn to the second hypothesis, which proposes that preaspirated stops are rare because they are diachronically unstable. Section 3 summarizes the prevailing explanations for the rarity of preaspirated stops, which crucially depend on the assumption that preaspirated stops suffer from a lack of perceptual robustness compared with postaspirated stops, and by extension are diachronically fragile. Section 4s describes a perception experiment which tests this assumption, and shows that it is untenable: the experiment demonstrates that in fact, preaspirated stops are not significantly harder to hear than their postaspirated counterparts.

In sum, this chapter provides both typological and experimental evidence which favors hypothesis (a), that preaspirated stops are rare because they are hard to innovate, and which disfavors hypothesis (b), that their scarcity is a product of perceptual fragility (contra e.g. Silverman 2003 and Bladon 1986).

3.1.1 Factors impacting innovation rates

There are at least four factors which affect the probability that some phonological pattern will be innovated in a given language: first, the presence of phonetic precursors; second, the abundance of antecedent structures; third, competition among multiple rephonologization candidates; and fourth, cognitive predispositions favoring some structures and disfavoring others.

Many sound changes have been linked to phonetic precursors: synchronic variation in speakers' articulations, which may induce listeners to misapprehend the intended phonological structure of the speech signal. If structure A is easily misheard as structure B, then learners of the language may assume that structure B is in fact part of the language's phonological grammar, instead of structure A (Blevins 2004, Ohala 1993). For instance, voicing contrasts may give rise to contrastive tone, as in Kammu, a Mon-Khmer language spoken in southeast Asia. Both the northern and the southern dialects of Kammu contrast voiced and voiceless stops; however, in the northern dialect, a high tone has been innovated after voiceless stops, a low tone after voiced ones (Table 3.1) (Svantesson & House 2006; Svantesson 1983). Such tonogenesis has been connected to the fact that, crosslinguistically, vowels preceding voiced stops have a lower fundamental frequency than those adjacent to voiceless stops (Ohala 1993; Löfquist et al. 1989; Hombert, Ohala, & Ewan 1979). The conditioning environment, final consonants, may then undergo deletion and leave the tone alternation as the sole marker of contrast, as in the language Jingpho (Hock 1991).

	S Kammu	*N Kammu*	
voiceless/high tone	klaaŋ	kláaŋ	"eagle"
voiced/low tone	glaaŋ	glàaŋ	"stone"

Table 3.1. Voicing contrasts and tonogenesis in Kammu dialects

However, phonetic priors corresponding to rare or unattested phonological patterns may be weak or missing. For instance, a nasal-voiceless obstruent sequence [NC̥] is illegal in many languages (Pater 1996). Languages employ a variety of strategies to avoid such sequences: the obstruent may become voiced, the nasal may lose its nasal feature, or either the nasal or the obstruent may be deleted. Metathesis, vowel epenthesis, or lenition of the obstruent are theoretically possible solutions as well, but according to Myers (2002) these strategies are unattested—precisely because there are no corresponding phonetic priors. For instance, if the nasal were released early, it might cause listeners to guess that the speaker intended that a vowel intercede between the nasal and the voiceless obstruent. But there is no evidence that such early nasal releases are systematically characteristic of [N̥C] clusters; thus, such clusters lack a precursor which could be phonologized as an epenthetic vowel.

The second factor affecting the innovation rate of phonological features is the abundance of antecedent structures: those phonological patterns or structures which are favorable to the development of a given phonological feature. Such structures may themselves be uncommon, affording relatively few opportunities for the innovation of the pattern. For instance, in order to innovate a series of preaspirated stops, the discussion in chapter 2 suggests that a number of conditions must be met: the language in question should possess a voiceless stop series, and a length contrast in those stops. (Voiceless geminate stops are known or suspected antecedents for preaspirated stops in the Nordic languages, Sienese Italian, Scottish Gaelic, and Bora, among others.) It would also be helpful if the language possessed a second series of stops, either voiced or aspirated and voiceless. If these are the prerequisites for the development of (most) cases of preaspirated stops, it follows that the innovation rate of such stops depends in the first instance on the frequency with which such prerequisites can be met. Harris (2007) makes a similar point: if the innovation of structure Y requires a greater number of steps than structure X, Y will most likely be rarer than X—particularly if the presence of X is a necessary precondition for the innovation of Y. To use Harris's example: circumfixes typically develop from prefixes and suffixes together; thus, a language must have both prefixes and suffixes before it is possible to innovate circumfixes. This prerequisite significantly reduces the odds that circumfixes will be innovated.

Third, it may be that phonetic priors or antecedent structures do exist, but innovation of the pattern of interest is impeded by competition: the antecedent structure may exhibit multiple phonetic realizations, any one of them a potential target of rephonologization. The phonemically geminate voiceless stops /pp tt kk/ in Sienese Italian are a good example of this scenario. Stevens and Hajek (2007) report that in a corpus of 380 tokens of expected geminates (both word-medial and word-initial products of *raddoppiamento sintattico*, or lengthening of word-initial consonants), 29.2% were not realized as phonetically long [p: t: k:], but rather as singletons preceded by some sort of glottal segment or oral fricative, including preaspirated tokens (Table 3.2). For instance, *tre case* "three houses" might be realized in a variety of ways, including [trekkase] and [trehkase], while *macchina* "car" might be realized as [makkina] or [mahkina]. Their results are illustrated in Figure 3.1.

Alternative realization		*N*	%
voiceless glottal fricative	[hC]	47	42.3
glottal stop/creak	[ʔC] ~ [V̰C]	30	27.0
voiced glottal fricative	[ɦC]	24	21.6
supralaryngeal fricative	[çC] ~ [θ̞C]	10	9.0
All alternate realizations		*111*	*100*

Table 3.2. Surface forms of phonemically geminate stops in Sienese Italian

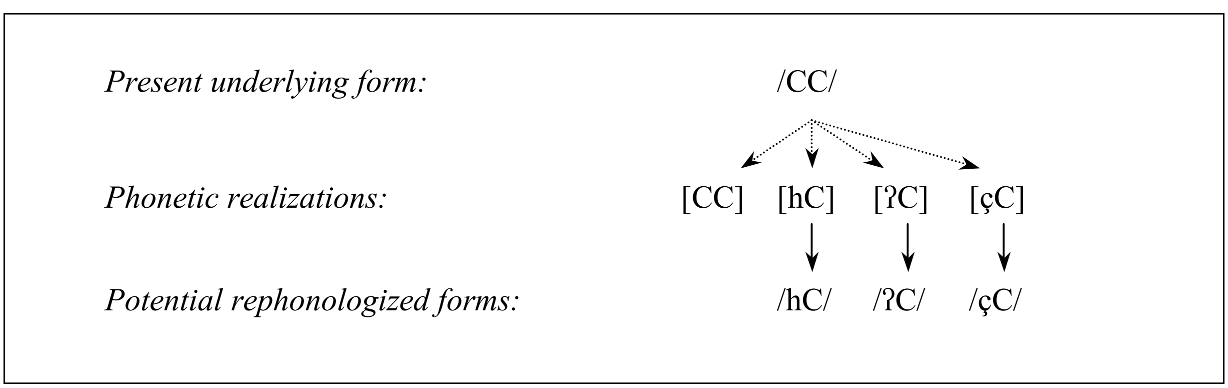


Figure 3.1. Potential competition among surface forms

It is not clear precisely what circumstances or conditions might in fact precipitate an actual rephonologization event, or favor one variant over its numerous competitors. If relative token abundance is the crucial factor (Blevins 2006a, 2004), then preaspiration would seem to be favored over the other alternate realizations of phonemic geminates in Italian. It may be that as long as phonetic geminates predominate in Sienese, no rephonologization will occur at all.

A second possibility is that phonologization may be triggered through a "priming" event brought about through contact with another language featuring the feature in question. Bilingual speakers may be more likely to reanalyze a phonetic feature in one language as contrastive if a similar feature is a cue to a phonologized contrast in a second language. This is evidently the case regarding tonogenesis, for instance: the clear concentration of tone languages in a few parts of the world strongly suggests that tone has been triggered by contact between neighboring languages, one tonal, one non-tonal. Tonogenesis in Kammu, for instance, may have been facilitated by the widespread competence in the tonal language Lao among Kammu speakers (Svantesson & House 2006). Similarly, the abundance of preaspiration among distantly or unrelated languages in Northern Europe, including members of the Celtic, Germanic, and Uralic families, may certainly be due to widespread bilingualism (Clement 1994; Borgstrøm 1974, 1940; .

Finally, it may be that there are cognitive predilections that militate against the innovation of some patterns while favoring others. Moreton (2008) reports that subjects learn vowel height-height correspondences in artificial languages much more readily than vowel height-consonant voicing correspondences. The first pattern is much more frequent typologically, yet the phonetic precursors to both correspondences are equally robust.

Moreton's study demonstrates that cognitive predispositions can yield such typological asymmetries. Similarly, Wilson (2006) finds that subjects trained in an artificial language featuring velar palatalization before the mid-front vowel [e] generalized that palatalization to environments preceding other front vowels in novel stimuli, whereas subjects trained to palatalize before [i] made no such generalization. Wilson's findings are consistent with the implicational universal that [k] > [tʃ]/_ e implies [k] > [tʃ]/_ i (but not the reverse), suggesting that there exists a cognitive bias in favor of that universal. Together, Moreton's and Wilson's findings are evidence that many typological patterns are correlated with cognitive priors.

3.1.2 Sources of preaspirated stops

A phonological structure or pattern A from which another pattern B tends to develop may be termed an antecedent to B. In chapter 2, I identified two probable antecedents to preaspirated stops: geminate voiceless stops in particular, but also nasal-voiceless stop clusters. Where the origins of preaspirated stop systems could be reconstructed or documented with reasonable confidence, they could be traced to earlier voiceless geminate stops in at least five instances: the Nordic languages (representing most likely a single innovation event), Irish and Scottish Gaelic (again, most likely a single innovation); the Sami languages; Forest Nenets; and Bora. [I am also exploring the possibility that PA stops in the Numic branch of Uto-Aztecan have the same origin.] In two separate instances, preaspiration could be linked to nasal-voiceless stop clusters: the central Algonquian languages Cree, Fox, Menominee, and Ojibwe (again, likely a single innovation), and Hopi. While other antecedents to preaspirated stops are certainly possible, I have been unable to confirm any such. In this section, I will explore the possible phonetic developments in voiceless geminate stops and nasal-voiceless stop clusters that may serve as precursors to the innovation of preaspirated stops.

3.1.2.1 Voiceless geminate stops

The notion that preaspirated stops could develop from earlier geminates is not new, extending at least to Marstrander (1936), who first suggested the possibility that preaspiration in the Nordic languages developed from geminate stops in Proto-Scandinavian. His suggestions were taken up again by in Chapman 1962, Thrainsson 1978, Ní Chasaide & Ó Dochartaigh (1984), and Ní Chasaide (1985). The hypothesis in some form has recently been reconsidered in Page (1997), Helgason (2002), and Hansson (1999) and found persuasive. Independently, Blevins (2004) and Blevins & Garrett (1993) have suggested a similar provenance for preaspirated stops in general, arguing that not only does the historical evidence support this hypothesis in available examples, so do the synchronic facts: restricted as they typically are to medial and (to a lesser degree) final position, preaspirated stops closely mirror similar phonotactic constraints on geminates.

If it is proposed that preaspirated stops evolve from voiceless geminates, and if circumstantially this hypothesis conforms with observed synchronic facts, it remains to isolate some phonetic pattern that might conceivably serve as a prior to this development. In line with other phonetic priors we have seen, such as those for tonogenesis or vowel epenthesis, we might reasonably expect that preaspirates owe their origins to a pattern of articulatory mistiming. If the phonological circumstances are favorable, and if the pattern is regular enough, this mistiming may be construed by listeners as a contrastive rather than a secondary cue.

Consider that an oral gesture and a glottal gesture have to be closely coordinated in a normal voiceless geminate: the oral closure must coincide with the cessation of voicing, while the voicing in turn should resume at or slightly after the opening of the oral stricture. (Intra-oral pressure is likely to suppress any resumption of voicing before opening the oral closure permits the necessary pressure drop.) Oral and glottal gestures for a canonical voiceless geminate stop [TT] are illustrated schematically in Figure 3.2a. However, if the gestures are mistimed such that the modal voicing ceases slightly before the oral closure commences, the result will be a period of phonetic preaspiration [^{h}TT] (Figure 3.2b). This is just the sort of phonetic prior that could potentially be misapprehended by listeners as a contrastive cue and consequently rephonologized.

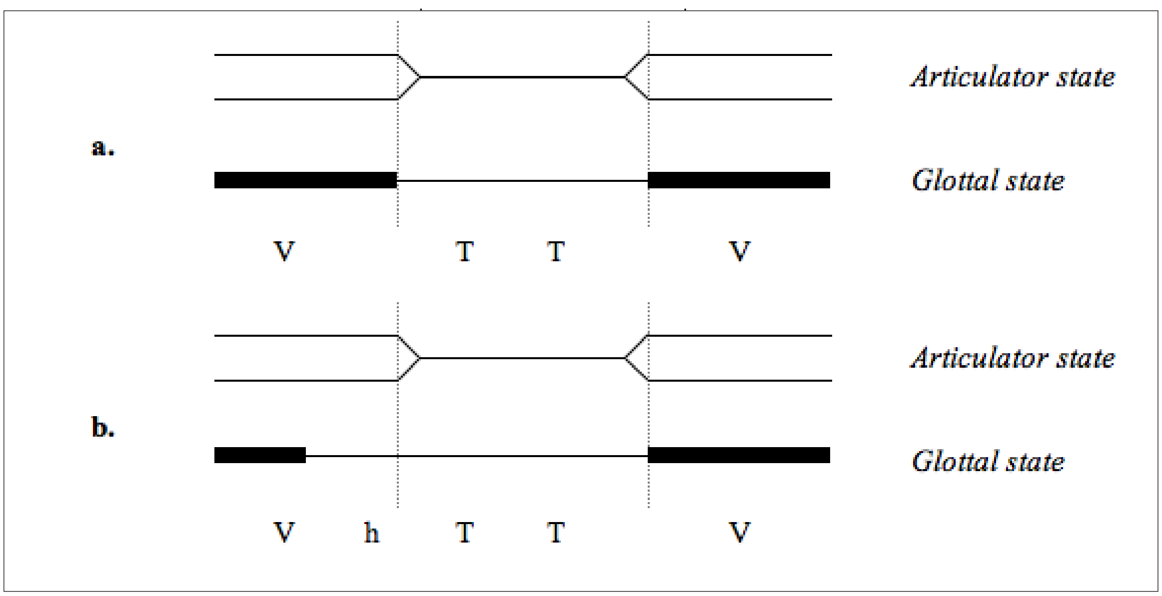


Figure 3.2. An intervocalic voiceless geminate stop [TT]: (a) with coordinated oral and glottal gestures, and (b) with leading cessation of voicing

A reasonable question is why such a mistiming may arise in the first place. While it is not out of the question that it could occur spontaneously, Marstrander (1936), recapitulated in Chapman (1962) and elaborated in Ní Chasaide (1985), proposes that the motivating event in Proto- Scandinavian may have been the loss of nasals in nasal-stop clusters. In Proto-Scandinavian, such clusters became voiceless geminate stops through assimilation of the nasals, and those geminates then became preaspirated in the modern languages: **mp *nt *nk* >*pp tt kk* > *hp ht hk*, e.g. Proto-Germanic **þankojan* > early Norse *takk* > Gudbrandsdalen Norwegian [tahkk] 'thanks,' or Latin *campus* 'hero' > early Norse *kapp* > Icelandic *kapp* [k^{h}ahp]. If the nasal consonant devoiced before assimilating, it may have left a trace of aspiration on the resulting geminate, Chapman suggests, thus: Germanic *nt* > *n̥t* > ^{h}*tt*. This preaspiration may then have been generalized to voiceless geminates from other sources. The preaspiration must then have persisted through subsequent phonetic degemination, since it is still reflected in some daughter languages, though it has not always been phonologized (Helgason 2002).

Ní Chasaide (1985) proposes that the rephonologization of the preaspiration may have been triggered by the loss of contrastive voicing in Norse. Where once a voicing contrast distinguished /TT/ (phonetically [hTT]) from /DD/ (phonetically [DD]), loss of voicing in /DD/ would have meant that the only significant remaining contrastive cue was the (heretofore) subphonemic preaspiration associated with /TT/. To summarize in phonetic terms, the contrast [hTT] < > [DD] developed with loss of voicing to [hTT] < > [TT]; after phonetic degemination of the former, the contrast seen in modern Icelandic emerged: [hT] < > [TT].

This scenario, while complex, seems to be reasonably well supported in the case of the Nordic languages. However, there are suggestions that preaspirated stops may develop from earlier voiceless geminate stops without any associated devoicing of nasal consonants. We saw above that in Sienese Italian, preaspirated voiceless singleton stops seem to have developed more or less spontaneously as an articulatory variant of phonemically voiceless geminate stops. In several other languages, preaspirated stops correspond with voiceless geminates in sister languages, as in Sami, Forest Nenets, and Bora. A possible line of development in such cases is represented in Figure 3.3.

I	**M**	**F**	
t d	t d tt dd	t d tt dd	
t d	t d ht dd	t d ht dd	*preaspirated singletons appear*
t^h t	t^h t ht tt	t ht tt	*contrastive voicing > aspiration*
t^h t	t^h t ht	t ht	*loss of length contrast*
t^h t	t ht	t ht	*merger of post/unaspirated OR post/preaspirated medial singletons*

Figure 3.3. Proposed diachrony for the phonologization of preaspirated stops

I suspect that this or something similar is what has happened in most of the examples of phonologized preaspirated stops that can be connected to earlier geminates, aside from the Nordic languages.

3.1.2.2 Nasal-voiceless stop clusters

A second antecedent structure is nasal consonant-voiceless stop clusters, from which preaspirated stops seem to have developed in at least two instances Central Algonquian and Hopi (I leave aside Norse, in which an intermediate geminate stage seems to have obtained). Bloomfield (1925) has proposed the reconstruction in Table 3.3 for Proto-Central Algonquian (also available as Table 2.2 in the previous chapter):

PCA	*Fox*	*Cree*	*Menominee*	*Ojibwa*
*mp	p	hp	hp	mb
*nt	t	ht	ht	nd
*nk (ŋk?)	k	hk	hk	ng
*hp	hp	hp	hp	hp
*ht	ht	ht	ht	ht
*hk	hk	hk	hk	hk

Table 3.3. Preaspiration in Proto-Central Algonquian and daughter languages

Manaster-Ramer (1986) provides the examples in (2) for Hopi:

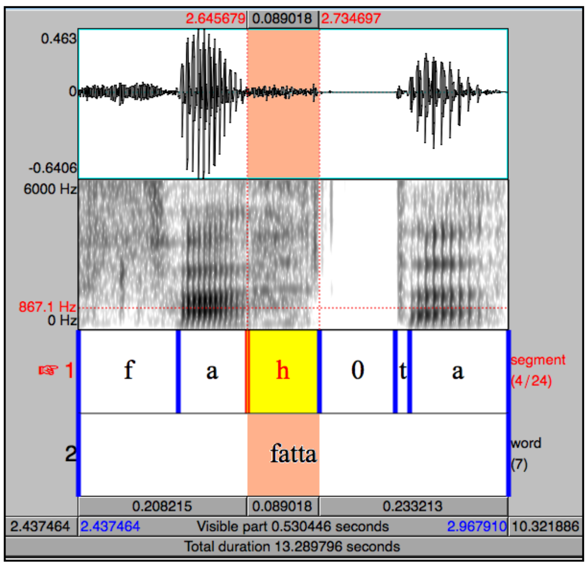
(1) a. **po*^{h}*ko* 'dog' < Proto-Uto-Aztecan **punku* 'dog, pet' (cf. Tubatulabal *puŋgu-l* 'dog, pet')

b. **na*^{h}*ka* 'earring' < PUA **nanka* 'ear' (cf. Tubatulabal *naŋha-n* '(his) ear')

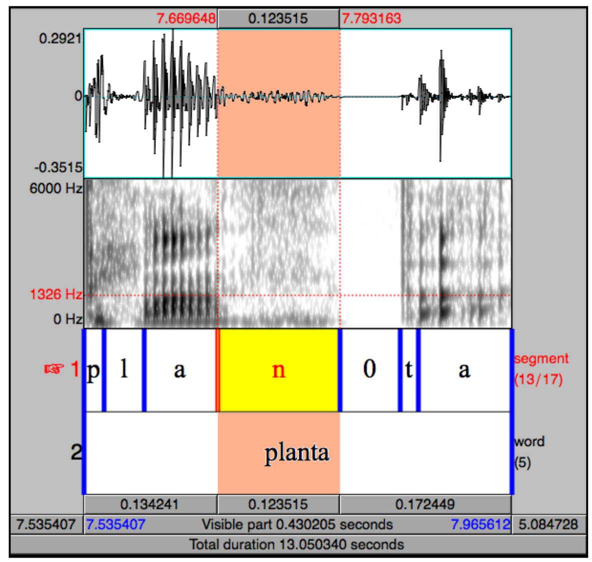
c. **nɨ*^{h}*tɨ* 'other' < PUA **nɨm* 'human being' (cf. Tubatulabal *nɨm-ʔ-mɨʔɨga-* 'to kill a human being') + an element of uncertain etymology

d. **sɨ*^{h}*k*^{y}*a* 'one' < PUA **sɨm* 'one' (cf. Tubatulabal *šɨɨ-wa-n* 'other', Aztec *cem* 'one') + an element of uncertain etymology

In a pre-voiceless stop environment, it is a natural development that the nasal should undergo assimilatory devoicing; indeed, this very process is seen in modern Icelandic, where nasals and liquids are voiceless before voiceless stops. As I pointed out in Chapter 2, such voiceless sonorants are acoustically very similar to preaspiration, the principal difference being that voiceless nasals have a somewhat lower intensity than the others, due to the filtering effect of the oral closure. The spectrograms from that discussion are reproduced here as Figure 3.4.



a.



b.

Figure 3.4. Icelandic (a) *fatta* 'figure out' with preaspiration and (b) *planta* 'plant' with nasal devoicing

Once devoiced, pre-stop sonorants might simply undergo deletion, perhaps with compensatory lengthening of the previous vowel, in which case they would no longer be relevant to our discussion. On the other hand, they could also be reanalyzed as glottal frication, which they greatly resemble. In that event, the result would be a set of preaspirated stops. The latter pattern of reanalysis would be greatly facilitated, one suspects, if the language in question already had a set of hC clusters, which apparently Proto-Central-Algonquian possessed.

The final process through which preaspiration seems to be innovated is through a spontaneous appearance in singleton voiceless stops. This has been seen in Tyneside English and Goajiro. The motivation in these two cases is frankly mysterious, though the relevant adjustments in articulator timing could probably occur little motivation. In neither case has the preaspiration been phonologized. Since Goajiro has only a single set of stops, there is no phonemic opposition to which preaspiration could serve as a contrastive cue. In the case of Tyneside English, preaspiration is sharply constrained in its distribution, appearing only prepausally, which is likely to inhibit its phonologization as a contrastive feature. Moreover, preaspiration is most common among younger females, strongly suggesting that the innovation has occurred very recently.

3.2 The State-Process Model

A simple lack of information prevents us from directly assessing the rates at which most linguistic structures are actually innovated (or perhaps any). With a few possible exceptions, neither can we directly measure how long a given structure typically lasts: the timescales are too great, our state of knowledge too poor. Thus any "absolute measure" of innovation or extinction rates (e.g. number of innovation/extinction events per year/ century/ millennium), while a significant desideratum, nevertheless remains out of reach. This does not mean, however, that we cannot make deductive judgments about such rates. We can, for instance, consider those typological characteristics—overall abundance or patterns of distribution, for instance—which could reasonably correlate with different rates of innovation and extinction, and result from the interaction of these rates. This is what Greenberg sets out to do with the State-Process model (1978, 1969, 1966), which I have graphically represented in Figure 3.5.[1]

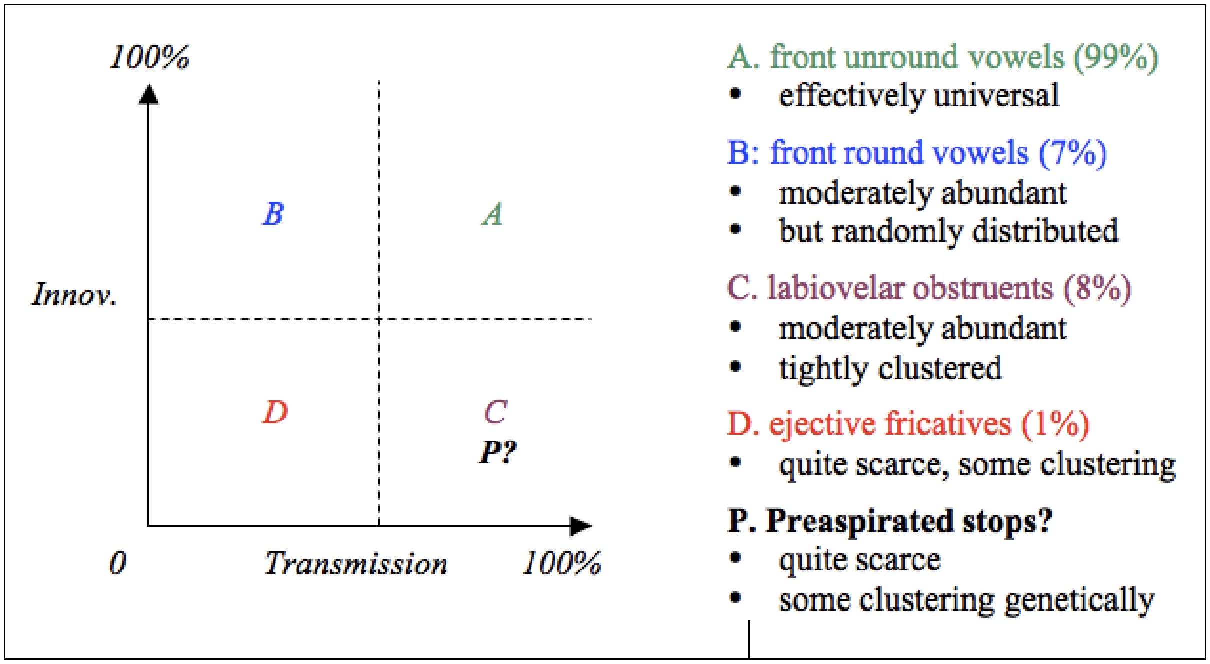


Figure 3.5. A graphic illustration of Greenberg's state-process model

Greenberg argues that a feature with a high probability of innovation but low transmission rate is likely to be randomly distributed among language families and moderately abundant crosslinguistically, e.g. front round vowels (item B on the chart) (Maddieson 2008a). (Both dimensions—innovation rate and transmission rate—are gradient of course, so in principle a given feature could occupy any position on the chart.) However, poor diachronic stability means that the feature will be unlikely to be a shared retention among many daughters of the innovating language, and thus will not cluster genetically, or

[1] It is precisely because the model is predicated on observed outcomes, not absolute measures of innovation and extinction rates, that the lack of such measures is no fatal flaw, as Harris (2007) charges.

else do so minimally. That very instability makes the feature equally unlikely to become an areal feature, and thus it should not cluster geographically either. This can be seen in Figure 3.6.

