On the rarity of pre-aspirated stops

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1. Introduction

A careful reading of the primary literature on pre-aspirated stops (stops preceded by laryngeally-generated noise, for example [^{h}p, ^{h}t, ^{h}k]) indicates that many putative cases of this sound pattern do not involve aspiration at all. Instead, "pre-aspiration" is usually employed as a cover term for a variety of configurations which typically involve a spirant homorganic to a following oral closure (e.g. [fp, çt, xk]), and/or a spirant that is influenced by the preceding vowel quality (e.g., [axk, içk]). In certain other cases, the term "pre-aspiration" is employed for a primary vowel length distinction, which might only rarely vary with a slight devoicing at vowel's end (e.g. [aːt] ~ [a^{h}t]). Finally, some researchers report that pre-aspiration is rare or absent for most speakers of the given language, and survives only sporadically, again oftentimes varying freely or systematically with a spirant. In this typological investigation I consider most of the languages that have been characterized as possessing pre-aspirates. While primary sources sometimes acknowledge that "pre-aspiration" is indeed a cover term for a variety of phonetic configurations, the secondary literature is typically remiss in carefully documenting this variability. The result is that a terminological shorthand has evolved into a folkloric narrative. In this paper then, my goal is to set the record straight on the rarity of pre-aspirated stops. Individual case studies are presented in Section 2.

In Section 3 I consider aerodynamic, acoustic, and auditory explanations for my typological findings, considering the inauspicious acoustic and auditory salience of pre-aspirates, especially in comparison to their post-aspirated counterparts. I also propose that the introduction of pre-aspiration into a system may sometimes be due to the loss of the oral features of an alveolar spirant, ([sp, st, sk]). This results in a sound pattern ([^{h}p, ^{h}t, ^{h}k]) for which the phonetic cues—aerodynamic, acoustic, auditory—are particularly meager. The instability of this pattern may lead in one or both of two directions: pre-aspiration's meager cues may lead to its eventual elimination from the system (with or without surviving vowel length) ([(ː)p, (ː)t, (ː)k]), and/or to the re-introduction of a downstream noise source that enhances the salience of the otherwise jeopardized contrast ([fp, çt, xk]). It follows corollarily that genuine pre-aspiration may best survive under stress, where its enhanced acoustic prominence increases pre-aspiration's chances of survival (see also Steriade 1999 on this point). Indeed, in several languages investigated, pre-aspiration or its spirantized counterpart is only found in stressed positions.

2. Survey of systems

In this section I consider individual systems in detail. The major works consulted for the typological study are Ruhlen 1975/6 (containing 706 segment inventories), and Maddieson 1984 (containing 317 segment inventories). Several additional cases are discussed by Steriade (1999). Almost all languages from these sources which are reported to possess pre-aspirates, as well as several additional cases, are investigated. Criteria for inclusion here are (1) the system's being listed by Ruhlen, Maddieson and/or Steriade as possessing pre-aspirates (2) my awareness of

other systems not mentioned in these sources, but reported elsewhere as having similar patterns (3) the availability of primary source material. In most cases, original sources were available at the main library of the University of Illinois.

For each language, I consider in as much detail as is available the articulatory properties of the relevant gestures. It is not always the case that linguistic descriptions of the relevant patterns are sufficiently detailed to draw unequivocal conclusions. In such cases, a sufficient number of puzzle pieces are usually provided in the source to come to a fairly conclusive answer. I further consider, again in as much detail as is available, the variability of pre-aspiration across allophones, across dialects, and across time (diachrony). Indeed, I will argue that all of these sorts of variability are intimately related. As I am not working in a segmental theory of phonology, I draw no distinction between systems characterized by their source as possessing h-stop clusters or single pre-aspirated segments. This distinction—real or imagined—has no bearing on the issues of present concern. Throughout, transcriptions are in accordance with the conventions of the International Phonetic Association's alphabet (IPA).

Tarascan (Foster 1969)

In Tarascan, pre-aspirates alternate with post-aspirates. While aspirates are always realized as post-aspirates in word-initial position, word-medially they are often transcribed as pre-aspirates in the context of an immediately preceding stressed vowel (1).

