On the Typology of Laryngeally Specified Consonants

0. Introduction

A correlation exists between the cross-linguistic prevalence of certain articulatory sequences, and their consequent degree of neural response at the auditory nerve. Specifically, some gestural timing configurations which are cross-linguistically prevalent seem to be associated with a comparatively *heightened* response at the level of the peripheral auditory system (e.g. Bladon 1986, Silverman 1995,6, Johnson 1997, Wright 2004); by contrast, less common timing patterns involving these same gestures may produce a relatively *diminished* auditory nerve response. Moreover, if a particular language possesses the less common timing pattern, it nearly always possesses the more common timing pattern as well (Silverman 1995).

This correlation may be viewed in several distinct ways. First, the auditory system may have evolved in its fashion in response to grammatical universals. This view is readily dismissible when considering that these auditory nerve firing patterns are observed in lower animals in response to non-linguistic stimuli. Second, it may be that our specifically grammatical—mental, psychological—endowment bears no relationship at all to the coincidental fact that these grammatical patterns have their observed physical correlates. Third, this correlation may be viewed as causally related: certain timing patterns are cross-linguistically prevalent exactly because they induce a higher rate of auditory nerve firing. In this paper I explore this third interpretation of the facts.

Consider the case of **hV** sequences versus breathy vowels (**V̤**). Both of these articulatory configurations, notice, involve voicing, a laryngeal abduction, and a supralaryngeal vocalic gesture. However, **ha** sequences are cross-linguistically far more prevalent than **a̤**, and, for that matter, **ah**. Moreover, if a language possesses **a̤**, then it seems always to possesses **ha** as well, even when breathy vowels are otherwise allowed, i.e., when they are preceded by consonantal gestures, for example **na̤** (Silverman 1995, 1997a). Of the 453 languages in the UCLA Phonetic Segment Inventory Database (UPSID), only five reportedly possess breathy vowels (Bruu, Dinka, Nyah Kur, Parauk, and Tamang). Of these five, only Dinka does not possess **h**. In fact, Dinka possesses a *pharyngeal* vocalic contrast, not a laryngeal contrast (Jacobson 1980, Malou 1988, Denning 1989, Andersen, 1993), and thus does not constitute an exception to the stated generalization.

(1) **ha** >> **a̤, ah** (even when breathy vowels are elsewhere attested)[1]

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[1] In Silverman 1995, 1997a I argue that vowels are sufficiently sonorous to allow three contrastive timing patterns upon laryngeal augmentation (**ha, a̤, ah**): observed auditorily sub-optimal timing patterns are normally maximally distinct from preferred timing patterns. As shown herein, consonants too display maximal dispersion in terms of their timing characteristics, although, given the shorter durations and the lesser overall acoustic energy of such constrictions, fewer contrasts are observed within any given system, i.e., a maximum of two, not three.

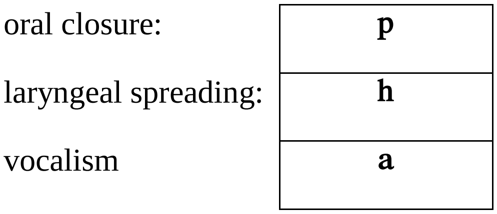
This generalization also holds when the involved gestures are preceded by a stop. That is, **tʰa** seems always allowed before **ta̤**. And again, if only one pattern is allowable among these contrastive gestures, it is always **tʰa**, and never **ta̤**, even when breathy vowels are otherwise allowed (again, for example, **na̤**).

(2) **tʰa** >> **ta̤** (even when breathy vowels are elsewhere attested)

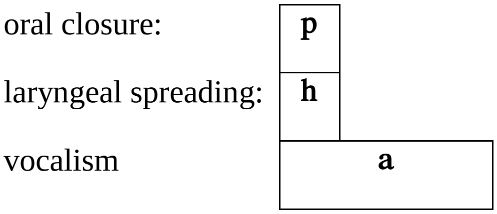
Also, post-aspirate **tʰa** seems always preferred to pre-aspirate **ʰta**.