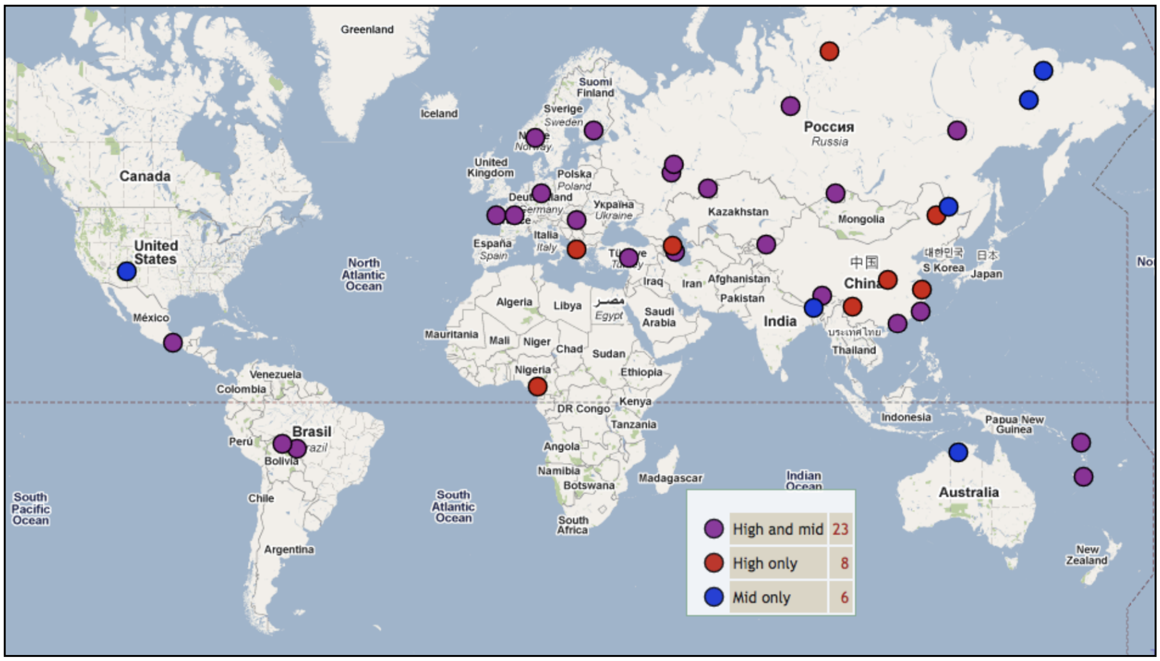


Figure 3.6. Front round vowels worldwide, from a 567 language sample (WALS)

If, on the other hand, the feature can easily be innovated, and just as easily transmitted, it is likely to be near-universal, like front unrounded vowels (A). If it is difficult to innovate and difficult to transmit, it should be very rare indeed—in fact, it may be difficult to find any examples of such a rare and fleeting phonetic animal. Ejective fricatives are a possible candidate (D).[2] Finally, if a feature is difficult to innovate, but quite stable once innovated, it is likely common to varying degrees, but prominently clustered among certain

[2] Among UPSID languages, only 10 languages have ejective fricatives, including Acoma, Dakota, Wichita, and Yuchi (Siouxan), Tlingit (Na-Dene), Berta and Koma (Nilo-Saharan), Kabardian (Caucasian), Mazahua (Oto-Manguean), and Socotri (Semitic). The fact that even in this small sample some clustering is seen suggests that such fricatives have at least a moderate degree of diachronic robustness.

language stocks and within certain geographic areas (stability being conducive to inheritance by daughter languages), like the labial-velar stops [kp gb] (C) (Maddieson 2008e), which cluster prominently in equatorial Africa (Figure 3.7).

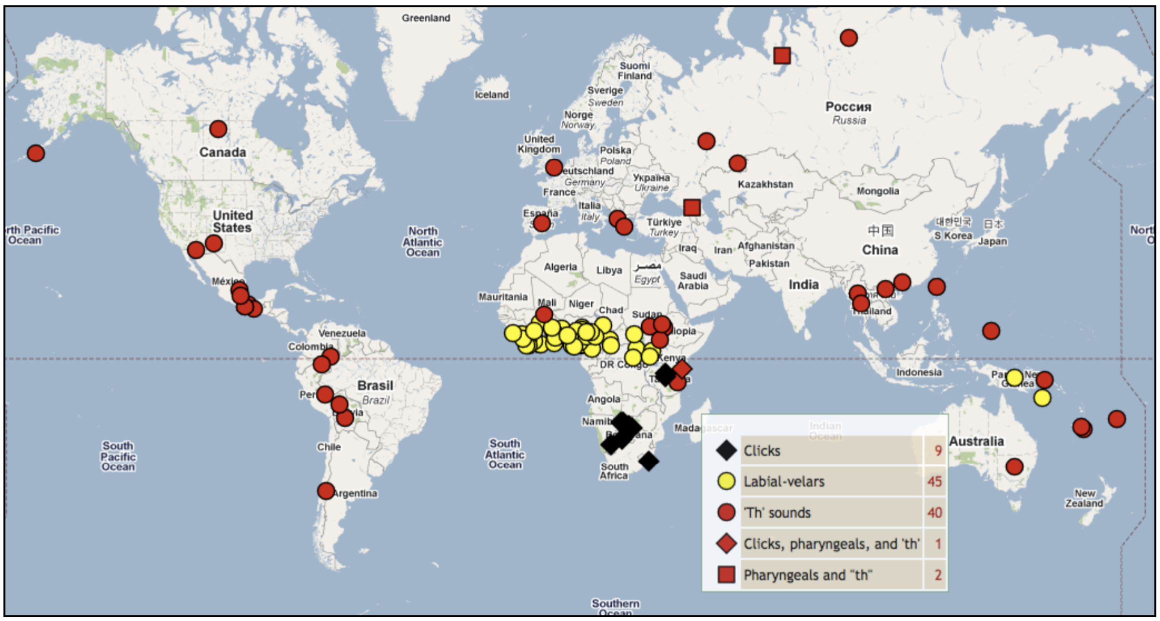


Figure 3.7. Unusual consonants around the world, including labial-velar stops (WALS)

Where do preaspirated stops lie on the graph? If they were frequently innovated, they would be high on the *y* axis, and thus either ubiquitous like front unrounded vowels (A), or reasonably frequent but randomly distributed like front round vowels (B). Preaspirated stops are certainly not ubiquitous, so unlikely to share a quadrant with front unrounded vowels. But neither are they randomly distributed like front rounded vowels; rather, they are highly localized to particular language families and geographical areas (Figure 3.8), much like C, labial-velar stops. But preaspirated stop systems are rather less common than labiovelar stops, suggesting that they may have an even lower innovation rate, but a similar degree of diachronic robustness. This is the state of affairs indicated by the hypothetical P in Figure 3.5.

Figure 3.8. Global distribution of preaspirated stops; colors represent language families

Moreover, there is considerable evidence that preaspiration can be quite durable diachronically. Its widespread occurrence in the Nordic languages is evidence of shared inheritance from the parent language Proto-Scandinavian, as Greenberg's model implies (and Hansson 2001 convincingly argues). In the Scandinavian case, this suggests a time-depth of at least a millennium—hardly consistent with a fragile phonological structure. The presence of preaspirated stops in Scottish Gaelic is similar evidence, whether one believes the phenomenon to be of local provenance or borrowed from Norse. If borrowed, the phenomenon must have been sufficiently robust to survive the transfer process; indeed, further evidence of this is found in the preaspiration contemporary Icelandic and Lewis Gaelic speakers bring to their English. Moreover, a similar time depth is still entailed: the transfer would have happened during the period of substantial contact between the Norse and Gaelic communities, which extended between approximately 800-1300 AD (Borgstrøm 1974). If, on the other hand, preaspirated stops evolved natively in Scottish Gaelic, then they have been present for at least five centuries, since the first written evidence for them appears in the Book of the Dean of Lismore (as an informative ad hoc spelling)[3], which was produced in the early sixteenth century (Clement 1994)—still a substantial length of time.

We therefore have a conundrum. Is the scarcity of preaspirated stops due to low diachronic robustness, brought about by poor perceptibility? The foregoing suggests that this is an inaccurate hypothesis. Experimental evidence is presented in the balance of this chapter confirming that conclusion. Alternatively, it may be such stops instead seldom innovated, either for cognitive reasons, lack of antecedent structures (see chapter 4), or competition among phonetic precursors.

3.3 Linking typology to perceptual robustness

There is no shortage of writers willing to impugn the perceptual robustness of preaspirated stops, notably including Bladon (1986), Kingston (1990), and Silverman (1997, 2003). Such discussions characteristically take for granted that preaspirated stops are some way perceptually ephemeral, an assumption that I will refer to as the *perceptual inferiority hypothesis*. Versions of this argument have been taken up subsequently by, among others, Helgason (2002) and Stevens (2007). The crux of the argument in each case is that the locus of an aspiration cue is key to its audibility: from a perceptual standpoint, aspiration is ideally realized after, not before, the stop closure. Association with the stop burst affords the

[3] Not to be confused with the Book of Lismore, a separate manuscript produced in Ireland in the early 15th century.

aspiration cue a tremendous perceptual advantage, it is argued: hence the abundance of postaspiration, which enjoys this advantage, compared to preaspiration, which does not. A lack of perceptual robustness may make a feature hard to hear, thus hard to learn—and in the long run, hard to transmit between generations of learners. A more detailed exegesis of the arguments provided by the principal exponents of this view is provided below.

3.3.1 Bladon (1986)

The goal of Bladon (1986) is to outline the contributions that instrumental phonetics can make to the formulation of a "hearer-based approach" to auditory phonetics and phonological typology. In doing so, the article provides a detailed, not to say forcefully expressed explanation for the scarcity of preaspiration. The core of the article consists of nine principles of auditory phonetics; that is, key physical and physiological characteristics of the speech stream which, Bladon avers, can permit a much more informed—and informative—analysis of speech perception than was possible before the development and widespread application of instrumental analysis of speech. Bladon examines a range of phonological structures and processes through this lens, including preaspiration, to which three of his principles are particularly germane:

(1) *On/off response asymmetry: spectral changes whose response in the auditory nerve is predominantly an onset of firing are much more perceptually salient than those producing an offset*. In other words, it is easier to hear the onset of a stimulus than its end. Preaspiration falls between a vowel segment and a stop closure, and thus is closely associated with a stimulus offset (the end of the vowel), whereas postaspiration is associated with a stimulus onset, the stop burst at the release of closure.

(2) *Short-term adaptation: after a rapid onset of auditory nerve discharge at a particular frequency, there is a decay to a moderate level of discharge, even though the same speech sound is continuing to be produced*. This decay occurs over approximately 30ms (Smith 1979, cited in Bladon 1986). Since a glottal fricative is spectrally quite similar to a preceding vowel (Bladon 1986, Kingston 1990), which is likely to be at least 30ms in length, the auditory nerve will have no opportunity to recover before the preaspiration cue commences. Thus, a preaspiration cue will never benefit from a full-strength auditory nerve discharge.

(3) *Neural recovery: silent intervals in speech sounds give rise to a rapid, high-amplitude discharge when interrupted.* Since postaspiration follows the stop closure—a silent interval—it will benefit from this neural recovery period; preaspiration will not, since no silent interval precedes it.

In short, Bladon argues that since the preaspirated stop is an “auditory-phonetic dinosaur” which “suffers from an accumulation of auditory handicaps” (p. 7), its typological rarity should come as no surprise.

Though they may be persuasive at first read, Bladon’s arguments concerning preaspirated stops have not gone without criticism. Helgason (2002), for instance, points out that the principle of short-term adaptation has less explanatory value than it might at first seem to. If preaspiration does in fact produce a lower discharge rate in the auditory nerve than postaspiration (something that has not been independently established), how is this different from oral fricative-stop sequences? Helgason argues that, while there may be a significant difference in discharge rate between [ahta] and [atʰa], the difference between [ahta] and [afta] is liable to be of much lower magnitude. Aside from preaspirated stops, fricative-stop clusters are by no means typologically rare. (Exactly how abundant they are, however, we are left to wonder.) Thus, relatively low discharge rates do not necessarily constitute an auditory handicap. In Bladon's defense, one might respond that the spectral content of an oral fricative is heavier in the higher frequencies than a glottal fricative, and less vowel-like, permitting such fricatives to overcome short-term adaptation. But this response does not strike at Helgason's most important criticism: a positive correlation between discharge rates and perceptual salience is not indubitably established.

Bladon's principle of on-off asymmetry has also come under fire in Pind (1998). Pind conducted a perception experiment in which subjects listened to non-speech stimuli composed of concurrent sine waves, one at 500 Hz, one at 1500 Hz. The stimuli were crucially varied by shortening the duration of the lower sine wave 0-50 ms compared to the upper sine wave, in intervals of 5 ms, either at the beginning of the stimulus (to simulate an onset) or at the end (to simulate an offset). Subjects were asked to report whether the sounds they heard were "continuous" or "discontinuous." The experiment found that subjects were equally able to detect offsets and onsets. The only significant variable was the length of the offset/onset: below 10 ms, subjects reliably reported hearing a "continuous" stimulus. These results are problematic for Bladon's claim that offsets are harder for listeners to detect than onsets, and thus weaken his argument that preaspiration is auditorily disadvantaged as a consequence.

3.3.2 Silverman (2003, 1997)

In his 1997 dissertation, Dan Silverman advances an argument very similar to, and partly drawn from, that of Bladon (1986). The central thesis of the dissertation is that the cues to contrastive features in a language's phonological inventory must be distinct enough from one another to be reliably and accurately learned by speakers; in other words, these cues must be perceptually recoverable (see also Wright 2004). To be perceptually "optimal," a particular phonological feature must either possess intrinsically highly perceptible cues, or arrange these cues in such as way as to maximize their perceptibility. Meanwhile, "suboptimal" features fail on both counts. For instance, Silverman argues that a stop burst is intrinsically highly salient and "particularly well-suited to convey contrastive information" (2003, p. 593), since it is a high-pressure and high-volume acoustic event. Coordinating a laryngeal abduction with the release of a stop, as in postaspiration, creates an optimal arrangement of articulatory gestures. Meanwhile, the onset of a stop closure is less salient, since air pressure has achieved a near-minimal level at this point in the speech stream. Coordinating a laryngeal abduction with the onset of a stop closure, as in preaspiration, is a perceptually sub-optimal arrangement; this perceptual suboptimality, in the long run, makes preaspiration difficult to reliably transmit between generations, and hence rare.

Silverman expands on this argument in a typological survey of preaspirated stops (2003). Synchronically, the article avers, suboptimality yields an implicational hierarchy: languages will preferentially express an underlying aspiration contrast through postaspiration. Preaspiration, if employed at all, will be restricted to those environments where postaspiration is difficult to realize, i.e. medially post-stress and in final position, while postaspiration will be used in initial position (cf. Steriade 1997). Thus, preaspiration implies postaspiration, but not vice-versa. In fact, I have found only two counterexamples: Whorf (1946) reports no postaspirated allophones at all in Toreva Hopi, nor does

Sammallahti note their presence in Forest Nenets, but both languages have preaspirated stops (Hopi in post-stress onsets, Nenets intervocalically).

Diachronically, Silverman argues that the suboptimal status of preaspiration results in its relatively rapid elimination from a phonological system. This elimination can happen in two ways. First, the aspiration contrast, as expressed through preaspiration, may simply be lost: if it is hard to hear, then a preaspirating system will be transmitted between generations only with difficulty. This neutralization may be accompanied by compensatory lengthening of the vowel preceding the (now absent) preaspiration. A second possible outcome is fortition, in which prototypical glottal frication is supplanted by oral frication. The key argument here is that oral fricatives are perceptually more salient than glottal fricatives: while the spectral content of glottal frication is similar to that of a preceding vowel, the spectral energy of an oral fricative is much more concentrated in the upper frequencies. This greater abundance of high-frequency energy is presumed to be sufficient to overcome short-term adaptation, Bladon's second principle. Silverman identifies several examples of such "prespirantization," including Scottish Gaelic [çc xk] (or even [xp] and [xt], depending on dialect), Fox [fp st çc], and Southern Paiute [çc xk]; to these examples might be added Faroese, in which preaspiration often contains an oral component as in [bɐ̞h^{x}kɐɹ] "banks" (see chapter 2 of this dissertation for more information). In fact, Silverman concludes that many, if not most, preaspirating stop systems feature such perceptually motivated prespirantization.

However, I think Silverman may be conflating two substantially different phonological states. On the one hand, there are cases in which buccal variants have actually become phonologized within a preaspirating system, partially or wholly supplanting prototypical preaspiration (a process which could at least potentially be attributed to some perceptual superiority) (see the discussion of buccalization as a preaspiration exit process in §4.2.1 of the next chapter). On the other hand are preaspirating systems in which preaffricated forms occasionally occur (perhaps for articulatory reasons), but are not phonologically obligatory. For instance, in Harris Gaelic, a "preaspirated" velar stop is obligatorily realized as [xk], and thus is an example of the phonologized prespirantization Silverman describes. (Whether the phonologization process was in fact perceptually motivated is another question—but it might have been.) By contrast, in Lewis Gaelic, a preaspirated velar stop is typically realized as [hk], though Lewis speakers may produce [çc] after high vowels ([xk] is rare or nonexistent in Lewis Gaelic, as a preaspiration variant). That this is a genuine phonological difference between the two dialects is demonstrated by the fact that Lewis speakers discriminate reliably between *bochd* [boxk] "poor" and *boc* [bohk] "buck,"[4] while Harris speakers consider the words perfectly homophonous and pronounce both as [boxk] (personal observation). What is more, it is crucial to recognize that in some languages, preaspirated realizations may alternate with preaffricated variants, even though neither form has yet been phonologized, as in Sienese Italian (Stevens and Hajek 2007). Such preaffricated allophones may compete with preaspirated ones for eventual phonologization, but the former probably do not owe their existence to any perceptual superiority over the latter; in fact, both have evidently come into existence at about the same time. In short, while there are clear examples of prespirantization developing from earlier prototypical preaspiration (as in Harris Gaelic), not all prespirantization is a perceptually

[4] The final cluster in SG *bochd* [boxk] is historically [xt]; compare the modern Irish form *bocht* [boxt].

motivated development of earlier prototypical preaspiration; such scenarios are thus probably not as widespread as Silverman has concluded. Treating both the occasional Lewis [çc] and the obligatory Harris [xk] as identical products of a perceptually motivated evolutionary process obviates a crucial distinction.

3.3.3 Kingston (1990)

Kingston (1990) perspicuously observes, based on the inventories described in Maddieson (1984), that contrastive glottal articulations are much more common among stops than among fricatives or sonorants, and that such glottal articulations are much more frequently associated with the stop release than with the onset of the stop closure. Kingston proposes that these two asymmetries can be attributed to a universal constraint he terms the "binding principle." The key assumption is that glottal articulations will gravitate—bind—to the release of a stop, rather than to the onset of closure, because the release is a high-pressure, high-volume, and noisy event, and therefore perceptually salient. Hence the relative abundance of VOT-related contrasts, as well as breathy-voiced stops and ejectives, but the rarity of preaspiration, in which the glottal articulation is coincides with the closure onset instead.

The binding principle can be experimentally evaluated, Kingston argues, on the basis of the following proposition: "if two articulations are coordinated with one another [i.e. bound], their individual durations will co-vary across global changes in segment duration" (p. 412). In other words, as the closure duration of a stop lessens or increases, so too will a period of postaspiration lesson or increase. But there should be no such co-variation in the duration of closure and aspiration periods in preaspirated stops, because aspiration would be less inclined to "bind" to the stop in that case. Kingston tests these predictions using production data from Icelandic preaspirated and postaspirated voiceless stops. His results are problematic: no positive correlation between the duration of the glottal gesture and the following closure was found in preaspirates, as the principle predicted—but postaspirates in Icelandic also failed to display any covariance between the period of aspiration and that of closure, as the principle did predict. Thus, the binding principle does not seem to play out in the production of pre- or postaspirated stops as Kingston anticipated.

Kingston's experiment is of course meant to illustrate the articulatory ramifications of the binding principle. But it does leave an important question unaddressed: What Kingston did *not* do was test for any perceptual ramifications of the binding principle, which after all was predicated on the notion that a stop release was a perceptually more salient event than the onset of the stop closure. Silverman (1997, 2003) and Bladon (1986) operate on a similarly untested assumption, taking for granted that preaspiration must be perceptually inferior to postaspiration. However, experimental testing of the perceptual inferiority hypothesis is essential: if confirmed, the hypothesis will indeed offer the explanatory power that Bladon, Silverman, and Kingston attribute to it. But if the hypothesis cannot be confirmed, then we must find another explanation for the rarity of preaspirated stops.

3.4 Testing the perceptual robustness of preaspirated stops

The perceptual inferiority hypothesis is predicated on the assumption that a preaspiration cue is less perceptually robust than a postaspiration cue. The prediction in (4) follows from this assumption:

(4) *Given two stops that differ only in presence or absence of aspiration, listeners should perceive that difference more reliably if the aspiration cue follows the release of the stop (postaspirated) than if the aspiration precedes the stop closure (preaspirated).*

This section describes a perception experiment designed to test this prediction. If the experiment confirms the prediction, the difference in confusion rates will be evidence that preaspiration is inferior to postaspiration as a contrastive feature because it is more easily missed by listeners. If preaspiration is indeed easily missed, that might create selective pressures favoring more discernable cues, like the oral fricatives which Silverman (2003) argues would be more audible than [h]; alternatively, speakers might fail to learn to produce the preaspiration cue (while preserving any postaspiration), but maintain phonological weight through compensatory lengthening. If on the other hand it can be experimentally demonstrated that preaspiration is no more readily overlooked by listeners than postaspiration, this would suggest that the perceptual inferiority hypothesis does not hold water, and that we must look elsewhere to explain the scarcity of preaspirated stops.

3.4.1 Design of the experiment

The experiment was designed to test the ability of participants to distinguish between words which differed minimally according to whether the stop in the target position was preaspirated, postaspirated, or unaspirated. Stimuli consisted of Gaelic-like non-words uttered by native speakers of Lewis Gaelic. This dialect was selected because it features an unaspirated-postaspirated contrast in initial position, and an unaspirated-preaspirated contrast in medial and final position. The experiment was set up according to a two-alternative forced-choice paradigm: participants were given a "same/different" discrimination task which they could perform with a minimum of training, using a simple keyboard interface. This paradigm was chosen over those which require participants to match audible stimuli with written representations: since I planned to use multiple speaker populations, I could not count on members of those separate populations being able to recognize written forms with equal facility. Nor does the same/different paradigm require participants to consciously distinguish individual segments (as in Mielke 2003, a study of /h/ deletion in Turkish), important when the segments under investigation are likely to be unfamiliar to many of the subjects. Instead, the "same/different" paradigm permits subjects to compare and pass judgment on entire word forms. As long as these word forms differ minimally by the key feature, the same/different paradigm should yield useful results. Finally, logistical limitations ruled out any lengthy training periods more complex paradigms might have required.

3.4.1.1 Participants

Three participant populations were included: 9 Scottish Gaelic speakers, 12 Polish speakers, and 11 English speakers. Multiple speaker populations allowed me to control for native-language familiarity with aspiration contrasts. Since the Gaelic speakers were natively familiar with both types of aspiration contrast targeted in the experiment, any difference in their ability to discriminate the two types should proceed from inherent differences between preaspiration and postaspiration. For the same reason, Gaelic speakers were predicted to have the best overall performance (i.e. lowest error rate). The Polish speakers were included due to the absence of aspiration contrasts in Polish (Ruszkiewicz 1990, Gussman 2007, Laura Janda p.c.); thus their lack of L1 familiarity with aspiration contrasts was congruent with the L1 familiarity enjoyed by the Gaelic speakers. Once again, differences in their abilities to discriminate aspiration contrasts should be an inherent feature of the aspiration cues themselves. The Poles were thus predicted to have a higher overall error rate than the Gaels, but the errors were predicted to be similarly distributed among the types of aspiration contrasts. Finally, the 11 American English speakers were selected for their L1 experience only with postaspiration; they could be expected to perform better at distinguishing postaspiration contrasts than preaspiration contrasts, and thus have an error rate among the former similar to the Gaels, but among the latter similar to the Polish speakers.

3.4.1.2 Stimuli

A significant problem was deciding what invariant baseline segment the two types of aspirated segments should be compared with. Voiceless unaspirated stops were chosen for several reasons: first, this choice reduced the number of variables between the aspirated stops and the comparand to the key feature, aspiration; second, the usual state of affairs among preaspirating systems is for an aspiration contrast to obtain between two voiceless stop series (see chapter 2), so the comparison to be made is one that already exists naturally "in the wild." Third, voiceless unaspirated stops are well-nigh universal (Maddieson 1984) and therefore unlikely to add any additional level of confusion, an important consideration since the study subjects were to be drawn from several different language communities. Finally, since unaspirated voiceless stops are a diachronic decay product of preaspirated stops (Clayton 2009), it was useful to test a possible perceptual basis for this pattern of evolution.

Three sets of stimuli were constructed, each set targeting initial, medial, or final word position. Each set consisted of word pairs differing minimally according to whether a nonaspirated, postaspirated, or preaspirated stop occurred in the target position: unaspirated versus postaspirated in initial position, unaspirated versus preaspirated in medial and in final position. This arrangement pitted aspirated segments directly against unaspirated segments, permitting the confusion rates between postaspirated and unaspirated segments on the one hand, and preaspirated/unaspirated segments on the other, to be directly compared.

Real Gaelic words were not used for this experiment for two reasons: first, lexical gaps prevented the construction of a complete list of words of the appropriate form. Second, using real Gaelic words would have created a potential confound, the Gaelic-speaking subjects hearing familiar lexical items, the other subject groups hearing only unfamiliar nonsense words; this would have given the Gaels a perceptual advantage (Ganong 1980). Instead, three sets of Gaelic-like nonsense word pairs were composed according to the templates [CV_1t̪], [t̪V_1C], and [t̪V_1Ca]. In initial position, the target stop was either unaspirated or postaspirated; in medial and final position, C was either unaspirated or preaspirated. Tokens of each place of articulation (bilabial, dental, or velar) were included for each position. The unaspirated voiceless dental stop [t̪] was used for all non-target stops. V_1 was either [a] or [u] (phonologically short tokens only), and was invariably stressed. (Scottish Gaelic is a stress-initial language and possesses a length contrast in vowels). The final target word list included of 22 CVC and 12 CVCV target stimuli, for a total of 34 (Table 3.4). In the contexts included here, orthographic “p t c” represent the Gaelic voiceless aspirated stops /p^h t̪^{h} k^h/, and “b d g” the voiceless unaspirated stops /p t̪ k/; orthographic “a u” indicate the vowels [a u]. Duplicate forms are indicated by *.