(1) um'ba^{h}pan̥i to heap things on the floor of the room
a'ʎa^{h}kun̥i to cut oneself on the hand

Foster reports that the pre-aspirates vary with both pre-spirantized stops, and with vowel length. The alveolar pre-aspirates "var[y] to pre-sibilantization following a voiced vowel either word-medially or with intervening non-pausal juncture" (p.19.): [^{h}t, ^{h}ts, ^{h}tʃ] vary with [st, sts, stʃ], respectively (2a). She provides no specifics on the phonetic details of the pre-aspirated labials and velars, and so we remain in the dark as to whether they too vary with some sort of pre-spirantization. She does report, however, that pre-aspirates which follow [ɨ] freely vary with vowel length" (p.17) (2b).

(2) a. variable pre-sibilants:
['p^{h}a^{h}tan̥i] ~ ['p^{h}astan̥i] to touch the metate
[p^{h}ahtsɨtan̥i] ~ [p^{h}astsɨtan̥i] to touch the table
[ka'tʃuhtʃan̥i] ~ [ka'tʃustʃan̥i] to cut off one's braid
b. variable vowel length:
['tsɨ^{h}kun̥i] ~ ['tsɨːkun̥i] to drop from one's hand

Tarascan is thus the first of many cases we will see in which "pre-aspiration" is applied as a cover term for a number of phonetically distinct properties. Oftentimes, as in Tarascan, the so-called pre-aspirate varies with a pre-spirant, its place of articulation homorganic to the following stop closure. Elsewhere, it is influenced by the preceding vowel quality. In Tarascan,

so-called pre-aspiration is variably realized as a lengthening in the context of a preceding [ɨ], without any aspiration or spirantization whatsoever.

Gaelic (Borgstrøm 1940, 1941, Dorian 1978)
While Gaelic has post-aspirates in word-initial position, pre-aspirates are found in medial position following stressed vowels, where they are in opposition to plain occlusives. This makes their distribution largely identical to those of Tarascan. On Lewis (the Ness and Bernera dialects), Borgstrøm (1940) reports that the pre-aspiration is "a short but quite audible *h*…shorter than an ordinary *h* in the same dialect" (p.2ff.). Examples are provided in (3).

(3) klaʰk grasp!
ɑʰkʲ(ə) with her
ɑʰt a fester

Intervocalic [h] is "only slightly influenced by surrounding palatal articulations." However, for ʰ*c* and ʰ*t*ʲ, the preaspiration is "distinctly palatal, without being as narrow as ç" (p.21): [çc, ç̣t]. In fact, Borgstrøm reports that the two palatal series are regularly pre-palatalized in addition to having a very short palatal offglide (1940:18). This characterization of pre-aspiration as being palatal in post-palatalized contexts shows that Borgstrøm employs the superscripted "h" as a cover term for a variety of phonetically distinct configurations, at least one of which involves a supralaryngeal constriction.

This cover-term usage of "pre-aspiration" is made more clear when Borgstrøm discusses dialects south of Lewis (Harris and Barra). Borgstrøm reports the following regarding the southern pre-aspirates: "Corresponding to the real preaspirated phonemes in Lewis…all the southern dialects have groups consisting of *h*, *x*, or *ç* followed by unaspirated occlusives" (1940:167). Regarding the velar pre-aspirates, [xk] seems to predominate in the context of a preceding back vowel (but also [æ])(4a), while [çk] is usually found following front vowels (4b) (note especially the [x]~[ç] alternation when "son" is pluralized). Finally, [hk] is found "only in a few late loanwords" (1940:168) (4c).

(4) a. maxk son
kʰrɔ̃xk a small field
sɔxkirʲ quiet
ʃæxk 7
b. miçkʲ sons
fɛ̃çkʲiŋ to see
kʰreçkʲ to sell
c. duʰkəɣ to wade (<Eng. duck)
ʃlʲaʰk slack
smɔʰkəɣ to smoke

Regarding the alveolar stop, it is genuinely pre-aspirated in most contexts, but is a palatal fricative following [i] (for example, [ljiçtʲirʲ] *letter*, [içtɔ] *a feather*); the labial stop is pre-palatalized only rarely, and is typically genuinely pre-aspirated (for example, [tʰaʰpɛ ljæʰt] *thank you*, [kʰrãʰp] *a lump*) (1940:169).

Borgstrøm's 1941 report considers the Skye and Ross-shire dialects. He writes that pre-aspiration on Skye "is identical with that of the Southern Hebridean [Harris and Barra] dialects" (p.43). In Red Point (Gairloch) and Aultbea, pre-aspiration involves "a very distinct and long *h*, frequently with a slight velar friction; this *h* is, however, different from *x*, which has more friction, and there exist such pairs as *bohk* 'a buck' boc ~ *bɔxk* 'poor' bochd. When the occlusive is palatal, *h* is not affected by the palatality" (p.100ff.). Finally, Dorian (1978:41) writes that pre-aspiration is entirely absent in East Sutherland Gaelic, including Brora, Golspie, and Embo.