(3) **tʰa** >> **ʰta**

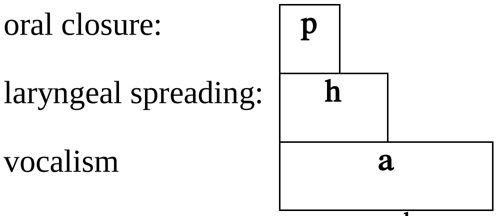
I argue in this paper that post-aspirated plosives are cross-linguistically prevalent due to their advantageous *articulatory*, *aerodynamic*, *acoustic*, and *auditory* characteristics, (thus expanding on the ideas earlier presented in Kingston 1985, 1990). Given their phonetic advantages, post-aspirates possess unmarked status in the world's languages (where the presence of marked values definitionally implies the presence of unmarked values). In contrast, both stops followed by breathy vowels, and pre-aspirates, do not enjoy these phonetic advantages. And while breathy vowels are marked in general with respect to plain vowels, breathy vowels preceded by a stop consonant are especially disfavored.



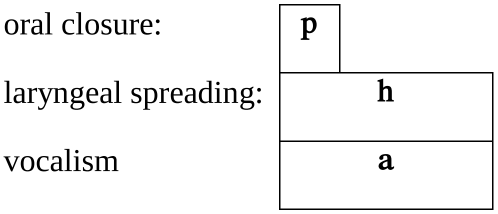
p



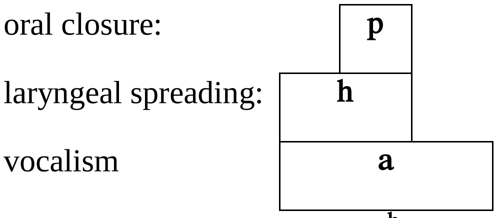
pa



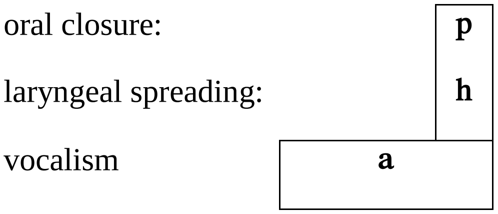
pʰa



pa̤



ʰpa



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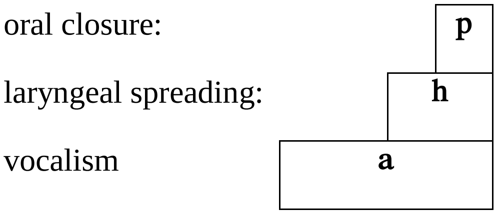
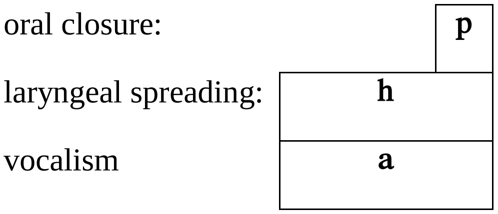
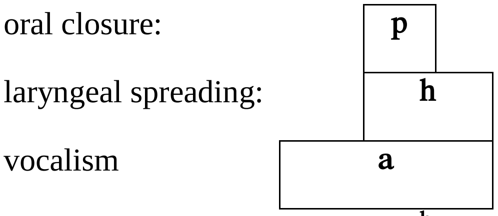


aa̤p



a̤p



apʰ

I further investigate the timing of the glottal spreading gesture with respect to fricatives, and also with respect to sonorant consonants—these are so-called "voiceless" (**n̥n**) and "breathy" (**nn̤**) nasals found in, for example, Burmese and Sukuma respectively—and how certain timing patterns here serve to better transmit the relevant acoustic information to the listener. And again, such "better" timing patterns are more prevalent cross-linguistically than other timing patterns. I continue with a similar discussion of approximants.

Section 2 consists of discussion of laryngeal spreading gestures vis-a-vis obstruents, considering in turn stops and fricatives, while section 3acond continuethe relevant articulatory gestures which are necessary to achieve both optimal and sub-optimal auditory ends, continuing with a brief discussion of aerodynamics, showing (pace Kingston) that the aerodynamic properties of stop releases ideally suit them for accommodating laryngeal contrasts. I briefly consider some of the major acoustic properties which the articulatory and aerodynamic systems give rise to in these contexts, presenting some relevant properties of the peripheral auditory system which introduce non-trivial non-linearities into the incoming acoustic signal. Finally, I consider specific systems.

2. Phonetic tutorials

As the focus herein is on phonetic explanations for phonological patterning,

2.1 Stops and vocal fold spreading

2.1.1 Articulatory, aerodynamic, and acoustic advantages of post-aspirated stops

Kingston (1985, 1990) reports that laryngeal articulations tend to be realized at the release of a stop consonant. His so-called "articulatory binding" generalizations observe two asymmetries in the patterning of laryngeal articulations with respect to oral ones. These are paraphrased in (4).