CVt		tVC		tVCa	
asp	*unasp*	*asp*	*unasp*	*asp*	*unasp*
pad	bad	dap	dab	dapa	daba
tad	dad	dat	*dad	data	dada
cad	gad	dac	dag	daca	daga
pud	bud	dup	dub	dupa	duba
tud	dud	dut	*dud	duta	duda
cud	gud	duc	dug	duca	duga

Table 3.4. Stimuli used in perception experiment

The word list also included two additional sets of stimuli to be used as distracters: (i) 8 CVC and 4 CVCV stimuli in which the nasals /m/ and /n/ were substituted for /p/ and /t̪/ (/ŋ/ for /k/ was excluded, since this segment does not occur phonemically in Gaelic), and (ii) 12 CVC and 6 CVCV stimuli in which V1 was phonemically long instead of short. The set thus consisted of 64 distinct stimuli in total.

The high front vowel /i/ was avoided for several reasons. First, most Gaelic speakers heavily affricate dentals and velars adjacent to the “slender” vowels /i/ and /e/, potentially obscuring both preaspiration and postaspiration. Second, I wished to keep the stimulus sets as short as possible—my informants were not inexhaustibly patient. Finally, according to both Wang & Bilger (1973) and Singh & Black (1966), the vowel [i] affects confusion rates among English speakers: both studies found that consonants preceded by [i] were relatively easily discriminated, while consonants followed by [i] were more difficult to discriminate; the two vowels [a] and [u] had no such effect on intelligibility. Since in the current study a

V_1 [i] would invariably precede preaspirated stops and follow postaspirated ones, use of this vowel would have produced a serious confound in the English-speaker data.

Three male speakers of the Lewis dialect of Scottish Gaelic were recorded reading the stimuli from a printed list. Each stimulus was produced within the Gaelic frame sentence *Thubhairt mi* _____ *dà thuras* [xur̥t̪ mi ____ t̪a hurəs] “I said X two times”). Each stimulus appeared twice in the list, so that the better token might be used. Since no sound-proof chamber was available at the time and place of recording, the recordings were made in the best available environment, a carpeted hallway, which resulted in a very light reverberation. However, quality was still quite good: the achieved signal-to-noise ratio varied between approximately 25 and 40 dB SPL (well above the threshold at which Wang & Bilger 1973 report near-perfect native speaker performance). Recording equipment included a Plantronics USB headset microphone, a MacBook laptop computer, and the Praat software (Boersma and Weenink 2006).

Once recorded, the stimuli were individually excised from the sound files and normalized for peak amplitude. The start- and endpoints of each stimulus were tapered over a 5 ms interval to remove audible evidence of cuts. Stimuli were then assembled pairwise into seven-pair blocks. Each block featured the target stimuli (e.g. “bad” [pat]/“pad” [p^hat]), in the four ordered pairs AB, BB, BA, and AA (the order in which each pair was presented varied); one target stimulus plus a nasal distracter AN or NA; one target stimulus plus one long vowel distracter AV or VA; and two nasal distracters or long vowel distracters, for a total of seven pairs. The arrangement is illustrated in Table 3.5. Individual stimuli were selected so that each member of a given pair originated from a different speaker, the goal being to encourage participants to listen for phonologically relevant cues, rather than for subtle, non-linguistically relevant differences such as might exist between multiple tokens of a word as spoken by a single speaker. Stimulus blocks were composed according to the template in Table 3.5, in which speaker 1 and speaker 2 might be any two of the three Lewis speakers who recorded the stimuli. Blocks were varied by speaker at least to this degree, but might include stimuli recorded by a third speaker as well. A similar set of stimulus pairs was constructed for each of the 34 target stimuli; where the target segment had no nasal counterpart (i.e. velar stops), only long-vowel distracters were used. A total of 238 stimulus pairs were generated in this fashion.

1.	nonaspirate (speaker 1)	aspirate (speaker 2)
2.	aspirate (speaker 2)	aspirate (speaker 1)
3.	aspirate (speaker 1)	nonaspirate (speaker 2)
4.	nonaspirate (speaker 2)	nonaspirate (speaker 1)
5.	nonaspirate (sp 1)	nasal distracter (speaker 2)
6.	aspirate + V: (speaker 2)	aspirate (speaker 1)
7.	nasal distracter (sp 2)	nasal distracter (sp 1) ***OR***
	aspirate + V: (speaker 1)	aspirate + V: (speaker 2)

Table 3.5. Template for stimulus blocks

Members of stimulus pairs were separated by 250 milliseconds; a 1000ms wait time followed each participant response. A uniquely random order of presentation was generated for each participant. Participants listened to the stimuli through a pair of Sennheiser circumaural headphones (frequency response 18Hz to 18 kHz). Stimuli were presented and responses collected using the ACTUATE software (Assessing Cases: The University of Alberta Testing Environment; Westbury 2007). Subjects responded using color-coded keys: green for “same,” red for “different.” Two types of errors could thus be made: subjects could erroneously respond “same” to different stimuli, or “different” to identical stimuli. No provision was made for self-correction: once a response was entered, the software would proceed to the next stimulus pair.

Instructions were offered to subjects both orally and textually at the start of the experiment. Subjects were told that they would hear pairs of words, each word spoken by a different person, and that they were to decide whether the two speakers were saying the same word or different words. POT/POT was offered as an example of "same" and POT/POD as an example of "different." Subjects were further instructed to make their decision as quickly as possible, responding to their first impulse, rather than deliberating over each choice. A short practice session was provided at the outset of the test to allow participants to familiarize themselves with the keyboard and to set a comfortable volume level. The six practice stimuli were not used elsewhere in the experiment. Participants were offered two breaks during the course of the experiment, which they could skip, if desired, by hitting the space bar. The usual completion time for the entire experiment was approximately 15-20 minutes.

3.4.2 Results and discussion

Figure 3-9 shows participant error rates broken down by language group and word position. The results are notable in three ways. First and most important, error rates do not correlate with aspiration type: participants did not, as a whole, find preaspirated stops harder than postaspirated stops to discriminate from unaspirated stops. Second, error rates *do* correlate with world position. Third, there is a clear correlation between error rate and language group, by and large confirming the predictions made in §3.1.1 (summarized again here):

- It was predicted that Gaelic speakers should do best overall, since stimuli are native-like; also, since these participants had an L1 familiarity with both post- and preaspiration, any differences in their ability to discriminate preaspiration and postaspiration should result from inherent differences in cues.
- Polish speakers have no L1 experience with either post- or preaspiration, so once again, any difference in their ability to discriminate the two must be a function of the aspiration type. These speakers were predicted to have a higher overall error rate than Gaelic speakers, since they had no L1 advantage, but their errors should be similarly distributed across conditions.
- English speakers should do better at making initial contrasts than Polish speakers, since postaspiration contrast is L1-like; in fact, they should resemble the Gaelic speakers in this condition; should otherwise have an error rate close to that of Polish speakers.

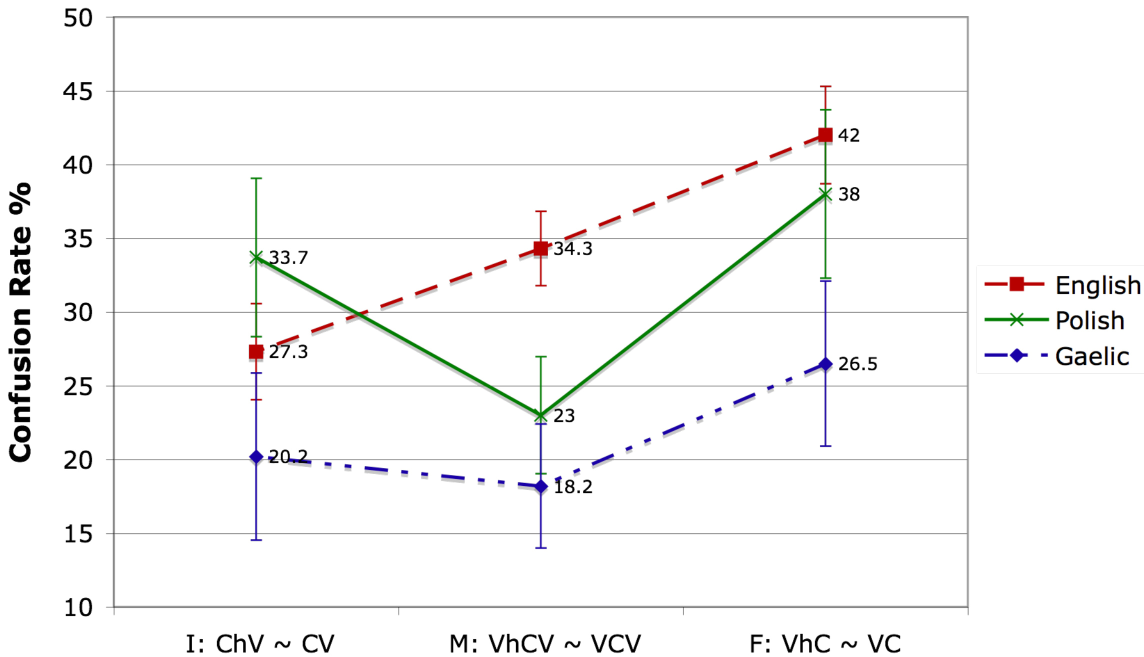


Figure 3-9. Error rates, by position and language group. Error bars represent 95% confidence intervals.

The results of the experiment indicate that confusion rates were in part a function of word position, not aspiration type, and are therefore problematic for the Perceptual Inferiority Hypothesis. For all three speaker populations, preaspiration in final position was significantly harder to discriminate than both initial postaspiration (β = 0. 5168, χ^2 = 41.54, $p < .0001$, by logistic regression) *and* medial preaspiration (β = 0.5241, χ^2 = 38.66, $p < .0001$). Furthermore, two of the three speaker populations did *not* find medial preaspiration to be harder to discriminate than initial postaspiration. Gaelic speakers detected medial preaspiration just as reliably as initial postaspiration (no significant difference, β = 0.9886, χ^2 = 0.0, p = .9663), while Polish speakers actually perceived the medial preaspiration contrast *better* than initial postaspiration (β = 1.5285, χ^2 = 5.92, p = . 015). English speakers were the only subject population for whom preaspiration contrasts were as a whole more difficult than postaspiration contrasts (initial vs. medial: $\beta = 0.7530$, $\chi^2 = 8.93$, $p = 0.0028$; initial vs. final: $\beta = 0.3912$, $\chi^2 = 23.50$, $p = < .0001$). However, this last is probably an L1 effect as predicted in §3.1.1, rather than the product of any intrinsic defect in the preaspiration cue: for English speakers, only the initial postaspiration cue is L1-like, giving them an asymmetrical advantage compared to the other two speaker populations.

Overall error rates for each speaker population confirmed the predictions in §3.1.1. That Gaelic speakers made far fewer errors overall (21.6%) than either Polish (31.6%) or English speakers (34.5%) is not surprising: both types of contrast under investigation were familiar to the Gaelic-speaking participants, and of course the stimuli were designed to conform to Gaelic phonotactics and were produced by native Gaelic speakers.

Unexpected was the Polish speakers' relatively good performance at discriminating preaspiration contrasts in medial position. This might be an L1 effect: the Polish speakers may have been assimilating the [hT] clusters in the Gaelic stimuli to medial [xT] clusters in Polish (e.g. *wachta* [vaxta] "watch" (nom. fem.)). Pruitt, Jenkins, and Strange (2006) found a similar effect when comparing the abilities of English and Japanese speakers to discriminate between Hindi dental and retroflex stops. Since there is no dental/retroflex contrast in English, English speakers performed relatively poorly at this task, compared to Japanese speakers. However, since Japanese possesses an apical contrast between the voiced dental stop /d/ and the voiced alveolar flap /r/, which may sometimes have a retroflex realization, Japanese speakers may have enjoyed an L1-related advantage over the English speakers. However, this explanation is problematic in the current situation, since the Polish participants should have been able to make a similar assimilation for final preaspirated stops as well, on the basis of such Polish words as *fracht* [fraxt] “freight” (nom. masc.). I must remain without an explanation for this anomaly for the time being, then.

3.5 Conclusions

This chapter has considered the factors which may contribute to the typological abundance of a given phonological structure, and the potential contribution of these factors toward the rarity of preaspirated stops. Broadly speaking, these factors fall into two categories: those that affect innovation rates, and those that affect diachronic stability (or rate of transmission). Innovation rates are a function of precursor robustness, the abundance of antecedent structures, competition between multiple precursors, and/or learnability; learnability in its turn is often connected to cognitive (dis)preferences (Moreton 2008, Wilson 2006). Diachronic stability is governed first by perceptibility and second by learnability—again, a priori cognitive predispositions which may or may not favor a particular kind of phonological structure.

In the case of preaspirated stops, it has frequently been argued that their low frequency is a product of low perceptibility (an argument I have called the Perceptual Inferiority Hypothesis). This chapter has first considered an alternative hypothesis, that preaspirated stops instead enjoy a low rate of innovation, but a high rate of transmission. Typological and historical evidence in favor of this hypothesis were presented. First, preaspirated stops tend to form both genetic and geographic clusters, a pattern predicted by Greenberg’s State-Process model for structures with high transmission rates. Second, the chapter considered evidence suggesting that preaspiration is capable of persisting intact for at least a thousand years (in the case of the Nordic languages, and possibly Scottish Gaelic as well), which seems inconsistent with the suggestion that preaspirated stops are diachronically unstable. Section 3 of this chapter then considered experimental evidence which tested the Perceptual Inferiority Hypothesis directly. Again, the experimental results do not support the PIH: there was no indication that subjects found preaspiration, as a whole, harder to detect than postaspiration, except where this could be readily explained by their first language experience. The experiment did confirm that L1 experience played an important role in determining overall success at discrimination tasks based on aspiration: where participants had such experience, their error rates were significantly lower than those participants without such experience.

If the rarity of preaspirated stops is due to their infrequent innovation, as this chapter concludes, what is the reason for that low innovation rate? Are the antecedent conditions difficult to meet? Or is there some cognitive constraint which retards their innovation? Both are real possibilities.

Chapter Four

Preaspirated stops: exit processes

4.1 Introduction

When a language systematically exhibits some grammatical feature F, it may be said that the language occupies the state F: the state of exhibiting feature F. By "systematically" is meant that the feature is an obligatory component of speakers' production; the feature does not occur sporadically and unpredictably. For any such linguistic state, processes must exist by which a language may enter the state; otherwise, the state would be unattested, or else attested exclusively among languages that spontaneously sprang into existence within the state (which seems improbable) (Greenberg 1978, 1969, 1966; Bell 1971, 1970). We may term any process through which a given state is entered an *entrance process* with respect to that state. By the same token, there must also be processes leading out from the state; otherwise, the set of languages occupying the state would remain static, or else expand inexorably until all extant languages occupied the state. Processes by which a language proceeds out of a state can be called *exit processes* with respect to that state.

To understand the lifecycle of a given linguistic feature, both entrance and exit processes must be enumerated and understood: What is required to engender the feature? What leads to its disappearance, and what residue, if any, does it leave behind once it has gone? What insights can we gain into the abundance, distribution, and behavior of the feature through examination of its entrance and exit processes?

This chapter has two main goals. The first and more general is to identify and describe those processes by which languages exit the state of preaspirated stops, of which I have identified five. These include buccalization (several examples, including Bora, Fox, Scottish Gaelic, and possibly Goajiro), deaspiration (Tarascan and Scottish Gaelic), spirantization (the Central Numic languages, including Shoshone), tonogenesis (one example, Hopi), and nasalization (one speculative example, the Ponapean languages). By investigating these processes, the study aims not only to provide a fuller picture of the lifecycle of the preaspirated stop, but also greater insight into the ways in which those exit processes lead to yet other states, secondarily illuminating those phonological phenomena connected thereby to preaspirated stops. The chapter addresses this goal in two ways: first, by considering descriptions of these phenomena available in existing literature; and second, by bringing to bear a body of production and perception data gathered from native speakers of preaspirating languages, including Scottish Gaelic, Icelandic, and Tohono O'odham.

The second and more specific goal of the chapter is to account for the peculiar patterns of variation in the operation of exit processes in Scottish Gaelic. In dialects of that language, both deaspiration and buccalization can be observed to have been phonologized to a greater or lesser degree, depending on the dialect (Figure 4.1). In some of these dialects, a subset of historically preaspirated stops have become deaspirated—no preaspiration is any longer associated with those stops. Meanwhile, other stops have undergone buccalization, such that historically glottal preaspiration has gained a phonologized oral component—the "preaspiration" associated with these stops is phonetically no longer [h] but rather [x].

Notably, each process applies asymmetrically across the set of preaspirated stops. Buccalization, when it is found in some dialect, always affects dorsal stops; it may, in addition, include coronal stops; finally, labial stops may be added to the first two. The place hierarchy *dorsal » coronal » labial* is thus implied. Deaspiration, meanwhile, applies according to an opposing hierarchy, preferentially targeting labial stops, then extending to coronals, and finally perhaps to dorsals (but this remains unconfirmed), implying the ranking *labial » coronal » dorsal*.

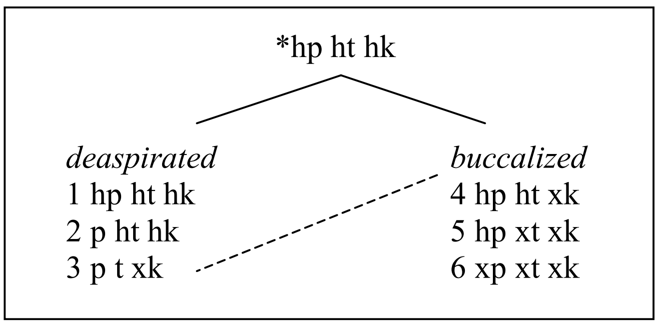


Figure 4.1. Dialect variation in Scottish Gaelic preaspiration

The chapter considers two competing analyses of these asymmetries, one cognitive and synchronic in nature, the other articulatory and diachronic. The first hypothesis assumes that an *analytic bias* is responsible, that is, a cognitive bias rooted in the language faculty. The analysis takes place within the framework of the P-map hypothesis (Steriade 2001a, 2001b), an extension to classic Optimality Theory which argues that asymmetries in the application of phonological processes can be attributed to perceptually motivated fixed rankings of faithfulness constraints. I show that the attested facts of Scottish Gaelic can be represented in standard OT, but that violations of the observed asymmetries can be as easily modeled; in other words, the standard analysis “overgenerates,” predicting unattested configurations like /xp ht hk/ or /hp ht k/. Modifying the original OT analysis via the P-map resolves the overgeneration.

Crucially, this modified analysis depends on scales of perceptibility. It further predicts that within and between-speaker variation in surface forms will respect these scales. Empirical evidence from the perception study reported in the previous chapter (§3.4) demonstrates that perceptual scales congruent with the P-map analysis of the deaspiration asymmetry do exist: participants are more prone to confuse unaspirated [p] and preaspirated [hp] than they are [t] and [ht], while [k] and [hk] are the least confusable pairs. (The second asymmetry in buccalization was not addressed by the perception study.) Additionally, the P-map predicts that so far as innovative speakers produce forms that deviate from "established lexical norms," these deviations will respect the relevant perceptual scales. Two production studies of Scottish Gaelic preaspiration described in this chapter (§4.6) find that some speakers (though not all) do in fact sporadically produce deviant phonetic forms, failing to produce preaspiration where expected, and where other speakers do in fact produce it. These omissions of preaspiration are by far the most numerous among labial stops, somewhat less numerous among coronals, and least common among dorsal stops, *hp* >> *ht* >> *hk*. This pattern is precisely congruent with the perceptual scale found in the perception study, in which labial preaspirates and nonaspirates were more confusable than coronal tokens, which in turn were more confusable than dorsals.

The alternative explanation proposes that these asymmetries are due to a *channel bias*, one rooted in the physics of articulation and propagation of speech sounds. The premise is that selective physical forces act upon the articulation and perception of the speech signal; over time, a form A prone to misapprehension as B will tend to give way to B, while a relatively perceptually nonsalient form C will tend to disappear altogether (Ohala 2005, Blevins 2004, Silverman 2003). As a corollary, certain patterns may seldom or never be phonologized because the necessary precursors are absent (Myers 2002): form B will not evolve if there is no precursor form A leading to it via some entrance process. The perception studies described in section 3.4 are indeed consistent with this diachronic account. In addition, the production studies of Scottish Gaelic preaspiration (§4.6) find that the duration of the preaspiration cue is place-sensitive, shortest before labial stops, longer before coronal stops, and longest before dorsal stops. The chapter concludes that this variation constitutes a robust phonetic precursor for both asymmetries in Gaelic. However, the channel bias account cannot explain in any principled way the pattern of individual variation in the deaspiration of underlyingly preaspirated tokens: this account can only address the means by which a form may become phonologized within a language. The P-map, by contrast, offers a straightforward explanation for the observed patterns in speakers' deviant productions.

The balance of the chapter proceeds as follows. Section 4.2 considers those diachronic processes by which languages are confirmed or proposed to exit the preaspirating state; these include buccalization, deaspiration, tonogenesis, spirantization, and nasalization. Section 4.3 describes in detail the curiously asymmetrical operation of buccalization and deaspiration in Scottish Gaelic. Section 4.4 elaborates on the theoretical underpinnings of the two alternative explanations for these asymmetries: the synchronic P-map account (an analytic bias) and the alternative diachronic model (a type of channel bias). Section 4.5 presents a naive Optimality-Theoretic analysis of these asymmetries, followed by the extended P-map analysis. Section 4.6 presents the alternative channel bias analysis, and describes the associated production studies.

4.2 Exit processes

In this section, I describe those processes known or proposed to provide exit routes from the state of preaspirated stops. These are illustrated in Figure 4.2, together with the entrance processes described in chapter 3 (line weight corresponds roughly with the number of identified cases of each process; ovals are labeled with the inputs for entrance processes, outputs for exit processes). Though these processes very likely do not operate with equal frequency, as we might expect, it is virtually impossible to determine the actual rate, either relatively or absolutely. It is likely that in many cases, the output of exit processes results in a merger of preaspirated segments with existing segment inventories, like deaspiration (hT > T) or spirantization (hT > θ), making identification difficult after the fact. Consequently, the number of instances of tonogenesis, spirantization, or nasalization that have been positively linked with earlier preaspiration is quite small, though the real number may in fact be substantially larger.

Only when the output of the exit process is similar in its distribution to the original preaspiration is detection easily accomplished, as for buccalized forms (hT > xT), or when the processes operate differentially across environments within a single language community. Even so, comparative evidence is invaluable to ensure that the feature under consideration is genuinely a residue of preaspiration. For instance, we may conclude that the preaffricated stops found in Bora (Aschmann 1993) are quite likely to be the residue of earlier prototypical preaspiration since buccalized, because they correspond to geminate stops in Bora's sister language Muinane, a correspondence typical for preaspirated stops (see chapter 2). By contrast, the preaffricated stops of Blackfoot are in fact the product of a wide range of consonant-stop clusters, including [hp tp nt ʔt hk tk lk] (Frantz 2009), and so represent a red herring.

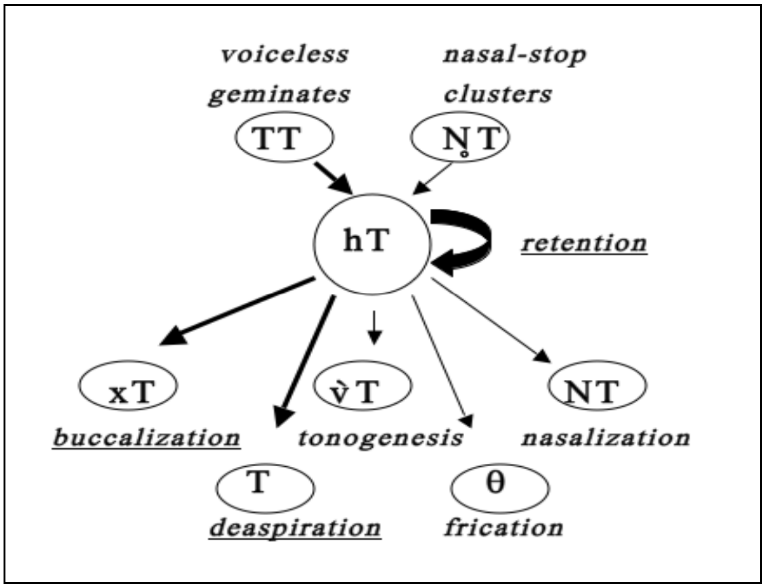


Figure 4.2. Entrance and exit processes for preaspirated stops

4.2.1 Buccalization

The most widespread identifiable exit process is buccalization. Through this process, an oral variant of the aspiration component of a preaspirated obstruent becomes phonologized, supplanting the earlier glottal form. Inasmuch as this development represents a departure from a purely preaspirating state, buccalization may be described as an exit process.

Generally speaking, preaspiration is described as a period of glottal frication that precedes an oral stricture. The term "voice offset time" has even been used, a deliberate adaptation of the earlier term "voice onset time" which is used as a measure of postaspiration (McRobbie-Utasi 2003; Steriade 1999, 1997; Pind 1998; Ladefoged & Maddieson 1996; Lisker and Abramson 1964). The review of languages described as "preaspirating" in chapter

2 finds that preaspiration was most commonly described as being a glottal fricative, [h], breathiness, or aspiration. It is thus reasonable to regard the glottal form of preaspiration as “prototypical” in some sense.

However, in many languages, preaspiration is also described as being sporadically realized with a noise source downstream from the glottis, i.e. as preaffrication (see §1.1). This downstream noise may be homorganic with the following obstruent, for instance [fp] [st] [çc] as in the language Fox (Jones/Michelson 1910, Silverman 2003), or [st] in Tarascan (Foster 1969). In addition, the quality of the preceding vowel may sometimes be a factor: frication in Central Swedish and Faroese speakers may be labial after rounded vowels, palatal after high front vowels, or uvular after low back/central vowels (Helgason 2002). Such physiological or aerodynamically motivated variants may be reinterpreted by listeners as the norm, rather than incidental by-forms, leading to a “mini sound change” (Ohala 1997, p. 3). The result is that these oral articulations become phonologized (“normalized,” to use Helgason’s term)—elevated to phonological status by members of the speech community. Once that has happened, the earlier glottal realizations of the preaspirated segment become an aberrant or uncharacteristic articulation within the speech community, and then we may say that the preaspiration has become buccalized, and is thus no longer prototypical. (See further discussion of phonologization below in §4.4.2.) In other words, at that point the language will have (at least partially) exited the state of preaspiration, and entered a secondary or derivative state, by the process of buccalization.

We thus have two categories of “preaspirating” languages. Languages in the first category retain prototypically preaspirated stops, but in these languages, preaspiration may occasionally be realized with an oral variant. In the second category, the oral variant is now the "normal" form, and the earlier glottal form is now aberrant: the language can no longer strictly be described as having preaspiration in the affected environments (or at all if the oral forms have become normalized across the board). (As I pointed out in §3.3.2, Silverman 2003 seems to conflate these two states—phonologized and unphonologized non-glottal preaspiration. The paper's conclusion that buccalized variants are perceptually advantaged evolutionary developments of earlier prototypical preaspiration could thus only be potentially true for those languages in which buccalized variants have actually been phonologized.)