In Gaelic dialects then, genuine pre-aspiration is present to different extents depending on the dialect, the place of articulation of a following stop, and/or the quality of the preceding vowel. Again, the term "pre-aspiration" actually encompasses a variety of distinct phonetic forms, many of which involve supralaryngeal constrictions of a fricative nature. As in Tarascan, both the following consonant and the preceding vowel influence its supralaryngeal characteristics, while in some dialects all forms of so-called pre-aspiration have been lost.

Icelandic (Liberman 1978, 1982, Thráinsson 1978, Kingston 1990, Silverman 1995), and other Scandinavian languages

Icelandic possesses both lexically contrastive and allophonic pre-aspirated stops. The series is sometimes described as involving a supralaryngeal constriction. Intervocalically, pre-aspiration is contrastive with post-aspirated stops, plain singleton stops, and plain geminates (5a). Also, pre- and post-aspiration bear an allophonic relationship in certain contexts (5b) (examples are considered presently).

(5) a. V^htV contrasts with
$Vːt^hV$ contrasts with
$VːtV$ contrasts with
$Vtː V$
b. V^htV alternates with
$Vːt^hV$ (in certain contexts)

Non-alternating pre-aspirates are contrastive in morphologically simple contexts where the preceding vowel is stressed. In (6) are some examples (all examples are from Thráinsson 1978).

(6) $ˈk^ha^hpi$ hero
$ˈθa^hka$ thank
$ˈha^htyr$ hat

Also, pre-aspiration is lexically contrastive where the involved stop closure precedes l or n, which in turn precedes an unstressed vowel (7).

(7)	ˈɛʰplɪ	apple	ˈɔʰpna	open
	ˈajʰtla	intend	ˈvɛʰtnɪ	hydrogen
	ˈɛʰkla	lack	ˈvaʰtna	wake up

Pre-aspirated alternants arise when a morpheme-final aspirate is followed by a homorganic aspirate. Homorganicity here may be lexical or derived through syncope and/or assimilation. Moreover, the homorganic cluster is not geminated, but instead is realized as a singleton stop closure. Post-aspiration does not appear here (8).

(8)	majtʰ+a → ˈmajːtʰa	meet (inf.)	majtʰ+tʰ+ɪ → ˈmaj̥tɪ	meet (past)
	vejtʰ+a → ˈvejːtʰa	grant (inf.)	vejtʰ+tʰ+ɨ → ˈvej̥ti	grant (past)
	nitʰ+a → ˈniːtʰa	utilize (inf.)	nitʰ+tʰ+a → ˈniʰta	utilize (past)

Additionally, pre-aspirated alternants appear upon attaching an l- or n-initial suffix to an aspirate-final root, as in (9).

(9)	pʰipʰ+a →	ˈpʰiːpʰa	pipe (nom. sg.)
	pʰipʰ+na →	ˈpʰiʰpna	pipe (gen. pl.)
	katʰ+a →	ˈkaːtʰa	street (nom. sg.)
	katʰ+na →	ˈkaʰtna	street (gen. pl.)
	kʰakʰ+a →	ˈkʰaːkʰa	cake (nom. sg.)
	kʰakʰ+na →	ˈkʰaʰkna	cake (gen. pl.)

Finally, to different degrees in different dialects, sonorants preceding aspirates vary with their devoiced counterparts. When devoiced, a plain stop follows; when not devoiced, an aspirate follows. In (10) are examples.

(10)	u̥lpa	~	ulpʰa	coat
	hejm̥ta	~	hejmtʰa	demand
	van̥ta	~	vantʰa	lack
	viŋ̊ka	~	viŋkʰa	wave

Liberman (1982) writes that certain researchers have reported that pre-aspiration varies with pre-spirantization, for example, [fp, θt, xk] (Goodwin 1905, 1908), [x], [ç], etc. (Fries 1977), and a non-laryngeal spirant after high vowels (Einnarsson 1927). However, Professor Liberman tells me that most researchers insist that this is a mischaracterizaton (personal communication 2001). Nonetheless, pre-spirantization is indeed reported in a number of other

Scandinavian languages. Regarding sounds that have traditionally been characterized as pre-aspirates, Liberman (1978:64ff.) clarifies their phonetic characteristics in the following ways (Professor Liberman tells me that "pharyngeal" refers to a standard [h], and that the "[f]" mentioned for Norwegian is "probably a typo."):