(4) paraphrase of Kingston's binding generalizations:
    (1) Voiceless plosives are much more likely to contrast for glottal articulations than are voiced plosives, fricatives, or sonorants.
    (2) Contrastive glottal articulations in voiceless plosives are more frequently realized as modifications of the release of the oral closure than of its onset.

Unlike a voiceless stop closure, the transition interval from a voiceless stop into a following vowel is an acoustically salient event which involves the pressurized expulsion of air that has been trapped behind the oral occlusion. This pressurized expulsion of air results in a high level of acoustic energy which is especially 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" toward this site so that they may be realized with comparatively heightened acoustic salience.

A glottal abduction allows air to pass across the glottis at a rapid rate. With a downstream closure, the oral cavity fills to capacity quite quickly. Typically, for aspirated stops, the glottal abduction is maintained, and often increases in magnitude around the transition from stop to vowel (Hirose, Lee, and Ushijima 1974, Löfqvist 1980, Löfqvist and Yoshioka 1980, Yoshioka, Löfqvist, and Hirose 1981). The pressure build-up behind the oral closure is thus released with a salient burst. Moreover—and this is especially important—timing the maximal laryngeal abduction with the transition from stop closure to vowel results in maximal airflow during this critical interval. As increased airflow may correlate with increased acoustic energy, source noise is saliently encoded in the speech signal. (It should be noted that laryngeal abductions are also common concomitants of *plain* stops. Here, the abduction is indeed timed more or less simultaneously with the oral occlusion, which inhibits the likelihood of closure voicing.)

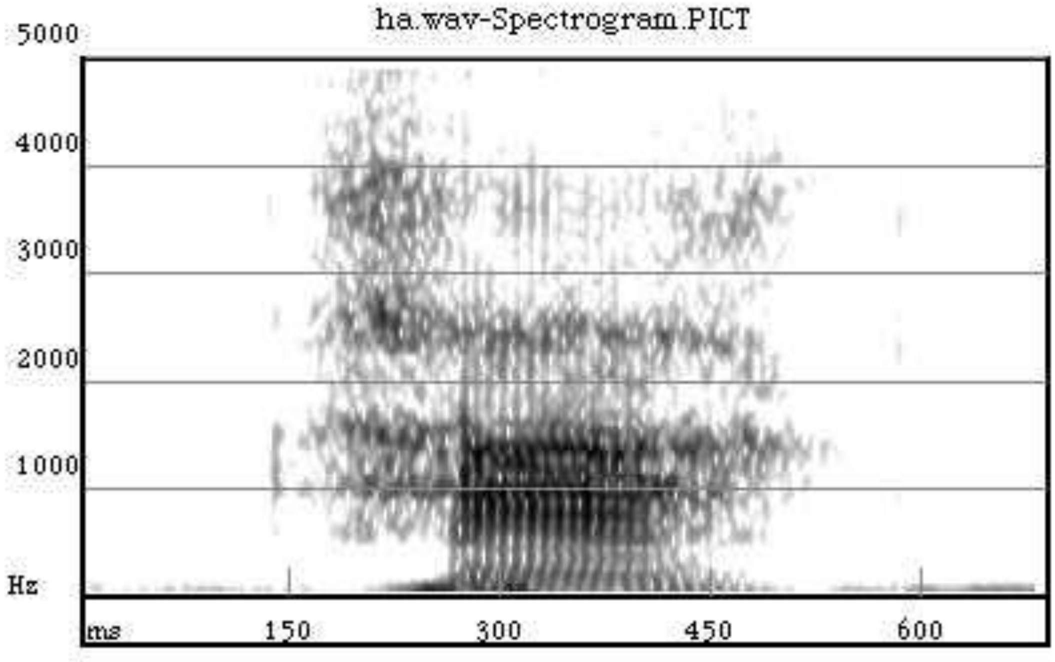
In contrast, Ladefoged (1975) shows that breathy phonation may be achieved by approximating the folds at one end, and simultaneously abducting the folds at the other end. When preceded by a stop, a breathy vowel, with its reduced level of flow in comparison to a pure aspirate, does not take full advantage of the free supralarygneal pressure build-up that is a consequence of oral closure; the release interval here is not exploited in as effective a manner. Indeed, breathiness is typically realized for the duration of the following vowel, as opposed to only the interval of release, perhaps enhancing the recoverability of the otherwise diminished salience of noise in this context.