The frequency with which preaspirating languages manifest oral variants is difficult to assess. However, it is probably quite a widespread phenomenon. Of those languages identified in the survey in chapter 2, at least six (approximately a quarter) are described as featuring oral forms that are not phonologized or obligatory. These include Faroese (Helgason 2002), Central Swedish (Helgason 2002), Tarascan (Foster 1969), the Lewis dialect of Scottish Gaelic (Ní Chasaide 1984, Oftedal 1956, Borgstrøm 1940, my own observations), and Goajiro (Holmer 1949). It is likely, however, that the number is larger, inasmuch as in many descriptive grammars and other discussion of a language's phonology, little space may be devoted to preaspiration, and even less to its variability.

If oral variants such as these occur, there is the possibility that they may become phonologized (perhaps once they have crossed a certain threshold of frequency): members of the language community may not simply tolerate them as tokens of /hT/, but in fact expect them. And so we find languages where oral variants are not merely possible productions of preaspirated segments, but obligatory. These languages include Scottish Gaelic (non-Lewis dialects), Bora, and Fox. The Gaelic situation is summarized above. In Bora, Aschmann (1993) describes "preaspiration" as consisting of a velar fricative [x], but provides little elaboration. In Fox, preaspiration has developed into a set of oral fricatives homorganic with the following stop (by the description in Jones/Michelson 1910, and as interpreted in Silverman 2003), [fp st çc], though in Fox's sister languages Cree, Ojibwe, and Menominee, the glottal form of preaspiration has been retained (Bloomfield 1925). Bloomfield does not indicate non-glottal preaspiration in Fox, but Michelson is fairly unambiguous in his description, and says nothing about the oral variants being occasional, sporadic, or unusual, so Silverman's interpretation is probably sound.

4.2.2 Deaspiration

A second exit process is the outright loss of preaspiration, or deaspiration. In some languages, preaspiration is lost without leaving any apparent residue, while in others, the vowel preceding the affected stop may undergo compensatory lengthening.

Examples of the former case may of course be difficult to identify, unless the researcher can spot the deaspiration process in progress. Such seems to be the case in Scottish Gaelic. In certain dialects of that language, deaspiration appears to have affected only a subset of historically preaspirated stops. While the dialects of Lewis and West Sutherland feature a full system of preaspirated stops [hp ht hk], and yet other dialects have partially buccalized systems, like that of Skye and Harris [hp ht xk], several dialects feature a partially deaspirated system. For instance, a variant of the West Sutherland dialect has lost preaspiration before labial stops, yielding [p ht hk], while the southern Argyll dialect has lost preaspiration before coronal stops as well, while simultaneously displaying a buccalized dorsal variant [p t xk]. (See further discussion in §2.2.1 above and §4.3 below.) Furthermore, production experiments indicate that even dialects which retain a fully preaspirated system may display sporadic deaspiration, especially after long vowels and before labial stops (see §4.6.1.5 below for a discussion). Neither phonological loss of preaspiration nor sporadic deaspiration are accompanied by compensatory lengthening of the preceding vowel in Gaelic.

At least two languages in which deaspiration is accompanied by compensatory lengthening have been identified. Tarascan features contrastive preaspiration (Foster 1969). However, preaspiration is sometimes omitted, and any preceding [ɨ] vowel undergoes compensatory lengthening: [ˈtsɨhkuni̥] ~ [ˈtsɨ:kuni̥]. (Apparently, this is the only vowel to undergo lengthening upon deaspiration.) In Goajiro, preaspiration is not contrastive and occurs only in some speakers' utterances (Holmer 1949); speakers that do not preaspirate instead produce lengthened vowels before the segment in question: [me:ke:ra] ~ [mehke:ra], [pe:ke:ra:] ~ [pehke:ra:] (examples cited in Silverman 2003 without glosses).

It is at least in principle to use such compensatory lengthening with a restricted distribution as a marker of earlier preaspiration. If, for instance, the researcher identifies vowel lengthening that occurs only before voiceless stops, this may be an indication that the language in question at one time previously possessed preaspiration.

4.2.3 Tonogenesis

Hopi provides an apparently unique example of a third exit process. Whorf (1946) identifies two sets of stops in the Toreva dialect of Hopi: an unaspirated series /p t tʃ c c^w k/ contrasting with preaspirated /hp ht htʃ hc hc^w hk/. The second series appears to have been a strictly preaspirating one without postaspirated allophones, according to Whorf's description (and is thus an example of a contrastively *preaspirated* stop series, which Ladefoged and

Maddieson 1996 describes as uninstantiated). Whorf found that plain stops occurred in all positions, while the preaspirated stops "occur only syllable-initial after a firm-stressed vowel" (p. 160).

However, an apparently unique and certainly very interesting development has taken place in this dialect of Hopi since Whorf's description of it. Where fifty years previously, Whorf reported short stressed vowels followed by preaspirated voiceless stops, later researchers have instead found long stressed vowels with a falling tone and no preaspiration. These vowels contrast with long stressed vowels with a high-high tone (Manaster-Ramer 1986). In (1) are examples as transcribed earlier by Whorf (1946, 1936), and as described in later works including Jeanne (1982), Malotki (1983, 1979), and Langacker (1978):

(1)	<u>Earlier</u>	<u>Later</u>	
	wɨ^{h}ti	wɨ̂ɨti	'woman'
	le^{h}pe	léèpe	'to fall'
	kɨ^{h}kɨ	kɨ̂ɨkɨ	'foot'

Whorf also reported a set of devoiced sonorants before voiceless stops. But later researchers have again found a falling tone instead. Examples include the following (where in Whorf's notation capitals indicate devoiced sonorants):

(2)	<u>Earlier</u>	<u>Later</u>	
	WaLpi	wâlpi	(village name)
	sikyaŅpɨ	sikyyáŋ̀pɨ	'yellow'
	soMta	sóm̀ta	'to tie'

Finally, Manaster-Ramer (1986) points out that later researchers have also found a falling tone on long vowels that precede /s/ in instances where Whorf described only a short vowel followed by /s/. Manaster-Ramer hypothesizes that in these examples, the sibilant may have actually been a preaspirated /hs/ in earlier Hopi, which would straightforwardly explain the falling tone in these examples. Since Forest Nenets also has a preaspirated /hs/ in addition to a set of preaspirated noncontinuants, Hopi would not be unique in this respect. Examples include those in (3), where Whorf's earlier description did not include preaspiration:

(3)	Earlier	Later	
	soso-	sóòso-	'all'
	posi	póòsi	'to fall'
	wɨsɨ	wɨ́ɨ̀si	'broom'

Tonogenesis has been observed in several other languages, including Seoul Korean (Silva 2006), Tibetan (Duanmu 1992, cited in Silva 2006) and Kammu (Svantesson & House 2006). In all three of these languages, a contrast based on voice-onset time (i.e. voicing or postaspiration) has developed into a tone contrast. In standard Korean, voice-onset time distinguishes so-called "lax" (i.e. voiceless unaspirated, or moderately aspirated) and voiceless aspirated stops (the language has a third set of stops sometimes called "tense"). But among younger speakers of the Seoul dialect, the VOT of historically lax stops has fallen together with that of historically aspirated stops; the two stop series are now distinguished instead by low tone on vowels following the previously lax stops, and a high tone on vowels preceding the formerly aspirated stops.

A similar development seems to have occurred in some dialects of Kammu, a Mon-Khmer language spoken in Laos (Svantesson & House 2006). Where Eastern Kammu has a voiceless initial segment, Northern and Western Kammu have a high tone on the following vowel. Where the initial segment is voiced in Eastern Kammu, the other two dialects have a low tone:

(4) Tone and VOT contrasts in Kammu dialects

Eastern	*Northern*	*Western*	
taaŋ	táaŋ	táaŋ	‘pack’
daaŋ	tàaŋ	t^{h}àaŋ	‘lizard’
t^{h}aaŋ	t^{h}áaŋ	t^{h}áaŋ	‘to clear’
r̥aaŋ	ráaŋ	ráaŋ	‘tooth’
raaŋ	ràaŋ	ràaŋ	‘flower’

This form of tonogenesis has been linked to a well-documented correlation between voice-onset time and the pitch profile of a following vowel (see e.g. Silva 2006; Hombert, Ohala, & Ewan 1979; Hombert 1978): cross-linguistically, a longer VOT corresponds to a higher F_0 in the subsequent vowel (Figure 4.3). This means that (at least) two salient cues, VOT and vowel F_0, are available to listeners tasked with distinguishing voiced and voiceless (or unaspirated and postaspirated) segments. Which of these cues is primary is potentially ambiguous to listeners, permitting them to reanalyze an existing VOT contrast instead as an F_0 contrast, i.e. tone.

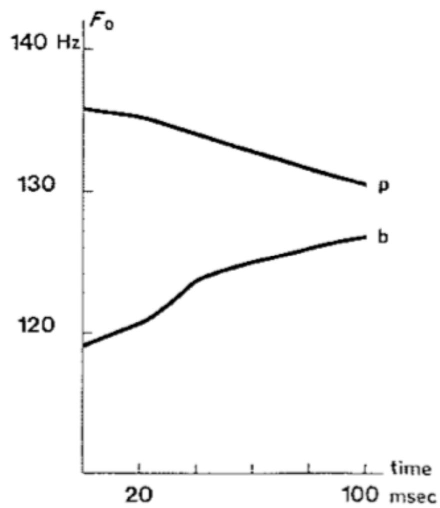


Figure 4.3. Average F_0 (in Hz) of English vowels after voiced and voiceless stops (five speakers) (from Hombert, Ohala, & Ewan 1979, p. 39).

If tone in Hopi has a similar origin—reanalysis of a phonologically secondary F_0 fluctuation as a primary cue—it should be possible to find evidence that such a fluctuation is also correlated with an unaspirated/preaspirated contrast. In this case, the pitch perturbation should work the opposite way from that seen in Korean and elsewhere: a preaspirated consonant should induce a drop in F_0 on the preceding vowel (and thus potentially motivate a low tone), while an unaspirated consonant should be associated with a level or higher F_0.

Hombert (1978) found exactly such a correlation. Data was collected on the pitch of vowels preceding the glottal stop [ʔ] and the glottal fricative [h], in the utterances of four Arabic speakers. It was found that a postvocalic [h] produced an F_0 drop of 25 to 50 Hz on the preceding vowel, while a glottal stop [ʔ] raised the vowel's fundamental frequency by 9 to 48 Hz (Figure 4.4). Significant differences in the pitch tracks preceding these two consonants appeared as early as 70ms before the vowel offset. A follow-up experiment (also reported in Hombert 1978) found that speakers of American English were easily able to detect such perturbations in pitch.

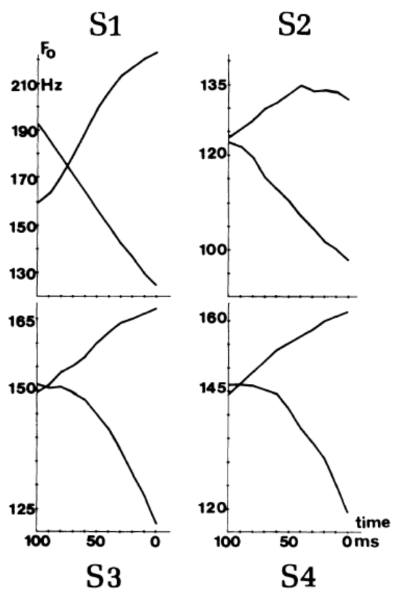


Figure 4.4. Average F_0 (in Hz) of vowels before [ʔ] (with positive slope) and [h] (with negative slope) in Arabic (four speakers) (from Hombert 1978, p. 93).

If we assume that post-vocalic [h] and the aspiration component of a prototypically preaspirated stop are phonetically similar, as I will argue below, Hombert's study provides a clear motivation for the development of contrastive tone from earlier preaspiration in Toreva Hopi.

4.2.4 Spirantization

A fourth process that results in the loss of preaspirated stops is spirantization, through which preaspirated stops become unaspirated voiceless fricatives [hT] > [θ]. This process is exemplified by the Numic languages of western North America, a branch of the Uto-Aztecan family which includes Comanche, Southern Paiute, Mono, and the range of Shoshone dialects. In the Numic languages, "short, unstressed vowels before geminates were devoiced and the geminate was degeminated and preaspirated. The preaspirated stops in Central Numic then became fricatives, yielding the distribution of voiceless fricatives currently found in Tümpisa Shoshone and in the various dialects of Shoshone, including Gosiute" (Elzinga 1999, p. 2). Once again, we have an instance of preaspiration being linked to earlier voiceless geminates—and fortuitously, a well-developed account of the subsequent breakdown of those preaspirated stops. The chain of development in (5) is representative (after Miller, Elzinga, & McLaughlin 2005):

(5) Lenition of Proto-Numic geminates in Central Numic

PN:	**puni-kka* 'see'	**na-puni-kka* 'appear'	
	**puni-kka*	**nabunikka*	after spirantization
	**puníkka*	**nabúnikka*	after stress assignment
	**puníkka*	**nabúnihka*	after degemination and preaspiration
	**puníkka*	**nabúNIka*	after vowel and sonorant devoicing
PCN:	**púnikka*	**nábunixa*	after stress shift and frication

Spirantization of preaspirated stops intervocalically should by no means be an unexpected development. Since the preaspirated stop is phonetically a singleton (whatever its underlying phonological status), it is subject to the same aerodynamic and articulatory forces that result in the widespread frication of singleton stops crosslinguistically, in particular intervocalically. Since vowels and stops are at opposites ends of the constriction spectrum, the articulatory effort entailed by movement between these two extremes is at maximum; hence, "[t]he primacy of intervocalic position as a context for lenition thus falls out from the natural assumption that the impetus to lenite more effortful gestures is stronger than the impetus to lenite easier gestures” (Kirchner 1998, p. 28). Kirchner (1998) provides an extensive catalog of similar cases of lenition; see also Hock (1991) and Harris (1984).

4.2.5 Nasalization

A final possible exit process from the preaspirated stop is through nasalization of the aspiration component, as Blevins and Garrett (1993) propose for the Ponapeic languages of the Pacific. The Ponapeic languages exhibit a phonological process known as nasal substitution, in which voiceless geminate obstruents are realized as nasal-obstruent clusters. In Ponapean, the process is still productive: underlying geminate obstruents derived through reduplication or affixation are realized as nasal-obstruent clusters, as illustrated in (6). In Ponapean’s sister language Mokilese, the process is no longer productive, but traces of its earlier application can still be observed; examples are provided in (7) (from Blevins & Garrett 1993). (A similar development from voiceless geminate stop TT to nasal-stop cluster NT has also been proposed for certain southern Italian dialects as well as Greek dialects of southern Italy by Schwyzer 1934 and Rohlfs 1949; both are cited in Blevins & Garrett 1993.)

(6) Nasal substitution in Ponapean

a. /pap-pap/ > [pampap] 'swimming' (pap 'to swim')

b. /$p^w up^w$-$p^w up^w$/ > [$p^w um^w p^w up^w$] 'falling' ($p^w up^w$ 'to fall')

c. /tit-tit/ > [tintit] 'building a wall' (tit 'to build a wall')

d. /sas-sas/ > [sansas] 'staggering' (sas 'to stagger')

e. /č̣ač̣-č̣ač̣/ > [č̣anč̣ač̣] 'writhing' (č̣ač̣ 'to writhe')

f. /kak-kak/ > [kaŋkak] '(being) able' (kak 'to be able')

(7) Nasal substitution in Mokilese (diachronic)

Mokilese	Source
a. iŋkɔŋ 'sharp'	*kkaŋ < *ka-kaŋi
b. um^{w}p^{w}ul 'flaming'	*p^{w}p^{w}ul < *p^{w}u-p^{w}ula
c. insa 'blood'	*č̣č̣a < *č̣a-č̣aa

Blevins and Garrett (1993) do not contest the reconstructed nasals in Mokilese or the analysis of underlying geminate voiceless obstruents in Ponapean. What concerns them is that there does not seem to be any phonetic precursor that might motivate a direct development of voiceless geminates to nasal-voiceless stop clusters *TT > NT; for voiced obstruents, yes (Schwyzer 1934), for voiceless ones, no. Blevins and Garrett suggest instead an intermediate stage of preaspiration, in which geminate obstruents degeminated into preaspirated forms *TT > *hT, a process that is indeed attested in several other languages (as I have been arguing in this dissertation), and not excluded by Kirchner's constraint against oral reduction of geminate stops (1998). The subsequent development from *hT to NT, they argue, is a much better motivated sound change than *TT > NT directly. According to Ohala (1975, p. 303),

> [h] may produce an effect on vowels that 'mocks' that of nasalization. Because of the open glottis during phonation accompanying an [h] (or breathy-voice), the spectrum of the vowel will be changed in the following ways: there will be upward shifting of the formants, espe- cially F1 ..., increased bandwidth of the formants, presence of anti- resonances in the spectrum and an overall lowering of the amplitude of the vowel ... This is identical to the effect of nasalization on vowels. Articulatory re-

interpretation may occur, i.e., actual nasalization may be produced on the vowel. (Cited in Blevins & Garrett 1993)

In the previous chapter, I have suggested the opposite development, N̥T > hT, as an entrance process for preaspiration, on the basis of arguments similar to those offered by Ohala above. However, if in truth both devoiced nasals and [h] are as similar acoustically and aerodynamically as Ohala argues, Blevins & Garrett's proposal seems sound, if necessarily speculative.

4.2.6 Interim summary

This section has identified five processes by which languages exit the preaspirating state: buccalization (Scottish Gaelic, Bora, Fox); deaspiration, with or without compensatory lengthening (Scottish Gaelic, Tarascan, Goajiro); tonogenesis (Hopi); spirantization (the Numic languages); and nasalization (proposed for Ponapean and Mokilese). Of these processes only two, buccalization and deaspiration, seem to be contemporarily in progress in some language and therefore observable. While Tarascan and Goajiro promise to be informative about deaspiration, Scottish Gaelic offers an ideal setting for investigation of both deaspiration and buccalization, since it features both processes. Moreover, the patterns displayed by deaspiration and buccalization in Scottish Gaelic raise a number of theoretical questions about the operation and underlying motivation of these processes. The balance of this chapter, therefore, is in the main concerned with addressing these questions, employing data gathered through a series of production studies of preaspiration in Gaelic, as well as the perception study of Gaelic preaspiration described in the previous chapter.

4.3 Preaspiration in Scottish Gaelic: two asymmetries in buccalization, deaspiration

There are two series of phonemic oral stops in most dialects of Scottish Gaelic. An aspiration contrast distinguishes these two series: voiceless nonaspirated/p t̪ t̪^{j} k^j k/ contrasts with voiceless aspirated /p^h t̪^{h} t̪^{hj} k^{hj} k^h/[1]. In these dialects, there is no voiced stop series (but see Ternes 1973 for a different view).[2] Aspiration in the second series is realized as post-aspiration in initial position before stressed vowels, and as preaspiration following stressed vowels in medial and final position, as illustrate in (6):

(8) a. Initial and final: *cop* 'foam' < > *gob* 'beak'

b. Medial: *bàta* ‘boat’ < > *fàdadh* ‘kindling’

There is a great deal of dialectal variation in Scottish Gaelic (though in recent decades, the number of distinct dialects has been greatly reduced due to language shift). A similar range of variation in the realization of preaspiration has also been documented. (Not all dialects are or were preaspirating.) The configurations taken by preaspiration in the major dialect areas are listed in 1-6; for their geographic orientation see Figure 4.5 (Ó Maolalaigh 2007, Clement 1994, Ó Murchú 1985, Ó Baoill 1980, Borgstrøm 1974, Oftedal 1956):

(9) 1. /hp ht hk/: Lewis, the northwestern mainland

2. /p ht hk/: west Sutherland variant

3. /hp ht xk/: western Inverness-shire, Skye, outer Hebrides except Lewis

4. /xp xt xk/: north Argyll, central Highlands

5. /hp xt xk/: southwest mainland (Ó Maolalaigh 2007).

6. /p t xk/: southern Argyll; portions of south-central Highlands

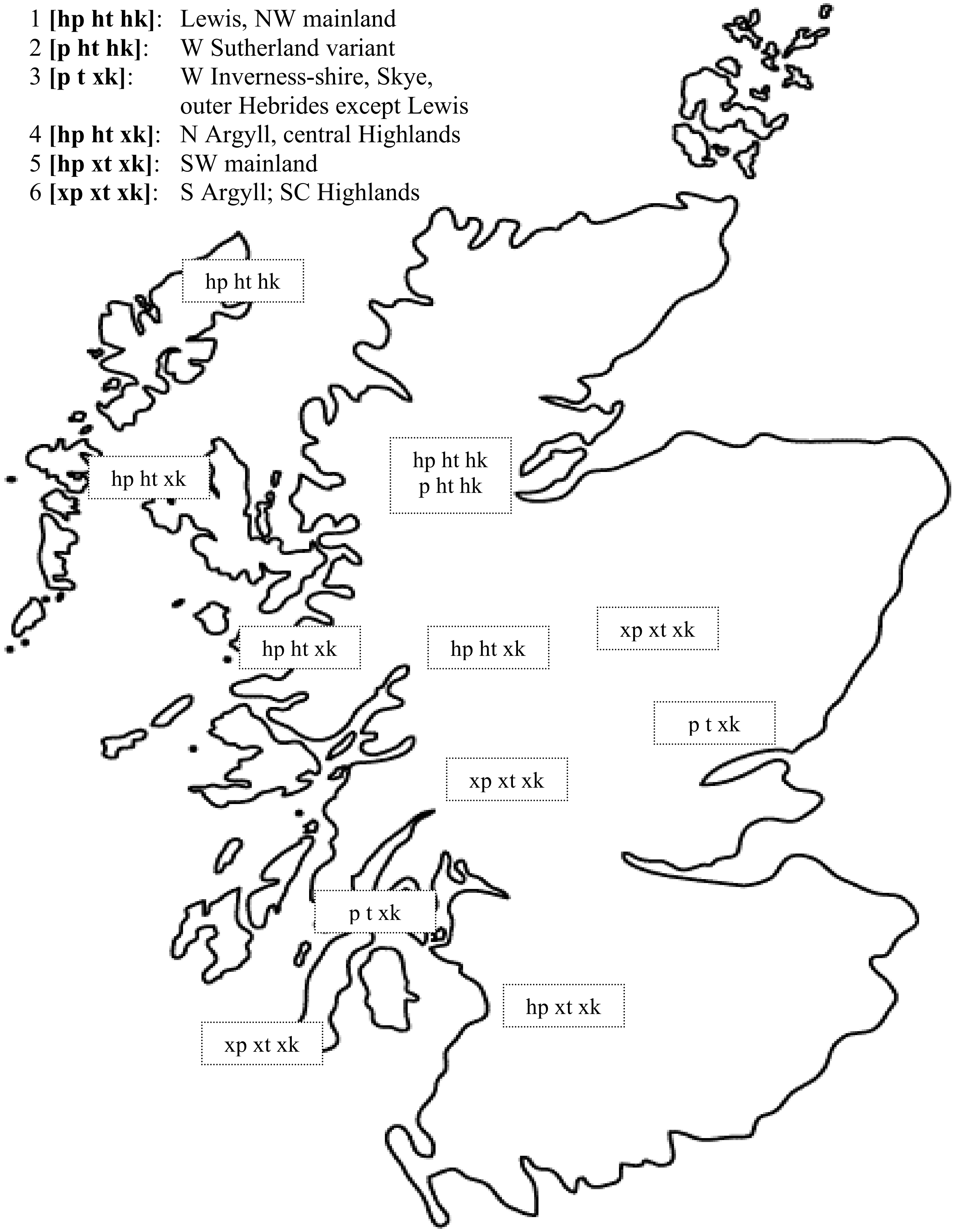
[1] Henceforth, the dental stops will be represented without diacritic for typographic simplicity.
[2] Ladefoged et al. (1998) also identify the palatalized bilabial variants in the Lewis dialect

Upon inspection, two asymmetries in these configurations are evident. The first asymmetry concerns deaspiration, or the loss of preaspiration before certain stops: labial stops most commonly lack preaspiration (west Sutherland; southern Argyll); coronal stops lack preaspiration only if labials do as well (southern Argyll). The second asymmetry concerns buccalization: a velar fricative [x] in place of prototypical glottal [h] is found in four of the six dialects (dialects 3-6). In all four of these dialects, buccalization has affected dorsal stops; in two (northern Argyll, southwest mainland) buccalization also extends to coronal stops; finally, in dialect 4 (northern Argyll), buccalization effects all places of articulation.

These two asymmetries beg explanation. If they are the product of diachronic pressures, as seems likely (and as my labels for them suggest), what is the nature of these pressures—are they phonetic, cognitive, or perhaps both? To answer this question, we must first determine whether these six dialectal forms of preaspiration can be plausibly shown to have developed from a single parent form; we can then explore the possible motivations and avenues for those developments. Unfortunately, no informative records of such a parent form of preaspiration exist. We must then pursue the next best alternative: if a suitably archaic form of preaspiration could be found among the range of modern dialects, it might well provide us with the clues we need.

There are historical, dialectological, and typological reasons to assume that the Lewis dialect (dialect 1) is just such an archaic form, and that the other configurations are derived either from it, or from a very similar early form (as argued by Hansson 2001, Ní Chasaide and Ó Dochartaigh 1984, and Borgstrøm 1974). Most compelling is the historical argument in favor of the Lewis dialect's archaic status. All dialects of Scottish Gaelic feature the cluster /xk/, as in the word *bochd* [boxk] "poor." This cluster has developed from Old Irish /xt/ quite independently of preaspiration; compare the modern Irish form of the word, *bocht* [boxt] (Ó Siadhail 1989). In any of the Scottish Gaelic dialects 3-6 featuring buccalized preaspiration, words like *boc* 'buck' and *bochd* 'poor' are homophonous: both are pronounced [boxk]. On the other hand, in the non-buccalized dialects 1 (Lewis) and 2, these two words contrast: *boc* 'buck' [bohk] and *bochd* 'poor' [boxk]. (I have confirmed this through consultation with speakers of numerous dialects, including Skye, Harris, and Lewis.) To assume that any of the dialects 3-6 are more conservative is to require an unconditioned phonemic split in the Lewis dialect, such that *boc* and *bochd* and similar putative ex-homophones now contrast, while to assume instead that dialect 1 is conservative entails a merger of /hk/ (preaspiration) and /xk/ (the inherited cluster) in the other dialects, a far more likely scenario. (The same arguments hold for dialect 2, on the mainland directly opposite Lewis. However, this dialect has lost preaspiration before [p] and is therefore less conservative than its Lewis counterpart.)