- Faroese: "Preaspiration is shorter and weaker than in Icelandic […] and sometimes sounds as a pharyngeal or a palatal fricative."
- Stockholm Swedish: "…[A] voiceless or voiced fricative homorganic to a preceding vowel or a subsequent consonant, i.e. it may be velar, dental, or labial. Sometimes preaspiration alternates with a [j]-like epenthetic sound or with the extra length of a preceding vowel…"
- Härjedalen Swedish: "either [h] or [x]."
- West Norwegian (Jæren): "Preaspiration varies in force and length and sometimes vanishes altogether. It is usually pharyngeal, but before [t] it is almost indistinguishable from [f]…in spectrograms it is perceivable as a high frequency [s]-like noise."

He goes on to make the following generalizations about Scandinavian pre-aspirates (p.65):

> "The place of its articulation is never fixed at one point: sometimes a pharyngeal noise seems to predominate, but more often than not it is assimilated to surrounding vowels and consonants…very few investigators have noticed (or even admitted) the influence of preceding and following sounds on Icelandic preaspiration, while in other languages the non-pharyngeal variants of preaspiration are perceived by all. The dynamic peculiarities of preaspiration in Icelandic…are much more salient in Faroese, Stockholm Swedish, and in Gimsøy and Senja."

Liberman's conclusions for Scandinavian are in keeping with the present findings concerning so-called pre-aspirates at the cross-linguistic level: typically, sounds which have been labeled as "pre-aspirated" are in fact pre-spirantized, and may also vary with vowel length or with zero, thus lacking a noise component altogether.

The same seems to be true of a Lule Sami, an areal neighbor to Scandinavian. Engstrand (1987) reports that this language has a series of stops which he terms "pre-aspirated," which contrasts with a plain voiceless series intervocalically. However, Engstrand reports that "pre-aspiration" is a cover term for various phonetic realizations of this series: "[T]he noise sound in question is frequently fricative rather than aspirative, particularly in the palatal and velar contexts" (p.105).

Toreva Hopi, and other Hopi dialects (Whorf 1946)

The Toreva dialect of Hopi is reported by Ruhlen (1975/6) and Steriade (1999) to possess pre-aspirates; the Hopi pre-aspirates are also mentioned by Trubetskoy (1939). Once again however, the term is applied somewhat indiscriminately to a number of different phonetic realizations in

various dialects; the Toreva dialect is specifically mentioned by Whorf as lacking pre-aspirates. In Hopi, as in both Scandinavian and Tarascan, both pre-spirantization and preceding vowel length are sometimes lumped under the cover term "pre-aspiration." Also as in those languages, the Hopi pre-aspirates may appear only when immediately following a stressed vowel (p.160); pre-aspiration is not found in other contexts, and indeed, the aspiration alternates with its absence: ˈpaːsat(ˌa) *field, abs. obj. sg* - ˈʔeʰˌpasa *thy field, const. nom. sg*. Furthermore, the pre-aspirates de-aspirate upon certain derivational processes (p.162). They occur "secondarily and rather irregularly in certain reduplications, prefixations, and suffixations (fn.7, p.162). Regarding the dialectal distribution of the pre-aspirated consonants, they appear only in the Oraibi dialect: "The pre-aspirates do not occur in Sipaulovi or Polacca, being replaced by plain stops, preceded by long vowels [[Vht] >> [Vːt]]. In Oraibi the pre-aspirates do not exist as single phonemes but are represented by h plus stop, h occurring freely before all consonants in Oraibi, whereas in Toreva h-clusters are very rare, and when they do occur, obviously something different from the preaspiration" (p160:fn.5).

The prevalence of pre-aspirates in the various dialects of Hopi was clearly quite low at the time of Whorf's writing. They were non-existent in the Sipaulovi and Polacca dialects. In Oraibi, they only appeared when the preceding vowel was stressed, and were subject to certain morphologically conditioned deletions as well. They were very rare in the Toreva dialect, and anyway were not pre-aspirates at all, but "obviously something different." Whorf's complete silence regarding the nature of these sounds precludes our hypothesizing about their phonetic characteristics, although we might hazard a guess that they involved some sort of oral, fricative-like component, which we are finding is usually present in most other putative cases of pre-aspiration. Suffice to say, *contra* Ruhlen's and Steriade's reports, we are not dealing with pre-aspiration in the Toreva dialect.