Relatedly, Ladefoged (1952) shows that word-initial **h** in English is accompanied by striking increases in internal intercostal muscular action. As the internal intercostals are the primary muscle group responsible for active external pressure on the lungs, their flexion here results in greater expulsive force, a force which in part might compensate for the lack of oral closure on which the laryngeal may otherwise "bind." This increased respiratory effort is perhaps present in pre-aspirates as well, which, like plain **h**, do not bind to a stop release.

Let us then turn to the acoustic advantages enjoyed by post-aspirates, in comparison to other timing relations among stops and laryngeal abductions.

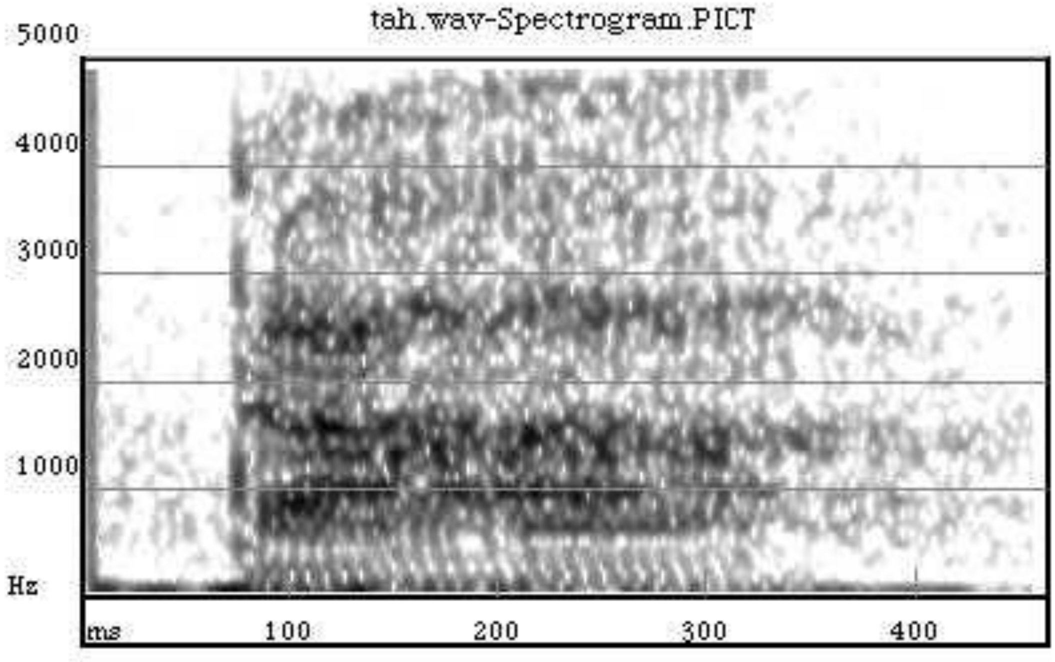
For **tʰa**, the full silence of the stop is followed by a sudden onset of noise at release, which is most pronounced at the characteristic transient frequencies, and continues until the periodic wave begins. The voiceless laryngeal abduction that characterizes the first portion of this gestural configuration produces random noise across a broad portion of the sound spectrum. During **h** sounds, the shape of the supralaryngeal cavity is contextually determined by proximal supralaryngeal gestures. Consequently, the noise of the aspirate is more prominent at these gestures' characteristic formant frequencies. At the onset of modal phonation (plain voicing), the sound spectrum changes from noise to the periodicity that is characteristic of a regular glottal pulse.