Figure 4.5. Geographic distribution of preaspiration in Scottish Gaelic, by dialect



Dialectally, a /hp ht hk/ starting point allows the most economical pattern of development, since preaspiration in Lewis would thus be minimally distant from all the other forms, requiring for each place of articulation only one step in either direction (buccalization or deaspiration) to derive each of the remaining dialects. To assume than any other dialect represents a conservative form would require an unnecessarily complex pattern of derivation. If one assumes, for instance, that the configuration /xp xt xk/ is the most conservative, then one has to explain an exceedingly complex pattern of development, for instance from /xp xt xk/ > /hp ht hk/ > /p ht hk/ on the one hand, but /xp xt xk/ > /p t xk/ on the other.

Typological evidence leads to the same conclusion. First, glottal preaspiration is the most abundant form cross-linguistically (see the survey in chapter 2). In addition, partly on typological evidence, Kirchner (1998) has proposed the *no half-spirantization* rule for lenition of voiceless geminate stops: his survey revealed no process that could lenite such stops directly to half-spirantized clusters *kk* > *xk*, but Kirchner explicitly permits half-debuccalization processes like *kk* > *hk*, such as seen in Icelandic and as proposed here for Gaelic.

If as the most conservative extant form of Scottish Gaelic preaspiration, the Lewis variant indeed resembles the parent form, then all other varieties of preaspiration in Gaelic must in some way be derivative. Where [xT] occurs in place of [hT], then buccalization must have occurred. Where preaspiration is absent before certain stops, then deaspiration must have occurred (resulting in a partial merger of the aspirated/nonaspirated stop series). Why these two processes should apply asymmetrically is not immediately obvious: what is needed is an explanation for the relatively fortis nature of preaspirated velar stops, and the relatively lenis nature of bilabials. The next two sections of the chapter describe two possible explanations: one rooted in cognition, the other in phonetics.

4.4 Explanations for phonological asymmetries

4.4.1 Hypotheses appealing to analytic bias

In Optimality Theory (Prince & Smolensky), a language's phonological grammar is assumed to consist of a set of preferences about the shape of an output or surface form (so-called "markedness" constraints) on the one hand, and preferences about the kind and degree of relationship between that output and the underlying or input form (or "faithfulness" constraints). These constraints are violable but ranked in language-specific hierarchies. Simply put, if some language features the constraint hierarchy *C1 >> C2*, the language will prefer an output candidate form X that violates the low-ranked constraint 2 but does not violate the higher-ranked constraint 1, in preference to another candidate Y that violates 1 but not 2 (and by implication, over any third candidate Z that violates both 1 and 2). Since the hierarchy can be permuted, it is in principle possible that some language will feature the opposite ranking *C2 >> C1*, and consequently prefer candidate Y over candidate X.

Let us consider a common example. Many languages prohibit voiced obstruents in syllable codas (like Russian and German), while licensing them in syllable onsets. In such languages, underlyingly voiced obstruents occurring in codas may be realized as unvoiced: a hypothetical form /tæb/ may be realized as [tæp], but not the fully faithful form *[tæb]. In OT, this prohibition is conventionally attributed to a markedness constraint *VoicedCoda ("voiced obstruents are not permitted in syllable codas") (Ito & Mester 2003, 1997; Steriade 2001a). If *VoicedCoda in some language outranks the corresponding faith constraint

Ident[±Voice] (whose task is to preserve the underlying voicing feature), then the language will prohibit voiced coda obstruents, like German. If on the other hand, Ident[±Voice] is ranked above *VoicedCoda, then the language will permit voiced obstruents in that position (all else being equal), like English.

Devoicing the obstruent is only one logically possible way to "repair" a potential violation of *VoicedCoda; there are several others. The language could hypothetically elect to delete the offending /b/ altogether, yielding [tæ]; turn it into a nasal [tæm] or a glide [tæw]; epenthesize a vowel after it and so make the /b/ an onset [tæba]; or even swap the /b/ with the preceding onset through metathesis [bæt]. In OT terms, a language would only need to rank the relevant faith constraint prohibiting each of these adjustments below *VoicedCoda. Classic Optimality Theory claims that any constraint ranking, and thus any of the associated output forms, should in principle be possible. In other words, the theory enables a "factorial typology," realized as a spectrum of grammars across which each possible ranking of a set of constraints is exhibited, one by one. Thus, we should be able to find languages employing metathesis, deletion, nasalization, and so forth in order to satisfy *VoicedCoda.

However, in many cases, factorial typologies produce a potentially troubling result, predicting unattested grammars. In the case of *VoicedCoda, the only attested repair strategy seems to be devoicing—languages systematically ignore the other possible repairs (Steriade 2001a). This is not the only such example. For another: in many languages, the sequence of a nasal followed by a voiceless obstruent is prohibited (through the markedness constraint *NC). Attested repairs include voicing the obstruent, deleting the nasal, deleting the obstruent, and replacing the nasal with its oral counterpart, but exclude metathesis and epenthesis, though these repairs should be equally effective (Pater 1996, Myers 2002).

This is a sticky wicket for Optimality Theory: the predictive capacity of the theory appears to be excessively powerful, leading to “overgeneration” or “the Too Many Solutions” problem. Many scholars are troubled by this problem. If the “central aim of linguistic theory is to account for significant linguistic generalizations” (Coetzee 2002, p.1), should not theory be able to accurately predict typology, including all its gaps and irregularities? Accordingly, a diverse range of remedies have been proposed, including *preference constraints* (Coetzee 2002), *targeted constraints* (Wilson 2001), and the *P-map hypothesis* (Steriade 2001a, 2001b).[3] The common goal of these proposals is to constrain in some way the predictive power of the theory, typically by invoking cognitive biases of one sort or another that favor the repair patterns reflected in attested typologies.

Coetzee (2002) suggests that there be invariant grammatical encoding of typological tendencies, by means of “Preference Constraints.” Preference constraints do not evaluate candidates, but rather constraint rankings; violations penalize realizations that are typologically rare or unattested. For instance, it is typologically rare for a language to have voiced aspirated stops but not voiceless unaspirated ones (Maddieson 1984). Consequently, a language featuring such a stop inventory would violate not only the markedness constraint militating against voiced aspirated stops [$*d^h$], but also the preference constraint against a ranking that permitted them to appear without the voiceless version, [$*d^h >> *t^h$]. In aggregate, then, the additional violations incurred by typologically dispreferred phonological patterns would enforce their continued rarity.

[3] Interested readers are referred to Blumenfeld (2006) for a comprehensive review of theoretical responses to the *Too Many Solutions* problem.

Wilson (2001) is a reaction to the cross-linguistic generalization that in biconsonantal clusters undergoing simplification, the first member of the cluster will delete, not the second:

(10) *First Consonant Deletion* (Wilson 2001, p. 148) Across languages, deletion processes that apply to intervocalic biconsonantal clusters consistently delete the *first* consonant (schematically, $VC_1C_2V > VC_2V$).

Again, this is an overgeneration problem. The simplification process is conventionally analyzed as a response to a markedness constraint which may be called *ClusterCondition, which disprefers sequences of two or more consonants. However, the constraint is incapable in principle of dictating which member of the cluster will undergo deletion; in other words, there is nothing to prevent repairs to the constraint from violating Wilson's principle. Wilson points out (drawing from Steriade 1997) that the first consonant in a cluster is perceptually "weaker" than the second, since it lacks the transition cues available to a consonant that releases into vowel. In response, Wilson proposes a category of *targeted constraints* which evaluate pairs of candidates, preferring those which yield outputs containing perceptually "strong" segments (i.e. VC_2V), while penalizing candidates containing "weak" segments (VC_1V).

Finally, Steriade (2001a, 2001b) proposes that the excessive predictive power of factorial typology may be constrained through the *P-map*, a component of the phonological grammar which incorporates speakers' knowledge of the "relative perceptibility of different contrasts, across the different contexts where they might occur" (2001a, p. 1). Consider the markedness constraint $*[+Voice\_]_{word}$ (a version of the constraint *VoicedCoda discussed above), which stipulates that voiced obstruents should not occur word-finally. As we have seen, repairs to this constraint seem to be limited, cross-linguistically, to devoicing the offending word-final obstruent. Unattested repairs include nasalization, gliding, or deletion of the underlyingly voiced final obstruent. The P-map hypothesis argues that preferred repairs will be those that entail the smallest perceptual departure from the underlying target form. Thus, the asymmetry in attested repairs to *[+Voice_]$_{word}$ occurs because the unattested repairs ([m], [w], [Ø], etc.) are perceptually less similar to the target [b] than the attested variant [p]. In Optimality Theoretic terms, this means that perceptual scales are capable of motivating fixed rankings of faithfulness constraints: those constraints which prohibit the unattested repairs (deletion, gliding, metathesis, etc.) must always outrank that which protects the affected obstruent from devoicing, and therefore candidates featuring such repairs are never realized.

Moreover, Steriade has explicitly designed the P-map hypothesis to account for between and within-speaker variability. According to Steriade, speakers may be "actively concerned with avoiding *perceptible* deviations from established lexical norms, but they are otherwise not averse to linguistic innovation, insofar as it remains covert" (2001a, p. 13). In a related paper, she stipulates that "if an innovative speaker contemplates articulatory simplification, . . . it is the P-map that will identify the optimal target of simplification: the consonant whose modification is least likely to be detected by his interlocutors" (Steriade 2001b, p.236). Thus, in order to test the hypothesis, researchers should demonstrate not only that fixed rankings resolve overgeneration problems like that above, but also that such rankings are additionally motivated by a congruent pattern of speakers' similarity judgments.

In sum, there are several theoretical responses to the Too-Many-Solutions problem which attribute observed typological gaps to cognition. However, there are also those who argue that such cognitive accounts are superfluous. Instead, they argue, typology is first and foremost a product of diachronic forces; cognitive explanations should be sought only when diachronic explanations cannot be found.

4.4.2 A channel bias-rooted alternative

A range of scholars have asserted that it is unnecessary—indeed, a bad idea—to modify phonological theory to allow it to distinguish attested from unattested patterns via synchronic grammar: “We should not simply assume a priori that the phonological grammar contains such information [concerning phonetic patterns] because it is possible to model it in such a way” (Barnes 2002: 353). Instead, many occupants of this camp argue that some sound patterns are unattested, not because there is a cognitive predisposition against them, but because the preconditions necessary for the innovation of such patterns seldom or never occur: “gaps in factorial typology do not constitute a problem for the formal theory of OT, but rather represent a manageable challenge for the theory of phonologization” (Myers 2002: 2).

Indeed, a number of scholars have relegated to the back seat any efforts to include phonetic information in a phonological grammar, as Steriade’s P-map (2001a, 2001b) and Wilson’s targeted constraints (2001) explicitly attempt, or have outright rejected such efforts. Blevins (2004) argues that “[p]rincipled diachronic explanations for sound patterns have priority over competing synchronic explanations unless independent evidence demonstrates . . . that a synchronic account is warranted” (p.237), while Ohala (2005) is more forceful: “[t]he ‘phonetic naturalness’ requirement in phonological grammars should be re-examined and probably abandoned” (p.1).

There is a common point of departure among these criticisms: the idea that many if not all phonological patterns can be attributed, not to biases in cognition, but to the diachronic operation of aerodynamic and articulatory pressures, or "properties of the communication channel between speaker and listener" (Moreton 2008, p. 86). Human languages, it goes without saying, are subject to tremendous within and between-speaker variation. There are nevertheless certain constraints on this variability, imposed by the structure and operation of the human vocal tract and the physics of air movement. Since these strictures apply to all human speakers, they will tend to produce the same outcomes across languages. According to the theory of phonologization, recurrent sound changes have their origin in these pressures: "recurrent synchronic sound patterns have their origins in recurrent phonetically motivated sound change" (Blevins 2004, p.8).

A typical account of the process is as follows. A speaker produces some realization of a phonological form /F1/, which is phonetically ambiguous: it sounds both like [F1] and [F2], and is therefore consistent with not one but two underlying representations. The listener receives this ambiguous speech signal, but misparses it, concluding that the speaker meant /F2/ instead of /F1/. For instance, tonogenesis is thought to have evolved by this process (§4.2.3 above) (Svantesson & House 2006; Hombert, Ohala, & Ewan 1979; Hombert 1978). Since voiced consonants trigger a drop in the F0 of the following vowel, and voiceless consonants trigger a rise in F0, an underlying voicing contrast in consonants is accompanied by a correlated pitch contrast in the surface forms: it is ambiguous which cue is intended, and which is a by-product. The consequence is that a listener could readily misparse an intended voicing contrast instead as a tone contrast; if this misparsing happens regularly enough, the voicing contrast could be rephonologized instead as contrastive tone.

Alternatively, misparsing may lead not to surface-level confusion between underlying features, but to a localized failure to realize an underlying contrast. If the failure is sufficiently systematic, then it may be internalized by language learners as a phonotactic rule. For instance, synchronic word-final devoicing rules could evolve, not as a response to an innate constraint against word-final voicing contrasts, but because the cues to a voicing contrast in that environment are inherently weak, relative to word-initial or medial position. In medial position, for instance, Steriade (1997, p.6) identifies seven available cues, but only four in word-final position:

(11) *Available cues to medial voicing contrast* /aba/ < > /apa/*:* closure voicing, closure duration; V_1 duration; F1 values in V1; burst duration and amplitude; VOT value; F_0 and F1 values at the onset of voicing in V2.

(12) *Available cues to final voicing contrast* /ab/ < > /ap/*:* closure voicing; closure duration; V duration; F1 values in V ; burst duration and amplitude.

The relative scarcity of available cues in final position may mean that the listener has a more difficult time accurately parsing contrastive voicing in word-final position, and in turn may not reproduce it in his/her own production. If such a failure to maintain the voicing contrast in the word-final environment is widespread in the speaker community, it may assume the status of a phonological rule, such that underlyingly voiced obstruents are consistently realized as voiceless word-finally.

Thus, there is a clear phonetic basis to the widespread word-final devoicing rule that yields [tæp] from Steriade's underlying /tæb/. But, as Myers (2002) suggests, the unattested patterns—nasalizing or gliding the underlying voiced stop, metathesis, deletion—have no corresponding phonetic basis (no *precursor*, in other words), and so are unlikely to emerge as synchronic phonological rules. Since the asymmetry can be explained by facts emergent in the phonetics, many scholars feel that it is misguided and unnecessary to posit mechanisms within a generative theory of phonology that do essentially the same work.

In sum, there are two competing strategies to account for phonological asymmetries. The first camp argues that typology can and should be attributed to cognition, even to the extent of attributing an abstract knowledge of production and perception to the phonological grammar. The second argues by contrast that cognition need not be invoked to explain such asymmetries, at least not when they can be readily explained through the diachronic operation of phonetic and aerodynamic forces. The balance of this chapter will be devoted to assessing the capacity of the cognitive and diachronic accounts to account for the asymmetries observed in Scottish Gaelic preaspiration: section §4.5 presents a classic Optimality-Theoretic account, showing that Gaelic preaspiration is an example of the Too-Many-Solutions problem, and then demonstrates that the P-map Hypothesis is capable of resolving the problem. Section §4.6 then considers a diachronic account of the Gaelic problem, employing data from a set of production studies.

4.5 Scottish Gaelic preaspiration: too many solutions

Recall from section §4.3 that deaspiration in Scottish Gaelic always commences in labial stops and works backward, while buccalization commences in velar stops and works forward. There is no obvious a priori reason to expect these mutually opposed asymmetries. Why should either process be at all finicky about place of articulation? I show that a naive

Optimality Theoretic model of the two asymmetries significantly overgenerates, predicting a range of unattested configurations of these two processes. This overgeneration is then successfully constrained through a modified OT model employing an extension to classic Optimality Theory, the P-map (Steriade 2001a, 2001b), which proposes that rankings of faithfulness constraints are linked to perceptual scales, in effect fixing the rankings of those constraints and preventing the overgeneration that characterizes an unconstrained OT model. Crucially, the fixed rankings employed by the P-map model entail corresponding perceptual scales. Empirical evidence for these perceptual scales is provided by the perception experiment described previously in Chapter 3.

4.5.1 Preaspiration as a marked structure

Both phonetic and typological arguments have been advanced to support the proposition that preaspirated stops are highly marked relative to postaspiration. The first line of argument is weaker than the second. Some scholars have argued that preaspiration is a phonetically weaker feature than postaspiration, notably Silverman (2003, 1997), Kingston (1990), and Bladon (1986) (see §3.3. The claim is that postaspiration benefits from the perceptual boost garnered by piggybacking on the high-energy release of a stop; meanwhile, preaspiration enjoys no such advantage. Since the release of a stop is accompanied by a high-volume, high-pressure burst (the argument continues), this point in the articulatory string is well suited to convey contrastive information. Hence the robustness of the postaspiration cue: it is situated in this aerodynamically ideal position. But preaspiration is located at the tail end of a sonorant and, crucially, just before the stop closure, where the volume and pressure of the airstream has achieved a near-minimal state, and is thus (it is supposed) not an ideal cue for encoding contrasts.

However, chapter 3 of this dissertation describes a perception experiment conducted to test this hypothesis; the experiment found that there was no significant difference in participants' abilities to distinguish preaspiration and postaspiration. Further, Pind (1999s) shows Bladon's related claim of "on/off asymmetry" (i.e. that it is easier for listeners to detect the offset of a stimulus than its onset) is empirically unsupported. Both studies thus cast doubt on this "perceptual inferiority hypothesis."

Much more persuasive is the typological argument. First, there is no question that preaspirated stops segments are exceedingly rare; chapter 2 of this dissertation identifies approximately two dozen confirmed examples, suggesting that preaspirated stops occur in fewer than one percent of the world's languages. (See also the typological surveys in Silverman 2003 and Helgason 2002.) Compare this number to the widespread occurrence of postaspirated stops, which are found in approximately a quarter of the world's languages, based on the UPSID database (Maddieson and Precoda 1989). Second, there exists an implicational hierarchy between preaspirated and postaspirated stops: preaspirated stops nearly always are present only when postaspirated stops are also present; alternate with postaspirated stops according to position—preaspirated in medial and final position, postaspirated in initial position[4]; and contrast with voiceless unaspirated stops.

In Optimality Theoretic terms, these typological facts imply the existence of a constraint militating against preaspiration, which may be referred to as *[hT]. Both deaspiration and buccalization can be framed as strategies for avoiding violations of this

[4] With one exception, Bora features word-initial preaspirated stops (Aschmann 1993).

constraint. However, the two repair strategies to not apply across the board in all places of articulation in several dialects, instead applying only to subsets of stops (e.g. bilabial stops in dialect 2, velar stops in 3), while leaving the others unaffected.

If we assume that *[hT] in fact represents a set of place-specific anti-preaspiration constraints which can be ranked individually, this allows us to address these place-based asymmetries: *[hp], *[ht], *[hk], for instance. However, freely ranking these place-specific constraints leads to overgeneration: more grammars are predicted than attested. Placing them in fixed rankings, on the other hand, undergenerates, predicting too few grammars. These facts are illustrated in the tableaux below, in which violations of *[hT] are assessed by assigning one star for each sequence of voiceless glottal fricative + voiceless oral stop in the output.

If we assume that the original configuration of SG preaspiration was /hp ht hk/ as in dialect 1 (Lewis), then *[hT] must be ranked below the relevant faithfulness constraints in order to preserve prototypical preaspiration. On the other hand, deriving the fortition in dialect 4 (/xp xt xk/) requires that *[hT] occupy a rank above IDENT[place], so that non-glottal frication is licensed, but with a higher-ranked MAX to prohibit deaspiration. These observations are reflected in 13 (a) and 13 (b) respectively:

(13) a. Dialect 1 [hp ht hk] (Lewis)

/hT/	MAX	ID[place]	*[hT]
☞ hT			*
xT		*!	
T	*!		

b. Dialect 4 [xp xt xk] (Perthshire)

/hT/	MAX	*[hT]	ID[place]
hT		*!	
☞ xT			*
T	*!		

Other configurations of SG preaspirated stops require that place-specific versions of *[hT] be ranked individually. For instance, dialect 3 requires that only *[hk] be ranked above IDENT[place], while *[ht] and *[hp] remain low-ranked; MAX remains high-ranked to prevent deaspiration (14a). Problematically, the same relative ranking of the members of *[hT] yields an unattested configuration should MAX be ranked lower than IDENT[place] (14b).

(14) a. Dialect 3 /hp ht xk/ (Harris, Skye) b. unattested */hp ht k/

/hk/	MAX	*hk	ID[place]	*hp	*ht
☞ xk			*		
hk		*!			
k	*!				
/hp ht/					
p t	*!				
xp xt			*!		
☞ hp ht				*	*

/hk/	*hk	ID[place]	MAX	*hp	*ht
xk		*!			
hk	*!				
☞ k			*		
/hp ht/					
p t			*!		
xp xp		*!			
☞ hp ht				*	*

Similarly, dialect 2 requires that *[hp] be individually promoted to a rank above MAX to allow place-specific deaspiration, but below IDENT[place] (15a). But if *[hp] is ranked above IDENT[place], the unattested configuration /xp ht hk/ is generated (15b). Thus, we have considerable overgeneration without having yet considered alternative repairs such as homorganic frication (/fp st xk/; recall preaspiration in Fox) or substitution of postaspiration for preaspiration, which would also satisfy *[hT].

(15) a. Dialect 2 /p ht hk/ (W. Sutherland) b. unattested */xp ht hk/

/hp/	ID[place]	*hp	MAX	*hk	*ht
☞ p			*		
xp	*!				
hp		*!			
/ht hk/					
t k			*!		
xt xk	*!				
☞ ht hk				*	*

/hp/	*hp	MAX	ID[place]	*hk	*ht
p		*!			
☞ xp			*		
hp	*!				
/ht hk/					
t k		*!			
xt xk			*!		
☞ ht hk				*	*

Alternatively, it may be that place-specific versions of the faith constraints MAX and IDENT are interacting with a unitary *[hT]. Since preaspiration of velar stops is most resistant to loss in Gaelic, and that of bilabials least, this would imply a hierarchy like MAX[hk] >> MAX [ht] >> MAX[hp]; meanwhile, an opposing hierarchy would obtain for IDENT, since preaspiration of velar stops is most vulnerable to buccalization, that of bilabial stops least: ID[hp] >> ID[ht] >> ID[hk]. Fixed rankings of these constraints would be capable of producing the two asymmetries without overgeneration: buccalization could never affect bilabials unless dentals and velars were also affected (as attested), and deaspiration could never affect dentals and velars unless bilabials were also affected (again, as attested). This is reflected in the following two example tableaux. In (16), IDENT[hk] is ranked below *[hT], but MAX[hk] is ranked above *[hT], permitting buccalization and disallowing deaspiration in the velar environment, while IDENT[hp] and IDENT[ht] are both ranked above *[hT], protecting prototypical preaspiration in bilabial and dental environments, to yield /hp ht xk/ (dialect 3). Progressively demoting IDENT[ht] and IDENT[hp] below *[hT] will allow buccalization to advance to dental and bilabial stops. To achieve an unattested grammar in which buccalization commences with labial (or dental) stops, IDENT[hp] or

IDENT[hp] must be demoted below *[hT] while IDENT[hk] is left above—but this would violate the fixed ranking.

(16) Dialect 3 /hp ht xk/ (Harris, Skye) via ranked faithfulness constraints

/hk/	ID[hp]	ID[ht]	MAX[hk]	MAX[ht]	MAX[hp]	*hT	ID[hk]
k			*!				
☞ xk							*
hk						*!	
/ht/							
t				*!			
xt		*!					
☞ ht						*	
/hp/							
p					*!		
xp	*!						
☞ hp						*	

In (17), ranking all IDENT constraints above all MAX constraints prohibits buccalization in any environment, and ranking MAX[hk] and MAX[ht] above *[hT] prohibits deaspiration in all environments except before bilabial stops, yielding dialect 2 /p ht hk/. (Demoting MAX[ht] below *[hT] will allow deaspiration of dental stops, and demoting ID[hk] below *[hT] would allow fortition in velars, yielding dialect 6 /p t xk/.)

(17) Dialect 2 /p ht hk/ (West Sutherland) via ranked faithfulness constraints

/hk/	ID[hp]	ID[ht]	ID[hk]	MAX[hk]	MAX[ht]	*hT	MAX[hp]
k				*!			
xk		*!					
☞ hk						*	
/ht/							
t					*!		
xt		*!					
☞ ht						*	
/hp/							
☞ p							*
xp	*!						
hp						*!	

As in the previous example, to reverse the asymmetry so that velars or dentals deaspirate first would require violation of the hierarchy: MAX[hk] or MAX[ht] would have to be lower-ranked than MAX[hp].

While effectively resolving the earlier overgeneration problem, these opposing faithfulness hierarchies seem ad hoc: there is no *a priori* reason that the rankings of place-specific versions of IDENT and MAX should be fixed in this way. But without fixed rankings, the overgeneration problem is unresolved.

4.5.2 Extending Optimality Theory: the P-map

It is conceivable that such hierarchies could be motivated by perception. Perhaps the preaspiration in [hp] sounds most like Ø, that in [hk] least; meanwhile, the preaspiration in [hk] may sound most like [x], that in [hp] least. Formalized in the grammar, these two gradient perceptibility effects would yield the hierarchies in MAX and IDENT, respectively. The P-map hypothesis (Steriade 2001a, 2001b) is one means by which such formalization could take place. In this section, I will demonstrate that the classic OT model developed above may be extended via the P-map to allow the projection of faithfulness constraints, and their ranking, to be determined by perceptual factors. This account successfully models the two asymmetries in Scottish Gaelic preaspiration while largely resolving the overgeneration problem.

The model is, however, fundamentally based on perception, since it relies crucially on the phonetic factors discussed earlier. Recall that the P-map is hypothesized to be a component of the phonological grammar which incorporates speakers' knowledge of the "relative perceptibility of different contrasts, across the different contexts where they might occur" (Steriade, 2001a, p. 1). The P-map stipulates that the preferred repair for a constraint violation be that which involves the minimal perceptual departure from the underlying target form. Translated into the terms of the P-map, the fortition asymmetry would be expressed this way: *the perceptual distance between [h] (the target) and [x] (the potential repair) is least before [k], and greatest before [p]*. The deaspiration asymmetry would be the converse: *the perceptual distance between [h] (the target) and [Ø] (the potential repair) is least before [p], and greatest before [k]*. These asymmetries are converted to Steriade's notation in (18) and (19); the corresponding hypothetical P-map fragment is illustrated in Figure 4.6.

(18) Δ(h - x) V_ p >> Δ(h - x) V_ t >> Δ(h - x) V_ k

(19) Δ(h - Ø) V_ k >> Δ(h - x) V_ t >> Δ(h - x) V_ p

Evaluated segments:	*context:*		
	V_p	V_t	V_k
[h] < > [x]	h/x	h/x	h/x
[h] < > [Ø]	h/Ø	h/Ø	h/Ø

Figure 4.6. P-map fragment: perceptual similarity of [h] to [x] and [Ø] by context. Degree of difference is indicated by letter size.