Eastern Ojibwa (Bloomfield 1957), and Cree (Horden 1881)

Eastern Ojibwa possesses a series of optionally, slightly pre-aspirated stops. Bloomfield reports that Eastern Ojibwa possesses fortis stops that are "often preceded by a slight aspiration," and "only occur after vowels," (p.8).

Closely-related Cree also possesses pre-aspirates. As in Ojibwa, pre-aspiration is rather irregular in terms of its phonetic properties: "It is usually breathed at the end of the syllable aspirated, and some words depend on the aspirate for their signification…But the aspirate is not uniformly observed, some tribes, and even members of the same tribe, aspirating their words very much more than others; it is therefore quite impossible to lay down strict rules for its observance" (Horden 1881:2).

As in all the cases we have investigated thus far, pre-aspiration in Eastern Ojibwa and Cree is variable in its realization—in particular, varying with its complete absence—although no mention is made of any supralaryngeal component. But when pre-aspiration is indeed present, it is only "slight."

Goajiro (Holmers 1949a)

Holmers describes the pre-aspirates of Goajiro as "rough h (or sometimes a weak Spanish jota)" (p.47). It is not fully clear what a "rough h" is, but once again we may be dealing with a weak spirant instead of a true [h]. Indeed, Holmers' comparing some instances of pre-aspiration to

"Spanish jota" certainly implicates the presence of some sort of constriction with velar frication. Although one of his consultants "pre-aspirates profusely" (p.47, fn10), nonetheless, "the pre-aspiration, as in te'ki· *my head* is not used by many speakers." (p.49). Indeed, many speakers have vowel length instead of the pre-aspiration: [meːkeːra] ~ [me^{h}keːra], [peːkeːraː] ~ [pe^{h}keːraː].

Pre-aspiration is reportedly in contrast with [h]+stop clusters. All short stressed final vowels are followed by [h], although it is rarely audible, instead being realized as a "very short i (or y [[j]])" (p.49). So, for example, [taihtaĩ] (I put) and [ihpa] (stone) are usually pronounced [taijtaĩ] and [ijpa], respectively. Despite the existence of morpheme-final [h]s, in at least one context, derived pre-aspirates are not created when a stop immediately follows. Instead, for example, the initial stop of the nominalizing particle [kal] is geminated, with concomitant loss of the root-final [h] (11) (see Holmers 1949b for fuller discussion of the [kal] particle).

(11)	mah + kal	→	makːal	place	(*ma^{h}kal)
	uʃuh + kal	→	uʃukːal	cooking pot	(*uʃu^{h}kal)
	kaʃih + kal	→	kaʃikːal	moon	(*kaʃi^{h}kal)

To summarize, so-called pre-aspiration in Goajiro was rarely actually encountered by Holmers, often being absent altogether with vowel length in its place, and when present, is described as a velar constriction that seems to have involved frication. Furthermore, at least some morphological contexts eliminate pre-aspiration in favor of gemination. Finally, the h-stop cluster is typically yodized (as in, for example, Stockhom Swedish). The Goajiro pattern thus possesses all the elements that should now be familiar: so-called pre-aspiration varies with its absence, varies with vowel length, involves supralaryngeal spirantization, and is subject to loss upon morphological derivation.

Fox (Jones 1910 (revised by Michelson), Bloomfield 1925)

Both Trubestskoy (1939) and Steriade (1999) write that Fox is a language which possesses pre-aspirates. But Jones (/Michelson) (Steriade's source for Fox) transcribes the relevant stop series ['k, 't, 'p], where the turned apostrophe "denotes a whispered continuant before the articulation of k, t, and p…it occurs also before *h*." Michelson adds that "[t]he 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'py'tc^{i} *when he came* is to be pronounced nearly as äfpy'tc^{i} with bilabial *f*" (p.742). The expression "reverse of the fricative" was probably intended as "reverse of the *af*fricative," since "affricative" is the term Jones employs to denote affricates, whereas he always uses the term "spirant" to denote fricatives. Anyway, the reverse of a fricative would simply be another fricative—which wouldn't make any sense to mention—whereas the "reverse of an affricate" is in keeping with the authors' description of these sounds: [pf] → [fp]. The other two stops are characterized in terms similar to the labial. Jones reports that the dental possesses an "audible hiss" before t, while the palatal also has a "hiss of breath" before oral closure. Indeed, "hiss" is a word rarely used to describe the broadband noise, with its comparatively low center of gravity, characteristic of aspiration, and seems more suited to the high frequency noise of a

sibilant fricative. Transcribing these sounds as [st, çc] thus reflects the reported "corresponding spirant [which] is heard faintly before the stop." As this "whispered continuant" also occurs before [h], it becomes quite clear that this spirant is not laryngeal in origin: the author(s) do not refer to this cluster as a geminate [h]. Regarding plain [h], Jones (/Michelson) write that "it is soft breath with feeble friction passing the vocal chords, and continuing on through the narrowed glottis," with no mention of "hiss," or "spirant," thus clearly juxtaposing it to spirants which may precede stop closures. As the source does not suggest that these sound are pre-aspirates, I conclude that Fox has a series of "reverse affricates."