(7) **tʰa**: silence followed by sudden onset of noise, especially in formant transition regions, followed by periodicity:



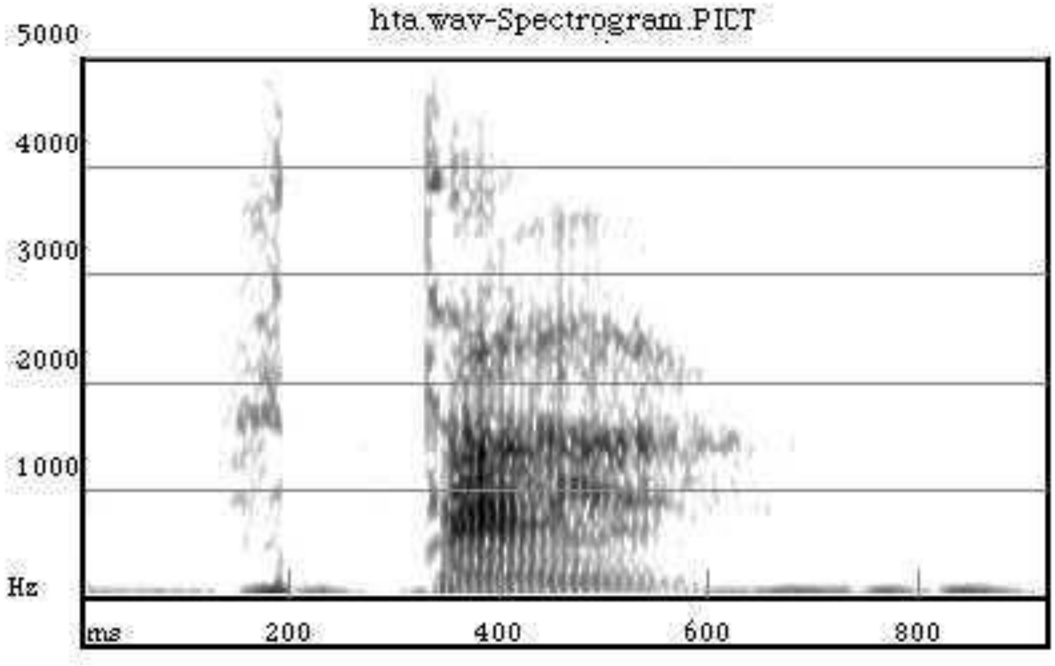
ta̤, by contrast, is rather similar in spectral characteristics to **a̤**, the main difference being the sudden onset of quasi-periodic energy and noise at stop release, along with a burst and formant transitions. Breathy phonation involves the *simultaneous* encoding of noise and (quasi-) periodic energy. As the larynx is but a single entity, the articulatory and acoustic qualities of breathiness cannot be a simple summation of component vocal fold abduction (yielding aperiodic energy) and vocal fold approximation (yielding periodic energy). Instead, the consequent acoustic signal possesses several emergent characteristics. As the acoustic signal possesses both harmonics as well as noise, a ratio between the two may be readily calculated; this harmonics-to-noise ratio has been shown experimentally to be of special import in the perception of breathy voice (de Krom 1994). Additionally, breathy phonation possesses a characteristic spectral tilt. Specifically, the first harmonic is enhanced relative to H2 (Bickley 1982, Ladefoged, Maddieson, and Jackson 1988) and/or F1 (Hammarberg, Fritzell, Gauffin, Sundberg, and Wedin 1980). Moreover there is an overall reduction in amplitude of the higher harmonics. Breathy voice may also be associated with high-end noise, which is also emergent, as it may be the result of air turbulence around the interval of (partial) glottal closure.

(8) **ta̤**: sudden onset of moderate broadband noise especially in formant regions, and quasi-periodicity:



Finally, a pre-aspirate involves noise followed by silence, and then burst, and a periodic pulse, especially in the formant regions. the spectrogram in (x) reveals the significant attentuation of overall energy during the noice component that is asosicated with the laryngeal spreading gesture, especially when compared the the robust noise asoicated with its post-aspirated counterpart.

(9) **ʰta**: broadband noise followed by silence, followed by sudden onset of periodicity, especially in formant regions:



With regards to the gross temporal organization of articulatory gestures which give rise to these sorts of acoustic patterns, Mattingly (1981) considers the special import of acoustic discontinuities in the speach signal. He suggests, along the lines of Liberman, Cooper, Shankweiler, and Studdert-Kennedy (1967), that the speech perception mechanism is especially designed to decode a signal involving the simultaneity of cues, and is less adept at decoding a signal consisting of discrete, non-overlapping cues. Specifically, alternating greater degrees of stricture with lesser degrees of stricture may result in a speech signal in which contrastive information is transmitted primarily during stricture transition intervals. That is, the transitions from C to V, and from V to C are the most informationally rich components of the speech signal.