Since the essential insight of the P-map is that candidates are evaluated by their degree of departure from the target, the P-map will be expressed in OT terms by means of correspondence constraints, as Steriade demonstrates in her discussion of directional asymmetries of place assimilation (2001b). The hierarchies in (18) and (19) would yield these constraint rankings:

(20) ID[h-x]/V_ p >> ID[h-x]/V_t >> ID[h-x]/V_k

(21) MAX[h-Ø]/V_ k >> MAX[h-Ø]/V_t >> MAX[h-Ø]/V_p

Earlier, I illustrated how the overgeneration problem could be largely solved by postulating place-specific forms of MAX and IDENT arranged in fixed hierarchies. Now, however, we can see how such constraints and their fixed rankings might be motivated: the constraints in (20) and (21) amount to elaborations of the provisional place-specific MAX and IDENT constraints posited previously, fixed in the same hierarchies. The tableaux in (16) and (17) are reproduced below in (22) and (23) with the updated constraint labels. Again, demoting a place-specific version of IDENT below the corresponding form of MAX and *[hT] yields progressive fortition, commencing with /hk/ and moving forward, as in (22); reversing the relative ranks of IDENT and MAX yields progressive deaspiration, commencing with /hp/

and moving rearward, as in (23). Because the place-specific forms of IDENT and MAX are ranked in a fixed order, neither fortition nor deaspiration can exhibit any other asymmetrical pattern.

(22) Dialect 3 /hp ht xk/ (Harris, Skye) via the P-map

/hk/	ID[h-x]/V_ p	ID[h-x]/V_t	MAX[h-Ø]/V_ k	MAX[h-Ø]/V_t	MAX[h-Ø]V_ p	*hT	ID[h-x]/V_k
k			*!				
☞ xk							*
hk						*!	
/ht/							
t				*!			
xt		*!					
☞ ht						*	
/hp/							
p					*!		
xp	*!						
☞ hp						*	

(23) Dialect 2 /p ht hk/ (W. Sutherland) via the P-map

/hk/	ID[h-x]/V_ p	ID[h-x]/V_t	ID[h-x]/V_k	MAX[h-Ø]/V_ k	MAX[h-Ø]/V_t	*hT	MAX[h-Ø]V_ p
k				*!			
xk		*!					
☞ hk						*	
/ht/							
t					*!		
xt		*!					
☞ ht						*	
/hp/							
☞ p							*
xp	*!						
hp						*!	

4.5.3 The P-map and perceptual scales: empirical evidence

The P-map analysis is driven by perceptual scales: it is “a mental representation of the degree of distinctiveness of contrasts in various positions” (Steriade 2001a, p. 9), which can in principle be tested through confusion studies that test the relative distinctiveness of contrasts in different contexts. In Chapter 3, I described a perception study designed to assess the relative confusability of postaspirated and unaspirated voiceless stops on the one hand, and of preaspirated and unaspirated voiceless stops on the other, in order to establish whether a notable differential in the confusability of these two sets could explain the much greater typological abundance of postaspirated stops (ultimately concluding that such an hypothesis was untenable). However, the study is also germane to the present question, insofar as the stimuli used in that experiment were selected not only to represent different kinds of aspiration, but additionally, to test the relative confusability of aspiration contrasts in various places of articulation. This aspect of the study design allows us to compare e.g. the confusability of the contrasts [hp] < > [p], [ht] < > [t], and [hk] < > [k]. The P-map analysis predicts that the first of these contrasts, between preaspirated and unaspirated labials, should be significantly harder for subjects to detect than that between coronals or especially dorsals, a hierarchy expressed formally in item (21), reproduced here as (24).

(24) MAX[h-Ø]/V_ k >> MAX[h-Ø]/V_t >> MAX[h-Ø]/V_p

A full description of the experiment is available in §3.4, but to summarize: Native speakers of Lewis Gaelic (the /hp ht hk/ dialect) were recorded reading non-word stimuli designed to contrast preaspirated and unaspirated tokens in medial and final position, across the labial, coronal, and dorsal places of articulation. Preceding vowels were either [a] or [u]. Target stimuli constructed included those in Table 4.1:

tahpa	tahta	tahka	tahp	taht	tahk
tuhpa	tuhta	tuhka	tuhp	tuht	tuhk

Table 4.1. Stimuli used for perception study from chapter 3

Participants included 9 Scottish Gaelic, 12 Polish, and 11 American English speakers. Multiple speaker populations allowed the study to identify language-specific patterns—though if the P-map is part of UG, all the speaker populations should respond reasonably uniformly. The Gaelic speakers were included because of their native experience with a preaspirated/unaspirated contrast, the Polish speakers because they have little or no L1 experience with aspiration contrasts at all (Gussman 2008), and the English speakers have L1 experience with a *post*aspiration contrast only. Numerical results are summarized in Table 4.2.

% Errors	ahk-ak	aht-at	ahp-ap		ahka-aka	ahta-ata	ahpa-apa
GAELS	9/36	8/45	16/36		7/54	10/45	14/54
POLES	23/48	21/60	27/48		21/72	18/72	18/72
ANGLES	22/44	22/55	19/44		27/66	25/66	28/66
	uhk-uk	uht-ut	uhp-up		uhka-uka	uhta-uta	uhpa-upa
GAELS	6/36	7/45	16/36		6/54	11/54	11/54
POLES	11/48	13/60	24/48		9/72	11/72	23/72
ANGLES	16/44	19/55	22/44		17/66	13/66	26/66

Table 4.2. Error rates distinguishing preaspirated and unaspirated tokens. Numbers in bold represent % errors, also presented as the number of errors over the number of trials.

The error rates were tested via a generalized linear model (Table 4.3). Two broad patterns are significant and relevant to this discussion. First, place of articulation is a main effect.

	Parameter	Estimate	Standard Error	95% Confidence Limits		Z	Pr > |Z|
	Intercept	-0.8267	0.0920	-1.0070	-0.6464	-8.99	<.0001
a.	l1	-0.4210	0.1531	-0.7211	-0.1208	-2.75	0.0060
b.	l2	0.0171	0.1194	-0.2169	0.2510	0.14	0.8863
c.	p	0.3240	0.0523	0.2215	0.4266	6.19	<.0001
d.	c1	0.1761	0.0410	0.0957	0.2565	4.29	<.0001
e.	g1	-0.2163	0.0524	-0.3191	-0.1135	-4.13	<.0001
f.	g2	-0.1503	0.0686	-0.2849	-0.0158	-2.19	0.0285
	l1_p	-0.0188	0.0706	-0.1571	0.1195	-0.27	0.7901
	l2_p	0.1047	0.0862	-0.0643	0.2737	1.21	0.2248
	l1_c1	-0.0984	0.0661	-0.2279	0.0310	-1.49	0.1361
	l2_c1	0.0777	0.0564	-0.0329	0.1883	1.38	0.1686
	c1_p	-0.0060	0.0394	-0.0831	0.0712	-0.15	0.8798
g.	g1_l1	-0.1999	0.0792	-0.3552	-0.0446	-2.52	0.0117
	g1_l2	0.0453	0.0705	-0.0929	0.1835	0.64	0.5204
	g2_l1	0.0440	0.1025	-0.1569	0.2449	0.43	0.6675

Table 4.3. General linear model of results of perception study. Intercept is English speakers, medial position, labial place of articulation.

Item (e) in the table tells us that error rates in condition *g1* (i.e. [k]) are significantly lower than the reference category (i.e. [p]). Item (f) tells us that error rates in condition *g2* [t] are also lower, though not as much as [k] is. In short, preaspirated and unaspirated stops are least confusable if dorsal, somewhat more confusable if coronal, and most confusable if labial—precisely what the P-map entails.

The second hierarchy (reproduced in item (25)), reflecting the degree of hypothesized perceptual difference between glottal and velar fricatives across the labial, coronal, and dorsal places of articulation cannot be addressed by this perception study, but a very similar study could be designed and carry out to test the hierarchy.

(25) Δ(h - x) V_ p >> Δ(h - x) V_ t >> Δ(h - x) V_ k

In sum, the P-map model expounded here is effective in resolving the overgeneration problem identified in §3. The model motivates the necessary fixed rankings by postulating that there are corresponding perceptual hierarchies; a perception experiment, in turn, substantiates at least one of these hierarchies.

4.6 Testing the channel bias/diachronic account

Though the P-map account in 4.5 successfully resolves the Too-Many-Solutions problem posed by Scottish Gaelic preaspiration, it remains to evaluate the channel bias/diachronic account in its turn. In this section, I evaluate this alternative to the P-map account of the place-based asymmetries in Scottish Gaelic. The principal source of evidence consists of a series of production studies of Gaelic preaspiration, which are supplemented by production data from Icelandic and Tohono O'odham. I show that the fundamental predictions of the diachronic account are borne out, in that there are clear phonetic features of Gaelic preaspiration which could serve as precursors the place-based asymmetries in its typology. However, the P-map account is shown in the long run to be the more elegant solution, since it accounts not only for the dialectal variation seen in Gaelic, but also for the patterns of within and between-speaker variation revealed in the production data. The channel bias/diachronic hypothesis is incapable, in its current form, of accounting for this variation.

4.6.1 Scottish Gaelic: first production study

According to Myers (2002) overgeneration does not constitute a flaw in Optimality theory which requires a remedy like the P-map. Rather, gaps in factorial typology are of considerable theoretical value, because they naturally provoke linguists to ask why some rankings should be attested while others are not, and thus highlight fruitful avenues for research. Because, Myers asserts, sound change is in the main driven by misperception, attested rankings illustrate not only what phonological configurations are likely to be misheard (marked configurations), but what they are likely to be misheard as (attested repairs): “attested cases are ones that arise out of a perceptual reinterpretation of a phonetic pattern, while the unattested cases are ones that do not correspond to a natural phonologization of a phonetic pattern” (Myers 2002, p. 28). According to Myers, Ohala (2005), Barnes (2002), and others, to ask that phonological theory account formally for these phonetic tendencies is unnecessary, undesirable, and redundant.

By Myers’ rationale, then, the asymmetries in Scottish Gaelic preaspiration should be derived from phonetic precursors present in the parent language. We have no direct access beyond written texts to the parent language from which the modern dialects of Gaelic have descended. But if the Lewis dialect is indeed conservative, as I argued in §4.3, then it is a reasonable place to look for such precursors. This section describes a production experiment conducted in order to search for them; the experiment's results are discussed in §5.

4.6.1.1 Hypotheses

Myers (2002), Ohala (2005, 1997), and Blevins (2004) argue that phonetically motivated misperception is a principal engine of sound change. Hence, the phonetic factors relevant to the observed typology of Gaelic preaspiration are likely to be those which render preaspirated stops vulnerable to misperception. These precursors may take varying forms. For instance, the preaspiration cue in [hp] may be shorter than in [hk], making the former less prominent than the latter, and hence easier to miss (as suggested by Ní Chasaide 1985). The result may have been that [hp] was readily mistaken for [p], while [hk] was not prone to be misheard as [k]. Indeed, a long, robust [hk] may even have been interpreted as a token of /xk/ (for reasons I will describe in §4.6.6). This leads to my first hypothesis:

(26) *Place-sensitive duration*: place of articulation will affect the duration of the preaspiration cue. The cue will be longest in velar stops, shortest in bilabial stops: [hk] >> [ht] >> [hp].

In accordance with Myers' argument, there also should be no precursors to unattested repairs to *[hT] in the parent language, e.g. homorganic frication aside from [xk], substitution of postaspiration for preaspiration, or outright deletion of preaspirated stops. This is my second hypothesis:

(27) *Restricted precursors*: there should be no phonetic forms which do not correspond to phonologized configurations of preaspiration in Gaelic, e.g. homorganic buccalization [fp st], postaspiration [p^h t^h k^h], or deletion of preaspirated segments.

Confirmation of these hypotheses will constitute strong support for the channel bias argument: the typology of sound change can be traced to the diachronic operation of phonetic factors.

4.6.1.2 Participants, stimuli

Eight speakers representing dialects areas 1 (/hp ht hk/) and 3 (/hp ht xk/) were recruited. These two areas were chosen because they either represent the prototypical form of preaspiration (as argued in §2), or a form minimally distant from it while still including reflexes of historical preaspiration at all places of articulation. All informants were native speakers of Scottish Gaelic, were literate in the language, and spoke it regularly. All possessed full dentition, and were without impediments to speech. They were distributed demographically as follows:

- Dialect area 1:
  - 4 speakers of Lewis Gaelic: 1 male, elderly; 3 female, 2 middle-aged, 1 in 20's
- Dialect area 3:
  - 2 Harris speakers: 1 middle-aged male, 1 female in 20's
  - 1 Benbecula speaker, male in 20's
  - 1 Skye speaker, female in middle age

Stimuli were selected in order to exemplify postaspirated and unaspirated stops in initial position, and preaspirated and unaspirated stops in medial and final position, in the labial, coronal, and dorsal places of articulation, and in the environment of phonologically short and long vowels. This created a total of 36 conditions (Table 4.4): 2 X ± aspirated X 3 positions X 3 places X 2 ± long V = 36. I made no effort to achieve a balanced distribution of vowel qualities, but did select stimuli that contained both long and short vowels. Because of the pronounced tendency for the high front vowel to palatalize coronals stops in SG, I deliberately avoided any stimuli containing adjacent to .

Stimuli consisted of real Gaelic words selected by consulting a variety of Gaelic-English dictionaries, among them MacBain (1896) and Dwelly (1902-1912). One word was selected to illustrate each condition; however, some conditions were actually met in multiple stimuli. Several choices were unfamiliar to certain speakers, who were reluctant to produce them in a small number of instances. Perhaps this problem is well-nigh inevitable in a language as highly dialectalized as Scottish Gaelic, since Ladefoged et al. (1998) report a similar difficulty in their study of the Gaelic of Leurbost, Lewis. Words were randomized and printed in groups of six per sheet of paper, then re-randomized and printed again in groups of six, such that forms appearing list-finally in the first set of 36 were not list-final in the second set of 36. Thus, each word appeared twice. Transcriptions reflect the Lewis dialect, i.e. with glottal preaspiration only. Stress in bisyllabic words is on the initial syllable.

t^{h}V	put [p^{h}uht] ‘buoy’	tog [t^{h}ok] ‘raise’	cop [k^{h}ohp] ‘foam’
Vht	cnap [k^{h}nahp] ‘lump’	brot [proht] ‘soup’	breac [preahk] ‘salmon’
VhtV	copag [k^{h}ohpak] ‘weed’	bata [bahta] ‘stick’	poca [p^{h}ohka] ‘bag’
t^{h}V:	pòg [p^{h}o:k] ‘kiss’	tùch [t^{h}u:x] ‘make hoarse’	càbag [k^{h}a:pak] ‘cheese’
V:ht	pàp [p^{h}a:hp] ‘Pope’	bòt [po:ht] ‘boot’	bòc [po:hk] ‘puff’
V:htV	ròpach [ro:hpax] ‘squalid’	bàta [pa:hta] ‘boat’	pràcais [p^{h}ra:hkɪʃ] ‘chit-chat’
tV	bac [pahk] ‘hollow’	dad [tat] ‘jot’	gob [kop] ‘beak’
Vt	cab [k^{h}ap] ‘gob’	ged [kɛt] ‘though’	cog [k^{h}ok] ‘fight’
VtV	clabog [k^{h}lapok] ‘bargain’	spadag [sp^{h}atak] ‘quarter’	daga [taka] ‘pistol’
tV:	bò [po:] ‘cow’	dòcha [to:xa] ‘probably’	gèadh [ki:ax] ‘goose’
V:t	còb [k^{h}o:p] ‘plenty’	clàd [k^{h}l̥a:t] ‘wool comb’	bròg [pro:k] ‘shoe’
V:tV	cùbaid [k^{h}upɪtʃ] ‘pulpit’	fàdadh [fa:tax] ‘kindling’	brògan [pro:kan] ‘shoes’

Table 4.4. Stimuli used in the first production experiment.

4.6.1.3 Recording

Most recording sessions took place in a soundproofed broadcasting studio, though some were also performed in unused classrooms. Recordings were made using a laptop computer, the Praat software (Boersma and Weenink 2006), and a Logitech desktop USB microphone (frequency response 100 – 16k Hz).[5] Speakers were told that the researcher was interested in a "natural, conversational pronunciation," rather than a "proper" one. Speakers were also asked to comment if they were unfamiliar with any items in the word list. Each stimulus was located within the frame sentence “Thubhairt mi _” [hur̥t mi] ('I said _ '), yielding a pronunciation approximating a citation form.

[5] In hindsight, another kind of microphone may have been preferable. The desktop microphone was intimidating to a number of informants, and it was additionally rather challenging to convince them to speak close enough to the microphone to get a high-quality recording. A headset microphone might be a better alternative.

4.6.1.4 Analysis

Arriving at a consistent method for the segmentation of recording material was among the more challenging features of this study. After some experimentation, I settled on an approximation of the method described in Ladefoged et al. (1998), in part because I wished my own results to be readily comparable with theirs, and also because this method made the best sense to me. Here I will describe how I made the measurements relevant to this study, i.e. the duration of vowel length, aspiration, and stop closure.

First, I placed a boundary at the beginning of the vowel concerned, marking the start of the first fully formed periodic waveform associated with the vowel. If the vowel was followed by a non-preaspirated stop, I marked the vowel/stop closure boundary at the end of the final recognizable periodic waveform associated with the vowel. A similar criterion was followed if the vowel was followed by a period of preaspiration: the beginning of preaspiration was taken to be the point at which the periodic vocalic waveform ceased, and the aperiodic high-frequency energy of aspiration commenced. The preaspiration/closure boundary was placed at the point where this high-frequency energy disappeared, and at the start of the relatively flat closure waveform. This is illustrated in Figure 4.7.

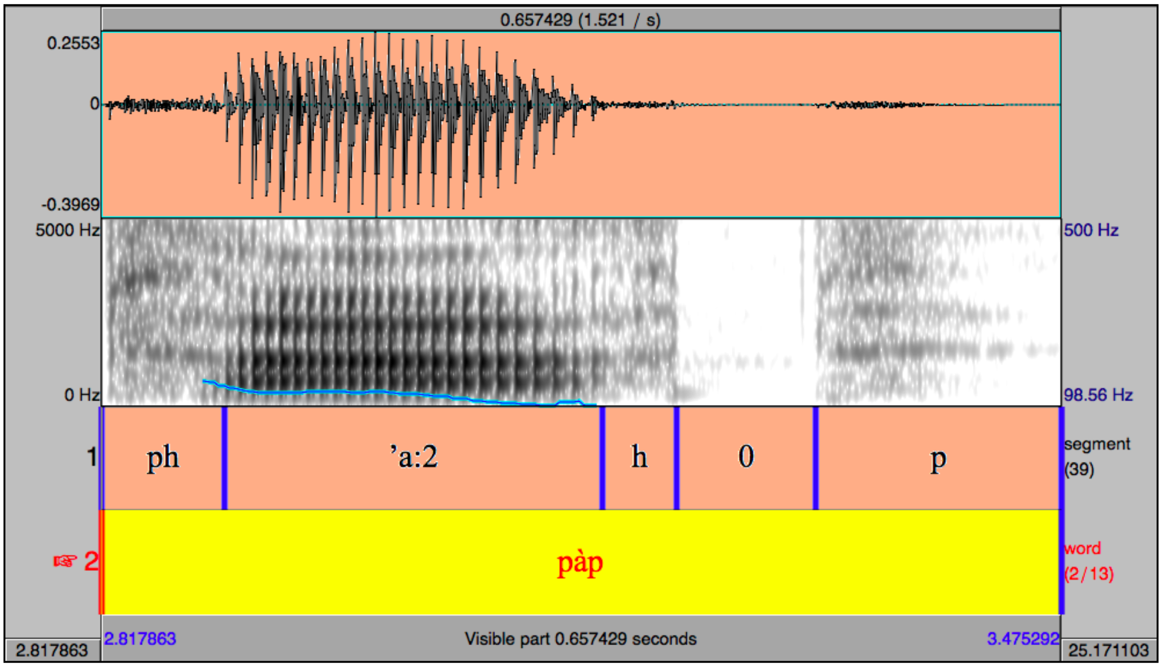


Figure 4.7. Segmentation of the word *pàp* [pʰa:hp] **'Pope"**

However, the procedure for demarcating preaspiration was complicated by the occasional presence of a period of breathy voice (approximately 10 – 50 ms) following the modal vocalic voicing in the speech of many informants (Figure 4.8). In certain cases, no "preaspiration" could be identified apart from breathy voice. When it was present, I segmented the breathy voiced component apart from the surrounding acoustic material, but included the breathy voice within the total duration of preaspiration. I made this inclusion because the distribution of significant breathy voice, invariably before underlyingly aspirated stops rather than unaspirated stops, strongly suggested that breathy voice functions as an articulatory component, or even variant, of preaspiration. Ladefoged et al. (1998) make no mention of breathy voice in data from their 11 Lewis speakers, but I found breathy voice to be present to a greater or lesser extent in most of my informants, as do Ní Chasaide and Ó Dochartaigh (1984).

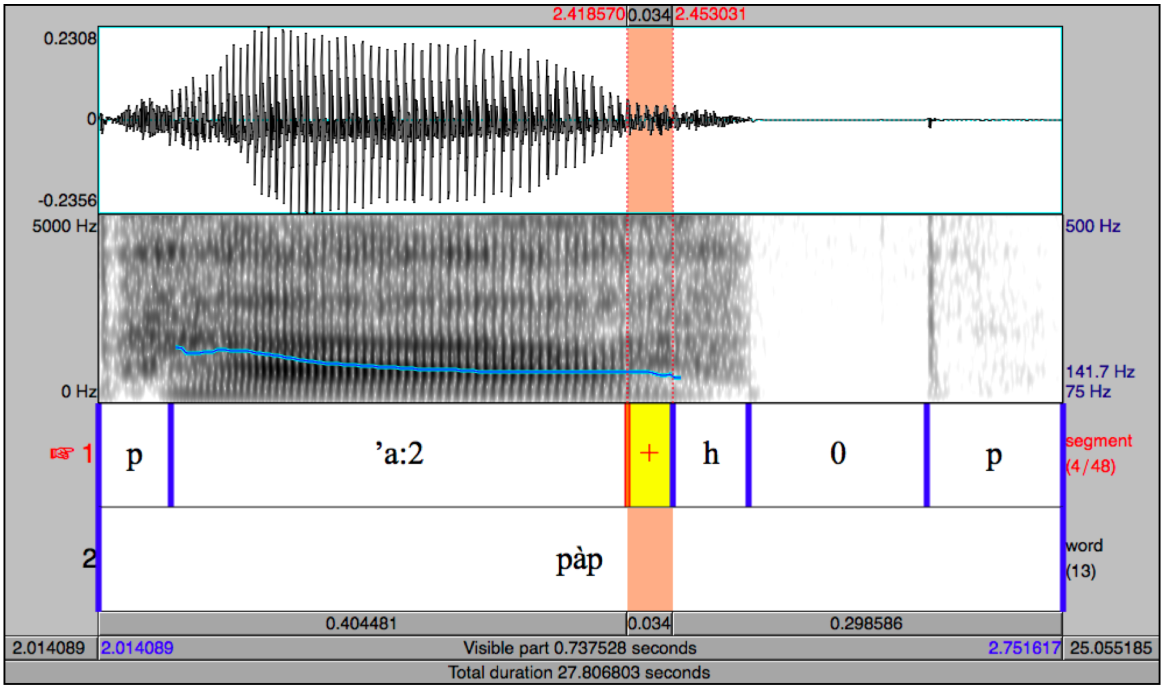


Figure 4.8. Breathy voice in *pàp* [pʰa:hp] **'Pope', marked with + .**

4.6.1.5 Results

Measurements were extracted and analyzed according to a mixed-model analysis of variance (Table 4.5), with standard error adjusted to account for multiple observations within subjects. The three variables place of articulation, vowel length, and word position, were main effects, having significant effects on the observed duration of preaspiration, and confirming the first hypothesis (26) *place-sensitive duration*. The second hypothesis, (27) *restricted precursors,* was entirely confirmed: no examples of typologically unattested repairs, or potential precursors thereto, were observed.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Intercept	SPEAKER	0.002641
Residual		0.001347

ICC=.6622

Estimates

Label	Estimate	Standard Error	DF	t Value	Pr > |t|
C vs O	0.03899	0.005887	189	6.62	<.0001
L vs S	-0.04311	0.005840	189	-7.38	<.0001
P vs T	-0.02724	0.007564	189	-3.60	0.0004
P vs K	-0.05206	0.007269	189	-7.16	<.0001
T vs K	-0.02482	0.006571	189	-3.78	0.0002

Least Squares Means

Effect	class1	class2	class3	Estimate	Standard Error	DF	t Value	Pr > |t|
class1*class2*class3	K	L	C	0.1509	0.02050	189	7.36	<.0001
class1*class2*class3	K	L	O	0.08378	0.02066	189	4.06	<.0001
class1*class2*class3	K	S	C	0.1858	0.01950	189	9.53	<.0001
class1*class2*class3	K	S	O	0.1309	0.02003	189	6.54	<.0001
class1*class2*class3	P	L	C	0.07046	0.02050	189	3.44	0.0007
class1*class2*class3	P	L	O	0.06202	0.02473	189	2.51	0.0130
class1*class2*class3	P	S	C	0.1363	0.01935	189	7.04	<.0001
class1*class2*class3	P	S	O	0.07442	0.02107	189	3.53	0.0005
class1*class2*class3	T	L	C	0.09371	0.02134	189	4.39	<.0001
class1*class2*class3	T	L	O	0.08317	0.02163	189	3.85	0.0002
class1*class2*class3	T	S	C	0.1532	0.01926	189	7.95	<.0001
class1*class2*class3	T	S	O	0.1221	0.02036	189	6.00	<.0001

Table 4.5. ANOVA of production study results.

The experiment found a significant effect for place of articulation on the duration of the preaspiration cue, confirming the first hypothesis (Figure 4.9)[6]:

(28) preaspiration in labial consonants (avg. 89ms) was shorter than dentals (110ms) ($t = 3.6$, df = 189, $p = .0004$)

(29) that in dentals (110ms) was shorter than that in velars (138ms) ($t = 3.78$, df = 189, $p = .0002$).

[6] These results partially confirm Ladefoged et al. (1998), who found that only bilabials were significantly shorter, while there was no significant difference between dentals and velars. They contradict Shuken (1980), who found no difference in duration by place of articulation.

(30) There was also a significant effect for vowel length (t =-7.38, df = 189, $p < .0001$) and for position (t = 6.62, df = 189, $p < .0001$). Short vowels and final position were more favorable to preaspiration, while long vowels and medial position disfavored preaspiration, as measured by duration of the preaspiration cue:

a. In medial position, the duration averaged 112 ms after short vowels, but 70 ms after long vowels.

b. In final position, duration averaged 160 ms after short vowels, but 100 ms after long.