Bloomfield (1925) does not further illuminate the particulars of the "reverse affricate" series, but the conclusion may be clearly drawn anyway: Fox does not possess a series of pre-aspirates. Instead, it has a series of "reverse affricates," the place of articulation of which seems to be determined by that of the following stop closure. Its patterning is consistent with our previous results.

Chamicuro (Parker 1994), and other Maipuran languages (Payne 1991)

As in Icelandic, Tarascan, and Oraibi Hopi, Chamicuro has contrastive pre-aspirates when the preceding syllable is stressed.

The language is quite unusual in that laryngeals (both [h] and [ʔ]) are found pre-consonantally, though never pre-vocalically. In (12) are some examples of pre-aspirates.

(12)	apehta	sardine
	ptʃahtoki	wild, savage, fierce
	ʂohta	big
	uitʃehki	it burns
	watoʂamahti	I wash

Payne (1991) reconstructs Proto-Maipuran with a syllable-final *h. In most daughter languages, this [h] has been lost, surviving as vowel length or other "non-standard sequences" (p.455). It has best survived in Chamicuro, and also in Amuesha, although even in these languages it has been lost in some words. So, while Chamicuro has a series of genuine pre-aspirates, its Maipuran neighbors have almost all lost this laryngeal gesture, usually replacing it with vowel length or some other sound.

Huautla Mazatec (Pike and Pike 1947, Kirk 1966, Steriade 1994, Silverman 1995)

The Huautla dialect of Mazatec (along with the Mazatlán de Flores, Santa María Jiotes, and San Jerónimo Teocatl dialects) possesses a series of pre-aspirates. Also of interest is the fact that pre-aspiration contrasts with [s]-stop clusters before the velar stop ([^{h}k] - [sk]), but only the pre-aspirate is present with the alveolar stop; [st] is missing. Some examples of pre-aspirated stops, and [sk] clusters are presented in (13) (from Pike and Pike 1947; labials are very rare throughout the Otomanguean group).

(13) <u>pre-aspirated alveolar stops</u>:

ʰti˩	fish
ʰtse˥˩	a sore
ʰtʃi˩	small

pre-aspirated velar stops:		[sk] clusters:	
ʰka˩	stubble	skˀao˥	it will break

Regarding the absence of [st], Kirk reconstructs the Proto-Mazatec reflex of modern [ht] as *st (1966:80ff.). This suggests that that present-day [sk] and [hk] might both originate in proto-Mazatec *sk, with some of these forms having evolved—on analogy with [ht]—into [hk] sequences, although Kirk provides no cognate sets involving Huautla [hk] forms. This proposed diachrony is outlined in (14).

(14)

Proto-Mazatec:	*st		*sk	
	↓	↙		↘
Huautla Mazatec:	[ht]	[hk]		[sk]

Summary

The table in (15) shows the sorts of variation that have been documented in our typological investigation. Variability here refers to any or all of the following: (1) conditioned or free synchronic variation, (2) dialectal variation, (3) diachronic change.

(15)

	variation (schematic):	language examples:
(A)	[ʰp, ʰt, ʰk]	Icelandic (?)
(B)	[ʰp, ʰt, ʰk] ~ [fp, çt, xk]	Tarascan, Gaelic, Stockholm Swedish, Lule Sami, Toreva Hopi (?), Fox
(C)	[iʰt, aʰt] ~ [içkʲ, axk]	Harris Gaelic, Barra Gaelic, Stockholm Swedish
(D)	[xp, xt, xk]	Red Point Gaelic, Goajiro, Härjedalen Swedish
(E)	[Vʰp, Vʰt, Vʰk] ~ [Vːp, Vːt, Vːk]	Tarascan, Gaelic, Ojibwa, Cree, West Norwegian (Jæren), Hopi, Goajiro, Maipuran
(F)	[fp, çt, xk] ~ [Vːp, Vːt, Vːk]	Hopi, Goajiro
(G)	[st, sk] ~ [ʰt, ʰk]	Mazatec
(H)	[ˈVʰt]/[ˈVçt] ~ [Vt]	Tarascan, Ness Gaelic, Bernera Gaelic, Scandinavian, Hopi, Chamicuro