But note that implicating transition periods *per se* may be insufficient to isolate those components of the speech signal that seem to be *most* successful at encoding information. Rather, above and beyond the boost provided by stop bursts, transitions from periods of greater stricture (Cs) to periods of lesser stricture (Vs) are optimal. As discussed in the following section, certain characterstics of the peripheral auditory auditory system may provide the key to understanding the primacy of CV transitions—even over VC transitions—with respect to gross gestural coordination of consoants, laryngeals, and vowels. As such, above and beyond the important insights of Kingston and Mattingly, it is argued that an auditory-based approach may be regarded as better underlying motivation for observed cross-linguistics patterns under consioderation herein. Let us then now turn to those relevant aspects of the peripheral auditory system.

2.1.2 Auditory advantages of post-aspirated stops

In this section I propose that, in addition to aerodynamic and acoustic considerations, there are *auditory* reasons why aspiration may be preferably realized around stop release, as opposed to simultaneously with the full duration of a following vowel, or preceding a stop closure. Indeed, speech discrimination must be based on information that is present at the level of the auditory nerve. This being the case, any non-linearities that are introduced at this level may play an important role in affecting the way acoustic signals are ultiamtely perceived by listeners. Bladon (1986) proposes some of the major principles of auditory phonetics. For present purposes, his principles (3), (4), and (5) are most relevant. These are quoted in full in (10) (1986:5).

(10) <u>Bladon's principles of auditory phonetics</u>:

- (3) <u>On/off response asymmetry</u>: spectral changes whose response in the auditory nerve is predominantly an onset of firing are much more perceptually salient than those producing an offset (Tyler, Summerfield, Wood, and Fernandes 1982).
- (4) <u>Short-term adaptation</u>: 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 (Delgutte 1982).
- (5) <u>Neural recovery</u>: silent intervals in speech sounds give rise to a rapid, high-amplitude discharge when interrupted (Delgutte 1982).

The level of auditory nerve response is not solely a function of the current level of the acoustic signal, but also reflects recent changes, and especially *increases*, in the level of that signal. Consequently, acoustic signals deriving from the same articulatory posture may evoke a greater neural response when in one context than when in another. Thus, stop releases involve a sharp increase in auditory nerve firing rate, which decays to a moderate level through the following vowel. Given the heightened auditory response at stop release (Principle 5), and the rapid decay of response across the steady state of a following vowel (Principle 4), it should not be viewed as coincidental that CV transitions (and, by necessary extension, CV sequences) are especially common.

As discussed by Johnson (1997:139), “After a brief period of silence [for the stop closure –D.S.] the auditory system responds more strongly than it does in a period of continuing sound. So onsets in general produce a large response in the auditory system. In stops this enhances the importance of release bursts...”

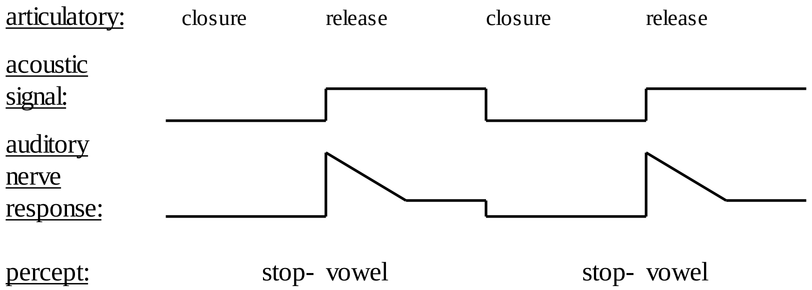
Delgutte (1982) goes into rather more detail on the subject, reporting on a computional model of physiological data gathered from auditory nerve fibers of anesthetized cats. Briefly, the computer program models the auditory nerve by passing a sound signal through a series of bandpass filters which correspond to particular fiber groups’ central or characterstic frequency (CF). After a smoothing procedure, further filters introduce nonlinearities that mirror those observed in the physiological data, depending on discharge rate across different loudness levels. The final filter models the observed decay of discharge rate over time, that is, short-term adaptation: at higher stimulus levels, decay is more rapid.

Feeding speech into the program, prominent peaks are generated when there is a sudden increase in energy at a given CF, followed by a rapid decay to a lower, sustained level. For obstruents, these peaks are observed at higher frequencies, while for sonorants, peaks are observed at lower frequencies. Moreover, the extent of these peaks across the frequency range seems in part dependent on the preceding speech sound. For example, utterance-initial sonorants generate peaks from 0 to 5000 Hz, whereas utterance-medial schwa generates peaks only between 2500 and 5000 Hz. In general, the quieter the preceding sound, the greater the frequency range of peaking when sound is re-introduced. Delgutte further reports that both shorter rise times and longer silence durations (as is found, for example, at the closure-then-release of a voiceless stop consonant), the greater the amplitude of the initial peak.