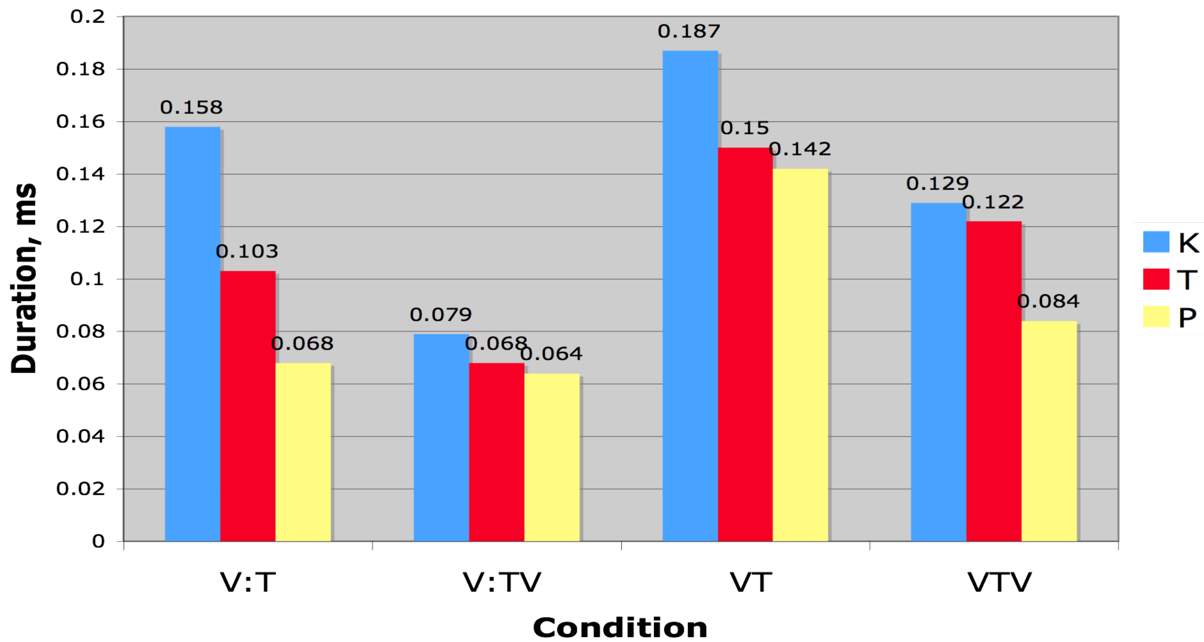


Figure 4.9. Duration of preaspiration cue, by context

The second hypothesis was confirmed: repairs which are theoretically possible but unattested in Gaelic, such as substitution of postaspiration for preaspiration, or homorganic frication in bilabials and dentals ([fp st]), were not observed in the data.

A final, unexpected phenomenon was observed. Most speakers sporadically produced unaspirated stops where preaspirated stops were expected, except for one (the older male Lewis speaker) who never did so at all. Conditions governing the frequency of this substitution were identical with those controlling duration reported above: substitution was most frequent among bilabial stops, after long vowels, and in medial position (Figure 4.10); when all three conditions were combined (i.e. /hp/ in medial position after a long vowel), substitution occurred over 70% of the time.

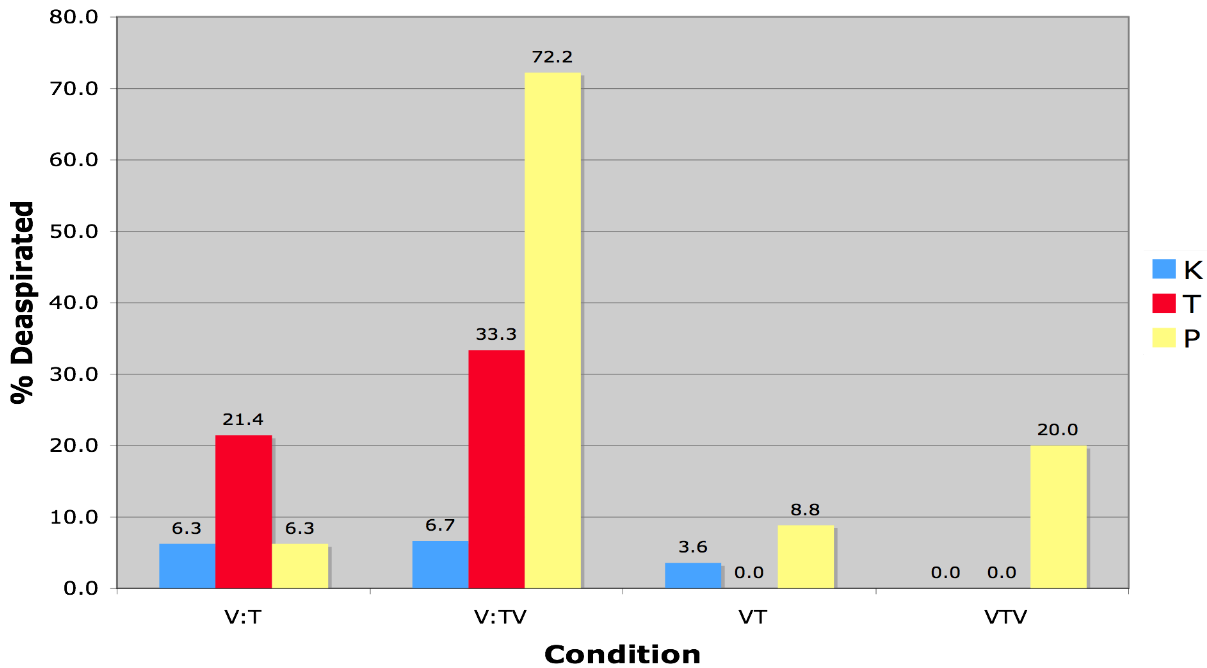


Figure 4.10. Deaspiration in the first Gaelic production study

4.6.2 Scottish Gaelic: second production study

A reasonable criticism of the first exploratory production study is that too little effort was made to control for the vocalic context of preaspirated tokens, the gender of the participants, and the dialects represented. Accordingly, a second production study of Scottish Gaelic was designed and carried out to correct for these issues. An additional value to the second study is that existing instrumental investigations of preaspiration in Gaelic have made little effort to systematically quantify distinctions between dialects, with the exception of Ní Chasaide and Ó Dochartaigh (1984). The latter study, while informative, suffered insofar as a single informant was consulted for each dialect or language; the production study described above found considerable individual variation in preaspiration.

A new set of stimuli was designed. In this set, vocalic context was restricted to the low vowel /a/, as an articulatorily relatively neutral segment. Once again, stimuli were balanced across position (initial, medial, final), place of articulation (labial, coronal, dorsal), and phonological vowel length (long or short), yielding 18 conditions (unaspirated tokens were not targeted, unlike the previous experiment.) At least two different stimuli were selected for each condition, unless lexical gaps prevented this, as for the long vowel, word-final labial condition for which only a single lexical item could be reliably identified. Selected stimuli are listed in Table 4.6; transcriptions represent the Lewis dialect. All bisyllabic words bear initial stress; the trisyllabic word *buntàta* ‘potato’ bears stress on the second syllable.[7]

	labial	**coronal**	**dorsal**
t^{h}V	paca [p^{h}ahka] ‘pack’ paisg [p^{h}aʃk] ‘bundle’	tabh [t^{h}av] ‘net’ tac [t^{h}ahk] ‘lease’	cas [k^{h}as] ‘foot’
Vht	cnap [k^{h}ɾahp] ‘knob’ sgap [skahp] ‘scatter’	slat [slaht] ‘twig’ brat [praht] ‘cloak’	bac [pahk] ‘hollow’ tac [t^{h}ahk] ‘lease’
VhtV	cnapan [k^{h}ɾahpan] ‘knob (pl)’ tapadh [t^{h}ahpaɣ] ‘success’	cnatan [k^{h}ɾahtan] ‘a cold’ bata [pahta] ‘stick’	facas [fahkas] ‘was seen’ acair [ahkɛr] ‘anchor’ facal [fahkəl] ‘word’
t^{h}V:	pàp [p^{h}a:p] ‘Pope’	tàbhach [t^{h}a:bəx] ‘net-fishing’	Càisg [k^{h}aʃk] ‘Passover’ càise [k^{h}aʃə] ‘cheese’
V:ht	pàp [p^{h}a:p] ‘Pope’	stàt [st^{h}a:ht] ‘pride’ gàt [ka:ht] ‘iron bar’	dràc [tra:hk] ‘drake’ stràc [stra:hk] ‘stroke’
V:htV	pàpachd [p^{h}a:paxk] ‘Papacy’ ràpach [ra:hpax] ‘noisy’	bàta [pa:hta] ‘boat’ buntàta [punˈha:hta] ‘potato’	stràcan [stra:hkan] ‘stroke (pl)’ gràcan [kra:hkan] ‘cackling’

Table 4.6 . Stimuli used in the second Gaelic production study

[7] Stress in Gaelic is usually initial, not penultimate as one might guess from these examples, but as a loanword, *buntàta* is anomalous.

Three dialects were targeted: those of Lewis, Harris, and Skye. The latter two are conventionally grouped together against Lewis in terms of the length of preaspiration as well as its form (Ó Maolalaigh 2007, Lamb 2001, Clement 1994), but I wished to test this directly, rather than take it for granted. Four representatives, two male and two female, were recruited from each of the three dialect areas, for a total of 12 participants.

Recording procedures differed somewhat from the previous study. Rather than a soundproof room (which was unavailable), recordings were made in quiet rooms using a headset microphone. Recorded material was analyzed according to the procedure described for the previous study. Results generally were in accord with the previous results. Once again, duration of the preaspiration cue was sensitive to place of articulation, vowel length, and word position (Figure 4.9). As for the previous production study, preaspiration before dorsal stops was by far the greatest in duration, while labial and coronal duration was considerably shorter. Unlike the previous study, however, there was no clear difference between the latter two categories: preaspiration before labial stops was shorter than before coronal stops only in the medial short vowel condition, but longer in the medial long vowel condition; measurements were very similar in the final condition after both long and short vowels. As in the previous study, long vowels were unfriendly to preaspiration, which was significantly shorter after long vowels than after short vowels.

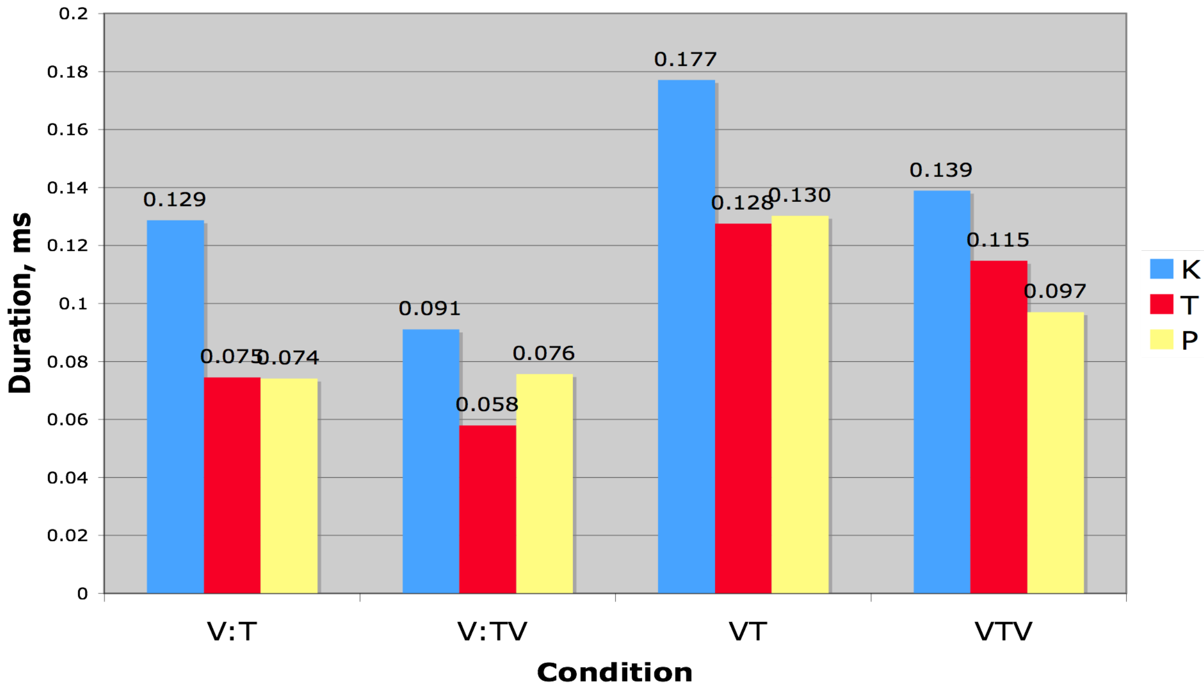


Figure 4.11. Second Gaelic production study: mean duration by position, POA, and V length

The study confirmed that dialect was indeed an important variable (Figure 4-10): in the Lewis dialect, preaspiration is substantially shorter than in the dialects of Skye and Harris. However, the latter two are so similar that there is solid justification to treating them as a single dialect area in terms of preaspiration, as previous literature has suggested (though principally on impressionistic, rather than empirical grounds, the exception being the comparative production study reported in Ní Chasaide 1985, and Ní Chasaide & Ó Dochartaigh 1984).

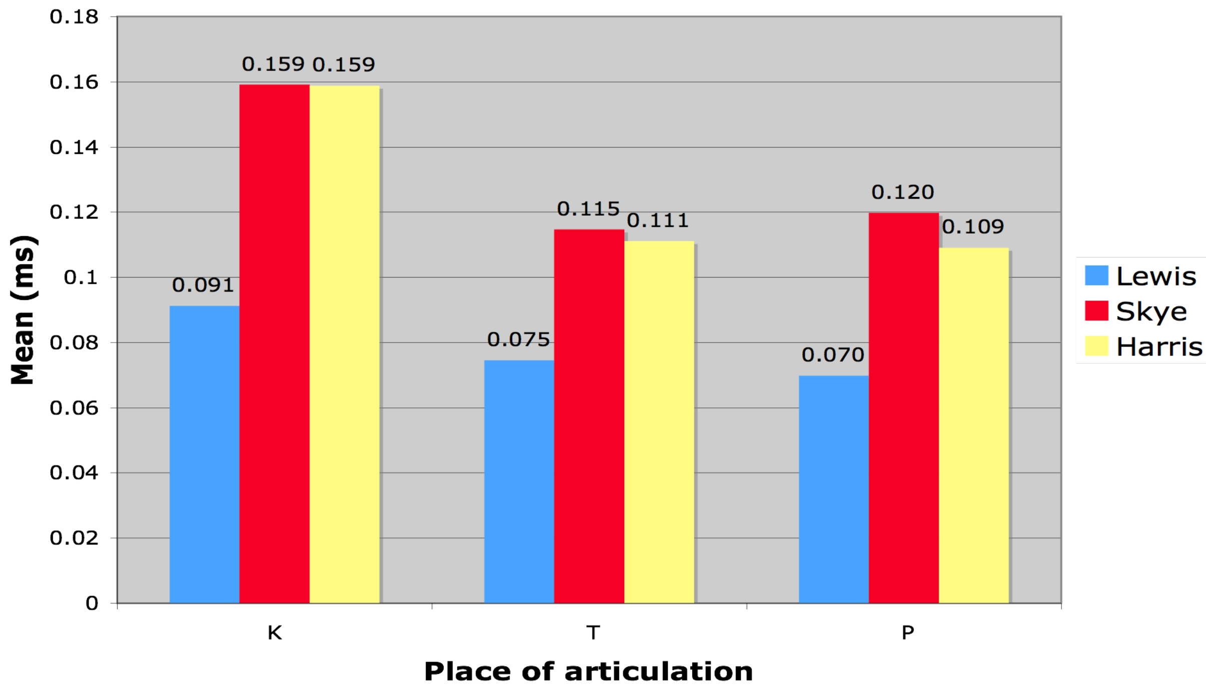


Figure 4.12. Average duration by POA and dialect

Finally, the sporadic deaspiration of underlyingly aspirated stops was widespread in the second study once again, though not to the same degree as in the first. In the first study, the greatest rate of deaspiration was among labials in medial position after long vowels, over 70 percent (Figure 4.13). In the second study, labials and coronals displayed similar rates of deaspiration, while once again, dorsals seldom deaspirated (Figure 4.14). Again, as in the first study, the environment of a long vowel encouraged deaspiration, though the highest rate was in closed syllables, rather than in open syllables like the first study.

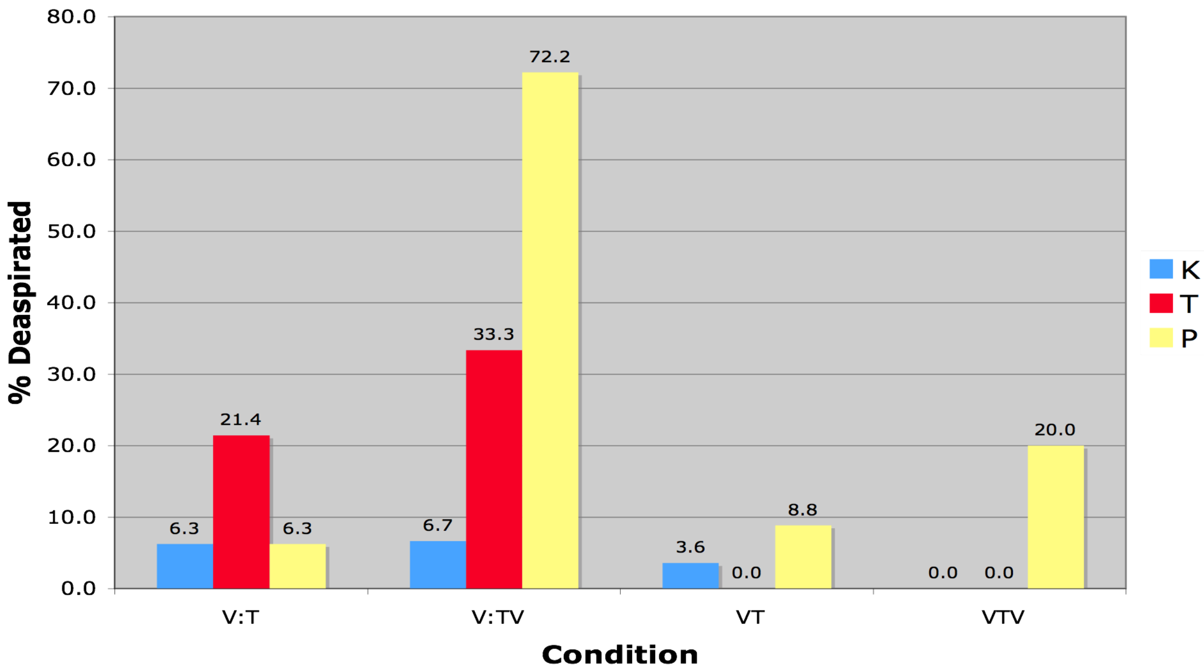


Figure 4.13. Deaspiration in the first Gaelic production study

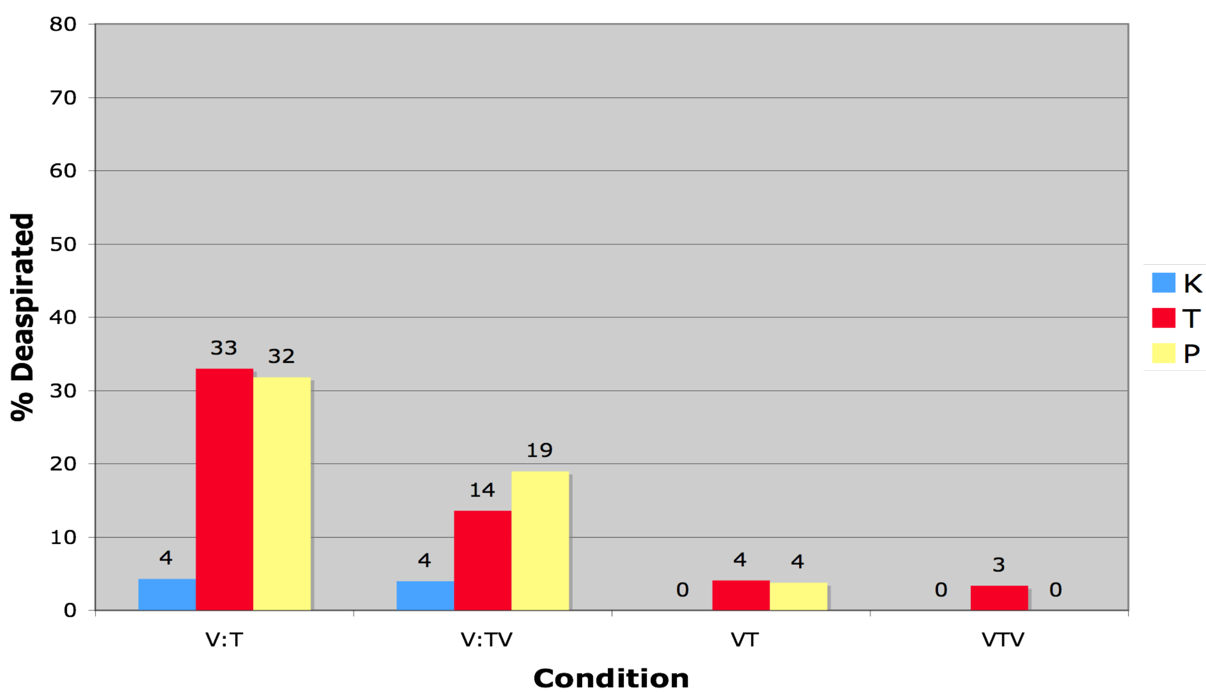


Figure 4.14. Deaspiration in the second Gaelic production study

4.6.3 Discussion

The two production experiments revealed two potential precursors for the deaspiration and fortition asymmetries in the typology of Scottish Gaelic preaspiration. The first is that the duration of the preaspiration cue tends to increase as one moves from the bilabial to the velar place of articulation. The second is that phonemically preaspirated stops are frequently realized as unaspirated stops; again, this happens most frequently in bilabial stops, least frequently in velar stops.

There is a reasonable basis for linking both the deaspiration and buccalization asymmetries to the place-connected differences in length of the preaspiration cue. In both cases, the asymmetries have likely resulted from the effects these durational differences have on the cue's relative perceptibility in each place of articulation.

It is possible that once the duration of preaspiration falls below a certain critical threshold, its value as a cue to the aspiration contrast is obviated. Since the typical duration of the preaspiration cue tends to fall as the place of articulation of the stop moves forward from velar to dental to bilabial, the reliability with which it meets that threshold may correspondingly fall. As a corollary, speakers may place progressively less value on articulating the cue, even to the point of omitting it altogether—substituting a plain stop for a preaspirated stop. If this substitution happens with sufficient frequency (as in bilabial stops), speakers may be prompted to assume that the underlying representation contains a plain stop instead of a preaspirated one. The durational differences would ensure that this misperception affected bilabial stops most often, velar stops least, resulting in the deaspiration asymmetry.

Buccalization, on the other hand, may be partly attributable to coarticulation, but not entirely. Prototypical preaspiration—unvoiced glottal frication—consists of a nearly unimpeded airstream. As the articulators are approximated preparatory to the closure of a stop, this airstream will become constricted, producing turbulence at the point of articulation. If this turbulence were prominent and frequent enough, a listener may interpret it as intentional frication, rather than incidental, and so it might become phonologized. Coarticulation is plausible in the case of /hk/ > /xk/, where coarticulation effects on the preaspiration cue may have rendered it difficult to distinguish from the previously existing, non-preaspiration related /xk/ cluster. It would also neatly explain fortition to homorganic fricative-stop sequences, e.g. Fox /fp st cç/. But coarticulation cannot explain SG /hp xt xk/ (dialect 5), and especially not /xp xt xk/ (dialect 4), where prototypical glottal preaspiration has given way to the velar fricative form exclusively.

Misperception may provide an explanation, however. A key factor in distinguishing place of articulation in fricatives is the location of their spectral peaks: "backer fricatives have greater noise at lower frequencies in keeping with the longer anterior cavity associated with relatively posterior [place of articulation]" (Gordon et al. 2002, p. 167; see also Johnson 2003); labial and interdental fricatives, on the other hand, are distinguished by their flat spectra with no notable peaks. Substituting [x] for [h] would therefore entail a relatively minimal perceptual adjustment, compared to other oral fricatives. (I leave aside the voiceless uvular fricative [χ], a place of articulation not employed in Scottish Gaelic). Further, the overall amplitude of [x] is substantially greater than that of [h], enhancing its perceptual value. Thus, if motivated to repair violations to *[hT], speakers would, on perceptual grounds, find [xp xt xk] to be more suitable than [fp st xk] (as would be more likely to result from coarticulation).

Both asymmetries may have been magnified—skewed further—by a factor known as *temporal summation of loudness*, which obtains in very short auditory stimuli (< 200ms), such as those associated with preaspiration (85% of tokens I measured were 200ms or shorter). Below this threshold, a longer stimulus will be perceived as louder, a shorter one as quieter, all else being equal (Zwislocki 1969).[8] Louder, in this case, might mean "more similar to [x]," given that a key difference between [h] and [x] is the latter's relatively greater amplitude. Quieter, on the other hand, might mean "more similar to [Ø]."

Finally, crosslinguistic comparisons reveal that in this position, the glottal fricative is in fact prone to buccal realizations. In certain dialects of Irish, for instance, coda /h/ may be realized as a velar fricative [x] (Ní Chiosáin 1991, Ó Siadhail 1989). Similarly, in Finnish, phonemic /h/ is realized as [x] in coda position between a back vowel and a consonant, as [ç] after a front vowel (Suomi, Toivanen, & Ylitalo 2008). In Turkish, coda /h/ may be realized as [x] (Underhill 1976); this is also true in Kammu (Svantesson 1983). The motivation in these cases may be the articulatory features of the preceding vowel: the fricative may be taking on the place feature of that vowel, as Helgason (2002) found for Faroese. As Ladefoged & Maddieson (1996) point out, "the shape of the vocal tract during h or ɦ is often simply that of the surrounding sounds" (p. 325); Maddieson (1984) says that a phonetic characterization of /h/ is "best made in terms of similarities to the properties of abutting segments" (p. 57). If we assume that preaspiration is insignificantly different from [h]

[8] Specifically, a ten-fold increase in duration (e.g. from 20ms to 200ms) may yield a reduction of 10 dB in an individual's auditory threshold (from 15 dB to 5 dB).

phonetically, it makes perfect sense based on the foregoing observations that it should exhibit a range of buccal variants, particularly dorsal ones like [x].

It is also of interest to explain why place of articulation should affect the duration of the preaspiration cue in the first place. A physical explanation seems likely, and indeed Ladefoged et al. (1998) offer two of them. On the one hand, anatomy may play a role: since in velar stops, the contact between articulators during the closure extends over a greater space than that in dental or bilabial stops, the release of this closure takes a concomitantly greater period of time. This view is shared by Ní Chasaide and Ó Dochartaigh (1984). On the other hand, since the body of air in front a velar closure is greater than that before a dental or bilabial closure, the period of time required for it to begin vibrating is longer. Furthermore, the pressure behind a velar stop may be higher (due to the smaller cavity there), and again, it may require more time for the pressure differential across the glottis to drop sufficiently for phonation to commence.