Summarizing the major findings, consider the following statements:

- Pre-aspiration is remarkably unstable both synchronically and diachronically
- Genuine across-the-board pre-aspiration is almost never found (A)
- When present, pre-aspiration typically varies with spirant-stop clusters (B,C)
- This spirant is typically homorganic to the following stop (B)
- The spirant is sometimes influenced by the preceding vowel quality (C)
- In some cases pre-aspiration is often implemented as a velar spirant (D)
- Alternatively, pre-aspiration/pre-spirantization may vary with vowel length (E,F)
- Pre-aspiration may diachronically derive from [s]-stop clusters (G)
- It is often the case that pre-aspirates/spirants are limited to stressed domains (H)

In the next section I consider phonetic reasons for the patterns that have emerged from this typological investigation.

3. Phonetic sources of pre-aspirates' diachronic instability

The rarity of pre-aspiration has been previously observed by Kingston (1985, 1990). He especially considers their rarity in comparison to the overwhelming prevalence of their post-aspirated counterparts ([p^h, t^h, k^h]).

Consider first Kingston's proposed explanation for the commonality of post-aspirates. In comparison to other CV sequences, the transition interval from a voiceless stop into a following vowel is an especially salient acoustic event which involves the pressurized expulsion of air that has been trapped behind the oral occlusion. The resulting high volume and velocity of particle flow produces an especially robust acoustic signal (at the burst, and the interval immediately following) which is particularly well-suited to bear contrastive information. Because of its salience, Kingston suggests that it is a preferred site for the realization of linguistically significant articulatory events. Laryngeal articulations thus gravitate, or "bind" to this site so that they may be realized with comparatively heightened acoustic salience, thus increasing the likelihood of unambiguous cueing to listeners.

Regarding pre-aspirates, there is very little experimental work which documents their aerodynamic and acoustic properties. But as pre-aspirates do not possess a stop closure immediately preceding the laryngeal abduction, there is no build-up of pressure to increase particle flow during the laryngeal. On the contrary, a continuation of the preceding vowel results in a further depletion of aerodynamic resources during this critical interval. Given the absence of a robust burst, the noise associated with "h" sounds is not so saliently present in the signal.

In addition to aerodynamic and acoustic considerations, there are auditory reasons why aspiration is so rare at the cross-linguistic level. As speech discrimination is necessarily based on information that is encoded at the auditory nerve, any non-linearities that are introduced at this level may play an important role in affecting the way acoustic signals are ultimately perceived by listeners. Such studies of the auditory nerve have been performed on, for example, Mongolian gerbils, rats, and cats; it is rather unlikely that the human auditory nerve is functionally dissimilar in its gross characteristics (Smith 1979, Delgutte 1980). Delgutte reports on the observation that there is a pronounced peaking of auditory nerve activity at the sudden onset of spectral energy; the shorter the rise time, and the greater the intensity increase, the higher the peaking, but also