Although Delgutte cautions that “the signal processing in the model is highly idealized” and that “it is not possible at present to conclude as to the use of average discharge rates versus fine time patterns of discharge for speech coding” (p.142ff), he further states that “Some of the present results suggest that both average discharge rates and fine time patterns of auditory-nerve fiber discharges contain cues for distinctions between speech sounds...In particular, there are prominent dynamic cues to the rapid changes in amplitude and spectrum that are important for phonetic distinctions” (p.142). Indeed, he concludes that “speech sounds seem to be well adapted to the properties of signal processing by the peripheral auditory system...This is a natural idea from an evolutionary perspective since the general plan of the auditory system is similar among almost all mammals, whereas the speech production appartus is more specific to humans” (p.146).

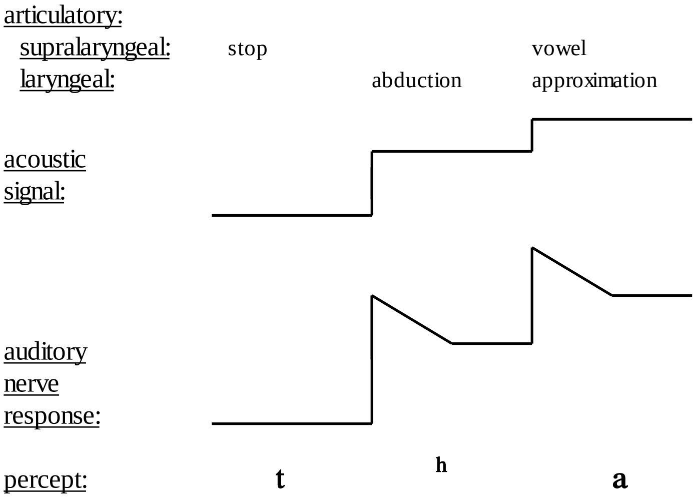
The schematic in (11) displays in gross terms the non-linearities that the auditory nerve imparts on the incoming acoustic signal in this context.

(11) <u>stop-vowel sequence</u>:



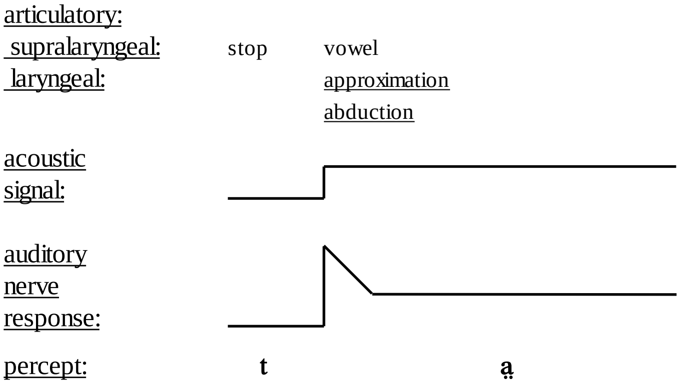
Now, if aspiration is sequenced to follow a stop closure, the sound spectrum changes abruptly from silence to burst and random noise. After the period of silence which auditorily characterizes the stop closure, spectral activity is suddenly and robustly re-introduced into the signal. Consequently, neural activation may be heightened due to the re-implementation of the stimulus (Principle 5), and thus the aspiration of post-aspirated stops is auditorily salient (14).

(14) post-aspirated stop:



In contrast, a stop followed by a breathy vowel does not possess as pronounced an amplitude modulation and consequent neural response as that which is present in post-aspirates.