Of these two explanations, the first seems the most plausible: the articulators involved are the same for both postaspiration and preaspiration. Since preaspiration is often viewed as the preclosure counterpart of aspiration, (e.g. in Pind 1999), it may seem natural to consider that the same aerodynamic conditions apply to both as well, as does Ó Maolalaigh (2007). However, I do not think it safe to assume that, because a cavity of a larger size takes more time to commence vibration than a smaller cavity (as in postaspiration), it therefore requires more time to cease vibrating before a closure (as in preaspiration).

A final but important unanswered question follows from the hypothesis that a physiological predisposition is at work. Such a predisposition should apply equally well in any language with preaspirated stops. So far as I am aware, however, no deaspiration asymmetry, or anything like it, has been reported in any other preaspirating language. A desideratum, then, is an exploration of place-related durational effects in other languages, to learn whether similar tendencies are to be found outside of Scottish Gaelic, even at the subphonemic level.

What about the sporadic omission of preaspiration? There is no ready explanation for this phenomenon via the diachronic/channel bias account: the "innocent misperception" hypothesis proposes that speakers mishear ambiguous contrasts, and so rephonologize them. It does not claim that speakers will sporadically choose to realize poor contrasts, or to neutralize them, as the mood strikes them so to speak. It is conceivable that an inconspicuous cue, such as that associated with labial preaspirates, renders maintenance of the contrast unreliable, and so speakers are simply not motivated to actively seek to maintain the contrast under such conditions. A non-teleological hypothesis such as this one has no recourse to speaker motivations such as articulatory simplification or "laziness," whereas the P-map alternative explicitly takes such factors into account.

The P-map, on the other hand, explicitly predicts that innovative forms will arise, not as a product of misperception, but as an active innovation on the part of the speaker. As the repository of speakers' knowledge of the perceptibility of available phonological contrasts, the P-map operates in part by confining speaker innovations to a subset of those which are logically possible: "if an innovative speaker contemplates articulatory simplification, . . . it is the P-map that will identify the optimal target of simplification: the consonant whose modification is least likely to be detected" (Steriade 2001b, p.236). Because speakers are "actively concerned with avoiding *perceptible* deviations from established lexical norms" (Steriade 2001a, p. 13), they will tend to prefer just those innovations, in just those environments, where their experience as language users has taught them that those innovations are least detectable. To the extent that speakers innovate by producing deaspirated tokens of underlyingly aspirated targets, and these innovations conform to place-related perception asymmetries, this behavior is consistent with the P-map account.

However, an important question remains: Why should there be variations in production which are not reflected in grammars? Why should the preaspirated < > unaspirated contrast be hardest for speakers to detect in final position, without a congruent asymmetry in production? Recall that the preaspiration cue is longer in final position than in medial, on average (Figure 4.11). Moreover, there is no grammar (in Scottish Gaelic, at any rate) in which preaspiration has been lost in final position, but not medial.

By the same token, why should speakers be more inclined to innovate (by producing deaspirated tokens of underlyingly preaspirated targets) in medial position than in final (according to the second production study of Gaelic), if the perceptibility asymmetry runs in exactly the opposite direction? Because the two production studies conflict in this respect (Figures 4.13 & 4.14), the results are not immediately problematic for the P-map. But a clear desideratum is to establish which of the two studies is more reflective of speaker behavior.

4.6.4 Icelandic

It is a reasonable question whether the durational patterns observed in the preaspiration of Scottish Gaelic hold in other preaspirating languages as well. If so, then that would tend to confirm that these behavioral patterns are indeed a product of articulatory or aerodynamic forces, rather than being language-specific. Ní Chasaide (1985) and Ní Chasaide & Ó Dochartaigh (1984) report that the duration of preaspiration in Icelandic follows patterns similar to those observed in Scottish Gaelic. Since the study in these reports was based on the production of a single speaker, I opted to conduct my own study with a larger number of speakers.

Accordingly, five native speakers of Icelandic were recruited. All were fluent English speakers as well, but made regular use of Icelandic. All were from the Reykjavik area originally. These participants were distributed by age and sex as follows:

- 2 males, one in his 30's, the other in his 40's
- 3 females, one in her 20's, the other two in their 50's

The recording and analysis procedures were the same as for the second Gaelic production study. Stimuli were chosen to illustrate preaspiration in medial and final position, before the three places of articulation [p t̪ k], associated with either underlying geminates (orthographically pp tt kk) or voiceless stop-sonorant clusters. The word list used is provided in Table 4.7. Participants read the stimuli within the Icelandic frame sentence *Ég sagði ______ tvisvar*, "I said X twice." Duration measures were extracted and subjected to a two-tailed T-test, indicating that place of articulation was a main effect: preaspiration before [k] was significantly longer than that before [p] (estimate = 0.02120714, $t = 3.43$, $p = 0.0008$), but not from [t] (estimate = -0.00209000 , $t = -0.35$, $p = 0.7254$). Preaspiration before [p] was also significantly shorter than that before [t] (estimate = -0.02329714, $t = -3.98$, $p = 0.0001$). The effect of vowel length was not measured, because only short vowels occur before preaspirates in Icelandic.

Med					
gem	trappa		fatta		pakka
clus	glapna		batna		rakna
nC	hampa		planta		bánka
Fin					
gem	kapp		hvatt		flakk
clus	japl		vatn		bákn
nC	skvamp		mont		bánk

Table 4.7. Word list used in the Icelandic production study

Durational measurements from the Icelandic study were similar to those from the Scottish Gaelic studies insofar as both languages show an increase in duration as the place of articulation becomes more posterior, suggesting that similar forces are at play in both cases. Figure 4.12, illustrating duration by place of articulation in each of the three Gaelic dialects, is reproduced here with the Icelandic means added (Figure 4.15).

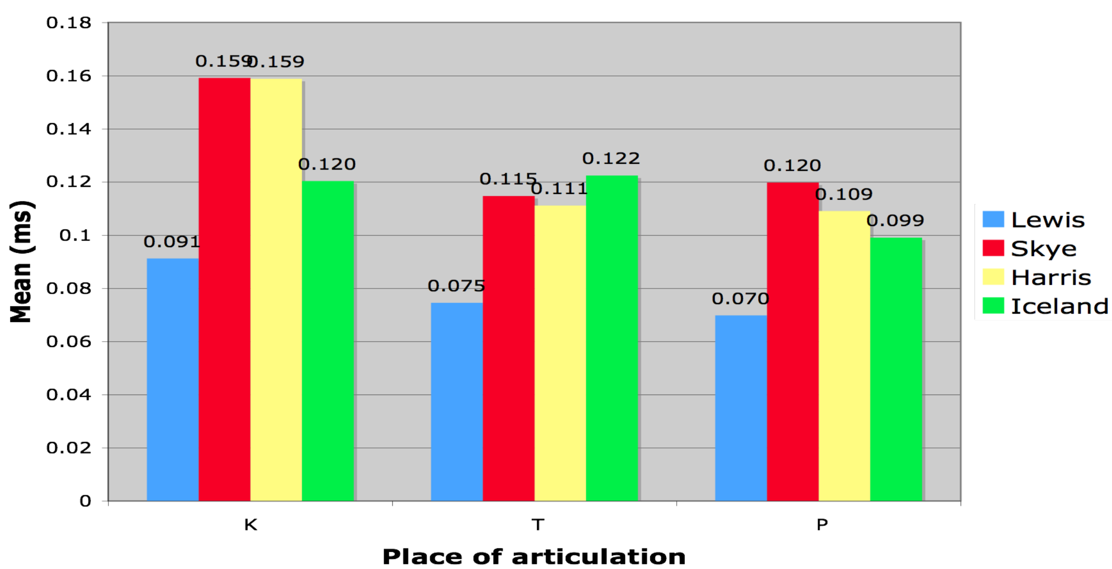


Figure 4.15. Mean duration by POA, Gaelic dialects + Icelandic

4.6.5 Tohono O'odham

A small sample of Tohono O'odham sound files are available as of this writing on the web page maintained by Mizuki Miyashita at the University of Montana.[9] The samples seem primarily to feature one elderly male speaker. While somewhat noisy, these files do permit a limited analysis of preaspiration in O'odham. Unfortunately, the samples available heavily favor velar stops, so no good comparison of duration according to place of articulation is feasible. However, reasonable numbers of preaspirated stops after both phonemically long and short vowels were available. The results provide an interesting contrast with Scottish Gaelic. In Gaelic, there is an inverse relationship between phonemic vowel length and preaspiration duration: preaspiration tends to be shorter after phonemically long vowels than after short vowels (Figure 4.16). In O'odham, the opposite situation seems to obtain: preaspiration is distinctly longer after long vowels than after short (Figure 4.17).

A tentative conclusion this comparison points to is that preaspiration plays a different phonological role in each language. In Gaelic, preaspiration is likely analyzed as part of the coda, distinct from the vocalic nucleus; as one grows heavier, the other is forced to grow lighter. In O'odham, perhaps, preaspiration is phonologically associated with the vowel nucleus; thus, as the vowel lengthens, it inevitably brings the preaspiration with it. Thus, though in both languages preaspiration (apparently) plays a similar role as a contrastive cue distinguishing aspirated voiceless stops from unaspirated voiceless stops, the interaction of preaspiration with other aspects of the language's phonology appears to be quite different.

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[9] http://www.umt.edu/ling/faculty/Miyashita/OodhamNeoki/OodhamNeokiHome.htm. Accessed February 6, 2010.

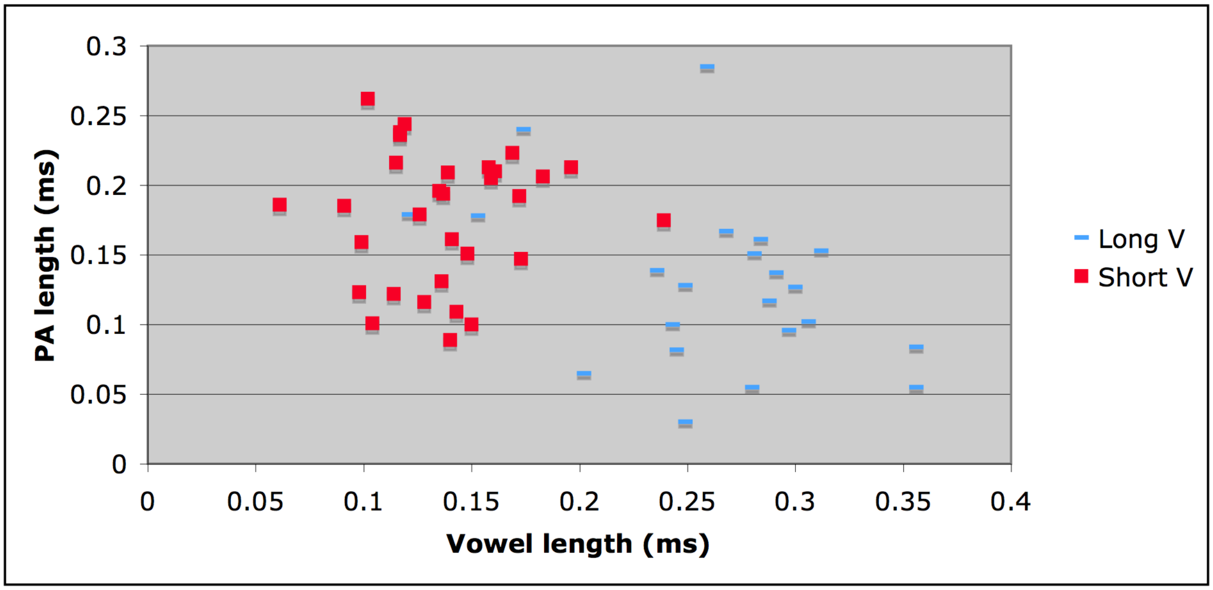

Figure 4.16. Preaspiration length after short and long vowels in Gaelic

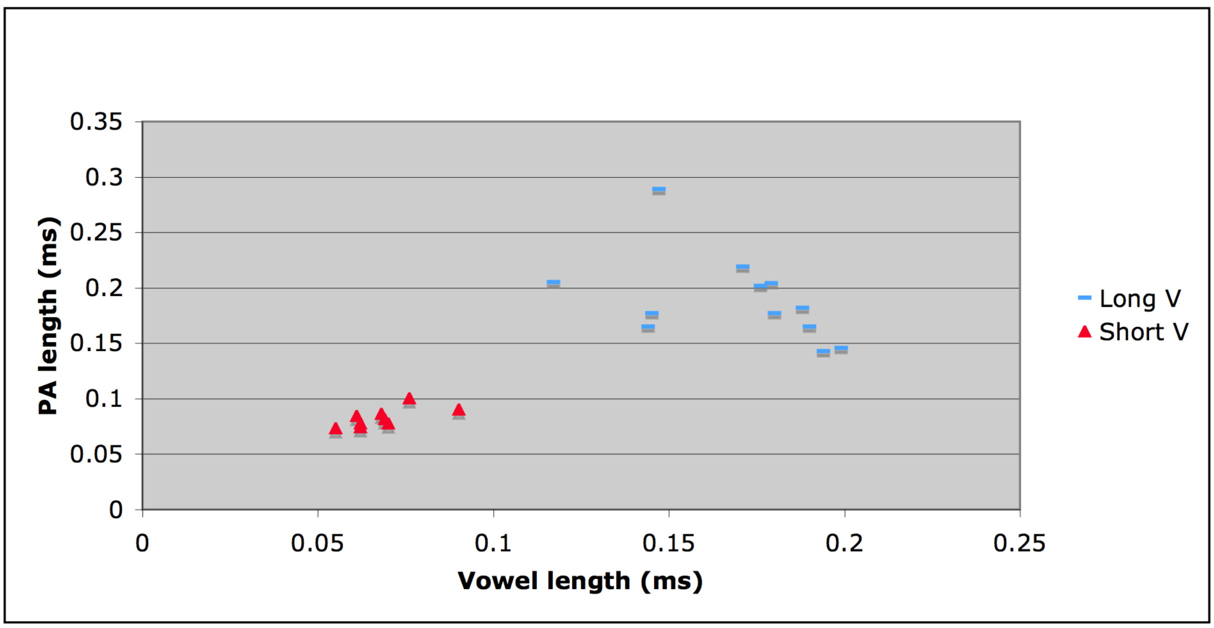

Figure 4.17. Preaspiration length after short and long vowels in Tohono O'odham

4.6.6 Interim summary

The diachronic/channel bias hypothesis attributes phonological typology at least in part to the presence of phonetic precursors which are subject to reanalysis on the part of listeners. Thus, it should be possible to link the asymmetries in Scottish Gaelic preaspiration to such precursors. The production studies described in this section were indeed successful in identifying such precursors. These precursors took the form of variation in the duration of the preaspiration cue which depended on the place of articulation of the associated stop, on the one hand, and of sporadic deaspiration which was also place-dependent. However, the studies revealed that other factors besides place of articulation were capable of exerting significant effects upon the duration of the preaspiration cue, among them the phonological length of the preceding vowel, and the position of the affected stop within the word. Neither of these two conditions correlate with a phonologized variation in the appearance or form of preaspiration in Gaelic. This raises an important question: under what circumstances does a precursor become phonologized, and when doesn't it? This question is of course part and parcel of the *actuation problem* (Weinreich, Labov, & Herzog 1968). An essential task remaining, then, is to seek to fine-tune the channel bias hypothesis, perhaps by intersecting it with sociolinguistic consideration, cognitive factors, or any factors which permit a more precise set of predictions than the hypothesis currently allows.

4.7 Conclusions

The first of this chapter's two goals was to inventory and describe the processes by which languages may exit the preaspirating state. A wide range of such exit processes was found, including tonogenesis, frication, buccalization, and deaspiration; a fifth, nasalization, has been proposed but remains unconfirmed. Of these, buccalization is the best attested, while tonogenesis is exemplified in but a single instance.

The second goal was to find explanations for within-language asymmetries in the application of these processes, as exemplified especially by deaspiration and buccalization in the preaspiration of Scottish Gaelic. Myers (2002) argues that gaps in factorial typology can be accounted for by phonetic factors: attested repairs to markedness violations are those which are likely to have arisen diachronically from phonetic precursors, while unattested but theoretically possible repairs are those that are unlikely to have developed by this means. Myers further argues, in company with Barnes (2002) and Ohala (2005), that attempts to modify Optimality Theory to rectify the "Too-Many-Solutions problem" (Steriade 2001a) are misguided: if the diachronic operation of phonetic factors can account for typology, it is redundant to expect synchronic grammars to do so as well.

This chapter has found that both hypotheses can offer useful insights. First, the study has shown that a standard Optimality-Theoretic account of preaspiration in Scottish Gaelic is characterized by substantial overgeneration. This overgeneration can be constrained using an analysis based on the P-map hypothesis (Steriade 2001a). The P-map allows the projection of faithfulness constraints and their rankings to be based on perceived similarities between target and surface forms. It is true that since the P-map based analysis is fundamentally rooted in the phonetics of perception ("rather mechanically" so, says Blumenfeld 2006, p. 60), it may be criticized as a redundant expression of phonetic facts. However, unlike the "innocent misperception" hypothesis, the P-map does not assume that sound change is non-teleological; in fact, it predicts that as speakers seek to impose articulatory simplifications on their output forms, they will do so in just those places where the associated perceptual cost will be lowest. The perception and productions studies of Gaelic preaspiration described in chapters 3 and 4 of this dissertation show that Gaelic speakers do in fact tend to neutralize preaspiration contrasts in just those environments where listeners find those contrasts hardest to perceive, with the important exception of final position.

Second, the chapter has nevertheless demonstrated that the observed asymmetries in the typology of Scottish Gaelic preaspiration may well have arisen through the diachronic operation of phonetic factors. These asymmetries involve *deaspiration*, which preferentially targets preaspirated labial stops, affecting coronals only if labials are already deaspirated, while (apparently) leaving dorsal stops untouched; and *buccalization*, which preferentially targets dorsal stops, extending to coronals only if dorsals are affected, and then to labials. A production experiment identified a robust phonetic precursor: the duration of the preaspiration cue is shortest, and optional deaspiration most common, in bilabial stops; conversely, the duration of preaspiration is longest, and optional deaspiration least frequent, in velar stops.

Finally, through comparison of preaspiration in Gaelic, Icelandic, and Tohono O'odham, the chapter has demonstrated that durational differences correlated with place of articulation do seem to hold cross-linguistically (as between Icelandic and Gaelic), while durational differences correlated with the phonological length of the preceding vowel can vary sharply (as between Gaelic and Tohono O'odham).

Chapter Five

Conclusions

5.1 Contributions

This dissertation has made contributions to our understanding of phonological typology in two areas, the first theoretical, the other empirical. First, it has explored and evaluated three important theoretical frameworks bearing on the sources of typology. These frameworks include Greenberg's *State-Process model* (1978, 1969, 1966), Steriade's *P-map Hypothesis* (2001a, 2001b), and the so-called *innocent misperception* model (Ohala 2005, 1993, Blevins 2004, *inter alia*). Second, the dissertation has broadened our knowledge of the typology, origins, and phonetics of preaspirated stops, through an inventory of known examples and a series of laboratory studies of their production and perception.

5.2 Theoretical frameworks

5.2.1 The State-Process Model

Greenberg's State-Process model argues that aspects of the diachronic development of some linguistic feature can be inferred from its synchronic typology. Features which tend to form genetic and/or geographic clusters are likely fairly easy to retain intact between generations; features which are randomly distributed are likely to be more difficult to transmit. Overall abundance of a feature is correlated with its ease of innovation. If accurate, Greenberg's observation represents an important research tool for linguists, since it permits us to make justifiable hypotheses about linguistic evolution when that evolution cannot be directly observed, or even reconstructed through comparative evidence. This aspect of the model is of particular value for research focusing on rare linguistic features (interdental fricatives, clicks, or labial-velars, to name just a few), for the simple reason that direct evidence concerning the lifecycle of such features may be difficult to acquire.

The dissertation tests the State-Process model by considering both the typological distribution and the perceptibility of preaspirated stops. The model predicts, based on their distribution, that preaspirated stops are likely to be diachronically quite robust, yet difficult to innovate. The prevailing view in the literature is that such stops are instead diachronically ephemeral, because of a putative perceptual inferiority to other more numerous types of stops, in particular postaspirated ones. The chapter describes a production study in which the perceptibility of preaspirated stops is directly compared to that of postaspirated stops, finding that there is in fact no significant difference between the two. This finding, plus additional clues gleaned from historical evidence, supports the projection made by the State-Process model. The strength of the model is thus confirmed as a framework within which additional exploration of phonological typology can be conducted.

5.2.2 The P-map

Optimality Theory argues that phonotactic phenomena such as those concerning deaspiration and buccalization in Scottish Gaelic reflect the ranking of phonological constraints. In principle, phonological constraints could be ranked in any order. However, freely ranked constraints predict phonological grammars violating the two asymmetries observed in Gaelic. Placing the relevant constraints in fixed hierarchies would resolve this overgeneration problem, but requires independent motivation to avoid being ad hoc. The P-map hypothesis (Steriade 2001a, 2001b) argues that such rankings should emerge from perceptual scales: speakers are more likely to produce modifications to a phonological form when the perceptual cost is low (that is, when the output form and the underlying form are perceptually close), and less likely to do so when the cost is higher (when output and underlying form are perceptually more distant from one another).

Evidence of such scales, congruent with the asymmetries observed in Scottish Gaelic, is provided by the perception experiment described in Chapter 3. The results of the experiment reveal a pattern of confusion rates which correspond closely to the prediction of the P-map: subjects found preaspiration to be harder to distinguish from unaspirated stops in just those environments where preaspiration is most likely to be neutralized, i.e. confusion rates fall as the place of articulation moves from labial to coronal to dorsal.

The P-map offers one additional advantage. The production studies of Gaelic described in chapter 4 find that speakers sporadically omit preaspiration according to a pattern which corresponds to the asymmetries seen in grammaticalized deaspiration: it is most common before labial stops, least before dorsal stops. The P-map predicts that speakers, when departing from conventional production, will do so in those environments when the departure is least likely to be detected, i.e. where the target form and the innovative form are perceptually closest.

However, the P-map model is not perfect. The perception and production experiments also reveal positional asymmetries which are *not* grammatically reflected. First, the perception study revealed that subjects found the preaspiration contrast most difficult to distinguish in final position. Meanwhile, the production studies found that omission of preaspiration was most abundant in initial and medial position, but relatively rare in final position—just the opposite of what the P-map predicts. This result evokes the question of actuation: under what circumstances do perceptual scales become grammaticalized (i.e. become part of the P-map), and when not? This problem is not unique to the P-map: the "Innocent Misperception" model leaves us with similar questions (below).

5.2.3 The diachronic/channel bias account

The third model tested in this dissertation is the so-called "innocent misperception" or diachronic model, which maintains that sound changes derive from the physics and physiology of speech production (Ohala 2005, 1993; Blevins 2004; Myers 2002). Thus, it should be that phonetic characteristics (or *precursors*) of a given linguistic feature should predispose that feature toward evolution in the direction of typologically well-attested patterns, while retarding evolution toward typologically rare or unattested patterns. A series of experiments investigating the production of preaspiration in Scottish Gaelic found evidence of such precursors: the preaspiration cue tends to be most robust (longest in duration, least prone to omission) in those environments where preaspiration is most resistant to loss in Gaelic, and indeed tends to undergo buccalization to a dorsal form (before dorsal stops), and least robust where loss is most common and buccalization least. However, much as was found for the P-map (above), the study also revealed patterns of phonetic variation which did *not* correspond to grammaticalized forms: the preaspiration cue was also shorter after phonologically long stops and in medial position, but no variant of Gaelic preaspiration has lost preaspiration in those environments. Thus, like the P-map, innocent misperception makes predictions which are only partially borne out.

5.3 The typology of preaspirated stops

The second type of contribution the dissertation has made is to our knowledge of the form, behavior, and diachronic trajectory of preaspirated stops, including both their origins and their exit processes. The survey of preaspirating systems in chapter 2 indicates that preaspirated stops tend to evolve from voiceless geminate stops, or less frequently from nasal-voiceless stop clusters. The case of Sienese Italian was explored, a dialect of Italian in which phonologically geminate voiceless stops are frequently realized as preaspirated singletons, suggesting a possible phonetic precursor for the phonologization of preaspiration, and lending support to those historical accounts of preaspirated stops reconstructing their origins in earlier geminates. Chapter 4 explored those phonological processes by which languages have been shown to exit the preaspiration state. Of these exit processes, buccalization and deaspiration are the best attested, whereas tonogenesis, spirantization and (potentially) nasalization have been identified only in unique cases.

The survey of preaspirating systems found that preaspirated stops tend to behave in a fairly uniform manner. In terms of their distribution, they almost always are restricted to medial and final position, most often post-stress. This may well be attributable to their origin in geminate stops, which exhibit similar restriction in distribution (as pointed in by Blevins 2004). When grammaticalized, preaspirated stops, there are two contrastive sets of stops, one voiceless unaspirated, the other voiceless and aspirated. In these languages, preaspirated stops are a positionally conditioned realization of the underlying aspiration feature: the aspiration is realized as postaspiration in initial position, as preaspiration in medial and sometimes final position.

A production study of preaspirated stops in three dialects of Scottish Gaelic (Harris, Skye, and Lewis) confirmed that a number of contextual factors influence the duration of preaspiration, as reported earlier in Ní Chasaide (1985) and Ní Chasaide & Ó Dochartaigh (1984). Place of articulation plays an important role: the preaspiration cue is longest before velar stops, shortest in labial stops. Duration also is longer in final position than in medial position. Finally, dialect is also a significant factor: preaspiration in the Skye and Harris dialects differs in no significant way, while that of Lewis is substantially shorter than in the other two regions. A production study of preaspiration in Icelandic confirmed that duration in that language is influenced by similar factors, suggesting that the observed variation in duration is indeed underlain by physiological and/or aerodynamic factors, and is not a language-specific phenomenon. Finally, production data from Tohono O'odham indicate that the relationship between preaspiration duration and phonological vowel length is variable between languages: in Gaelic, the relationship is a negative one, such that preaspiration is shorter after contrastively long vowels, longer after short vowels; whereas in O'odham, preaspiration is longer after long vowels, shorter after short vowels.

5.4 Further questions

Many questions remain to be answered about preaspirated stops. As always seems to be the case, more empirical information would be useful; few preaspirating languages have been studied phonetically. In my own work I have been able to make use of production data from only three languages: Gaelic, Icelandic, and Tohono O'odham. Of these, two (Gaelic and Icelandic) have already been the subject of phonetic study. But it would surely be informative to look at more languages, especially those in which the configuration of preaspiration has been debated, like Fox.

Also interesting would be a controlled production study designed to test the interaction between vocalic F_0 and preaspiration. My own production studies may be able to yield some information, though I have not yet established this securely, but I suspect that the lack of control in my studies over participants' intonation patterns may mean that the interaction between preaspiration and fundamental frequency is obscured.

Finally, in terms of lacunae in this study, a perception experiment testing the confusability of glottal and buccalized preaspiration (i.e. [xT] versus [hT]) would be useful, not only because a related perceptual scale is entailed by the P-map analysis in chapter 4, but also to test Silverman's (2003) claim that the buccalized form of preaspiration is perceptually superior to the prototypical glottal form.

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