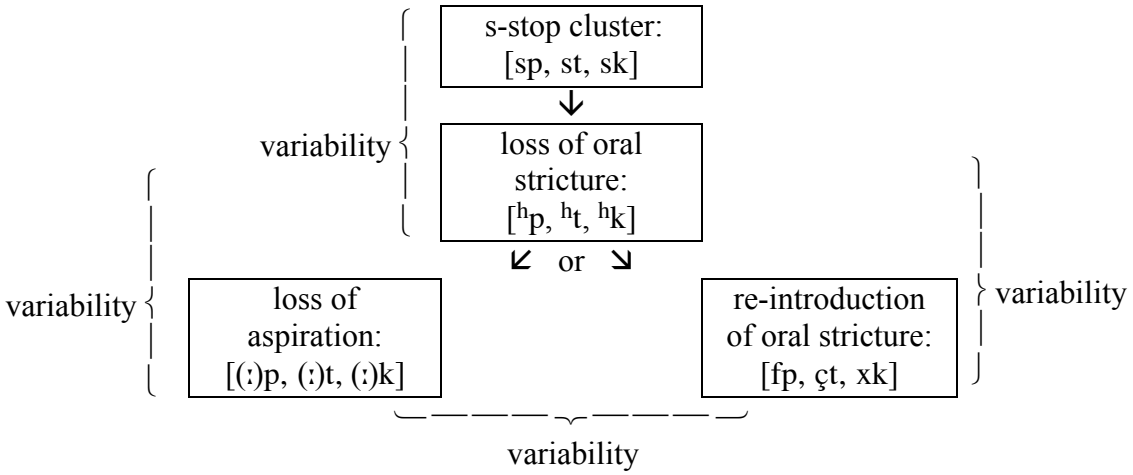
the more precipitous the subsequent reduction in firing. Also, he reports on short-term adaptation: the auditory nerve fires less robustly as the same sound continues to be produced over time. For example, he shows that the fast rise-time of the affricate tʃ produces a higher peak and faster decay than the slow rise time of the fricative ʃ. He concludes that "the coding of envelope rise time for speech-like sounds involves an interplay of the saturating character of rate versus intensity functions and the dynamics of short-term adaptation" (p.845). Indeed, he suggests that short term adaptation may have functional benefits for speech communication: "In general, at the beginning of a speech segment, units tuned to the major frequency components of the preceding (adapting) segment would discharge at lower rates. Thus, short-term adaptation would increase contrast between successive segments in the profile of discharge rate versus CF [characteristic frequency]" (p.848). If aspiration is sequenced to follow a stop closure, the sound spectrum changes abruptly from silence to burst and random noise. After the period of silence which auditorily characterizes the stop closure, spectral activity is suddenly and robustly re-introduced into the signal. Consequently, neural activation may be heightened due to the re-implementation of the stimulus. Moving abruptly from silence to sound should induce peaking across a broad range of the tonotopically arranged auditory nerve.

Pre-aspirates, due to their aerodynamic, acoustic, and auditory disadvantages are likely to be diachronically unstable. In order to salvage their contrastive function, an oral constriction might be introduced to enhance their noise characteristics, thus resulting in a series of pre-spirants, or "reverse affricates": [^{h}p, ^{h}t, ^{h}k] → [fp, çt, xk]. Alternatively, the cueing of the noise might be sufficiently poor so that all traces of noise might come to disappear from the system. If some sort of phonological contrast is now to survive, the period of noise might reduce to a prolongation of the preceding vowel quality: the oral configuration remains, but laryngeal noise gives way to standard voicing. This results in the introduction of a vowel length contrast: [V^{h}p, V^{h}t, V^{h}k] → [V:p, V:t, V:k]. Alternatively, pre-aspiration might survive in contexts where it is rendered more prominent by stressing the vowel on which it resides, alternating with its absnece upon de-stressing. As our typological study has demonstrated, these are exactly the patterns that are present in purported cases of pre-aspiration.

There is another noteworthy observation about the sorts of phonetic variation documented in Section 2. We observed that pre-aspiration typically varies with homorganic spirant-stop clusters and/or with vowel length. In the case of Huautla Mazatec, at least some pre-aspirates diachronically derive from [s]-stop clusters. However, there are no languages in the typological study in which homorganic spirant-stop clusters vary with [s]-stop clusters (*[sp, st, sk] ~ [fp, çt, xk]). If the diachronic route from s-stop clusters to the "reverse affricate" first passes through a stage of unstable pre-aspiration, then the absence of this second pattern of variation may be accounted for. Since some internal sound changes have been argued to proceed from the variability in speech production (Paul 1880, Martinet 1975, Ohala 1989, Janda and Joseph 2001), it follows that the form of immediate diachronic neighbors is constrained by the variability found at the synchronic level. Consequently, as s-stop clusters to vary with pre-aspirates, and pre-aspirates to vary with "reverse affricates" and/or vowel length, then it follows that these sorts of variation will also be found among diachronic neighbors, for example, {sk–^{h}k}, {^{h}k–xk–(:)k}. Moreover, as s-stop clusters are hypothesized to be diachronically non-

adjacent to reverse affricates, we do not expect them to often vary with each other: *{sk–xk}. And indeed, this is exactly what our typological investigation has shown. A proposed diachronic flowchart, with observed patterns of synchronic variability, is sketched in (16).

(16)



4. Concluding Remarks

It is understandable that phonologists, engaged as they are in making cross-linguistic generalizations about sound patterning, sometimes simplify their descriptions of complex phenomena. In the case of so-called pre-aspirated stops, I have shown in this paper that the simple cover-term "pre-aspirate" does not do the facts justice. Genuine across-the-board pre-aspiration is rarely if ever found, the reasons for their rarity and diachronic instability lying in their inauspicious phonetic salience. Instead, these sounds typically involve oral stricture in some or all of their realizations. Upon the introduction of this added noise component, the salience of the pattern increases its likelihood of diachronic survival.

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