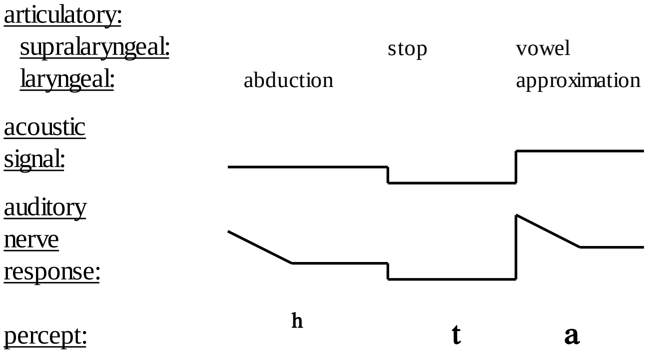
(15) stop-breathy vowel sequence:



Although auditory nerve response may be heightened in this context, for present purposes, the important point is that a stop-then-voiceless aspiration sequence should induce a *greater* response than stop-then-breathy phonation sequence, for these latter configurations lack the aerodynamic and consequent acoustic boosts which induce such effects.

Finally, consider pre-aspirated stops. Here, Bladon notes that, word-internally, aspiration is realized as a devoicing of the latter portion of the previous vowel. Thus there is little spectral shift in the transition from modal vowel to voicelessness. Consequently, the auditory nerve undergoes short-term adaptation (Principle 4): neural discharge decays throughout the vowel-**h** sequence. Since auditory response is much greater for the onset of spectral activity as opposed to its offset, the likelihood of recovery here is rather diminished (Principle 3). As Bladon concludes, “...given that preaspiration suffers from an accumulation of auditory handicaps, it would not be a risky prediction that languages would rarely make use of this auditory-phonetic dinosaur” (p.7).

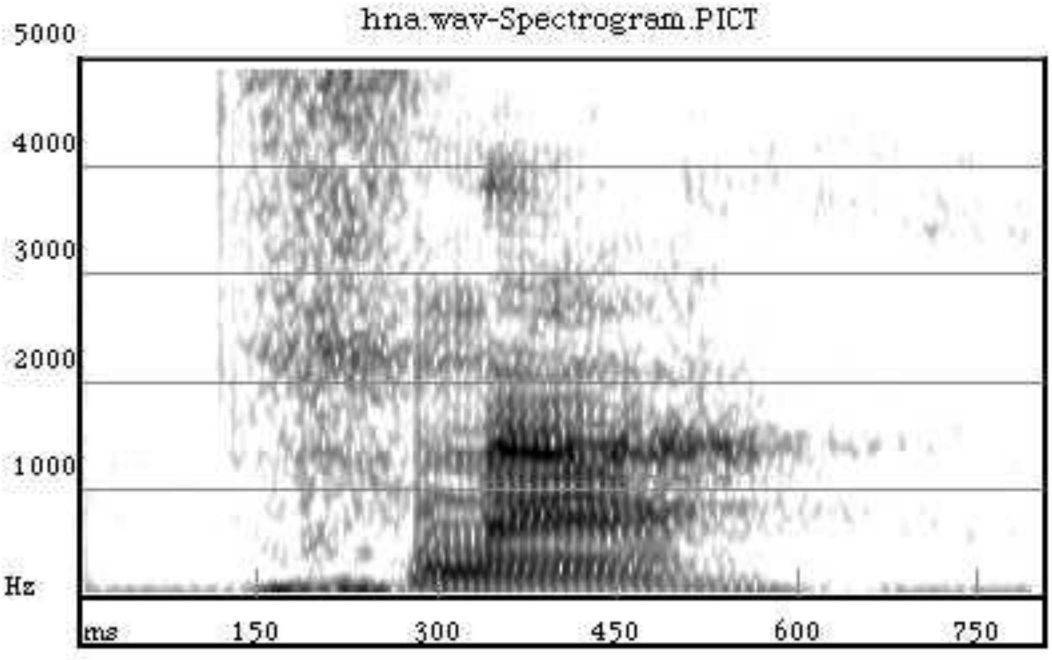
(16) pre-aspirated stop:



To summarize, frequent, abrupt rises in amplitude result in a heightened auditory nerve response. Moreover, amplitude plateaus result in the decay of auditory nerve response. On the reasonable assumption that auditory nerve response is non-trivially correlated with overall auditory salience, gestural configurations are more effectively conveyed to listeners to the extent that amplitude increases incrementally and frequently.

4.1 Voiceless nasals

If a spread glottis is implemented simultaneously with a nasal stop (for example, **an̥a**, **am̥a**, **aŋ̥a**) what are the acoustic consequences? A laryngeal abduction occurring with a nasal stop involves a dramatic decrease in acoustic energy in comparison with its voiced counterpart. Ladefoged and Maddieson (1996) hypothesize that the reduced energy associated with voiceless nasals may obscure formant transitions between the nasal and a neighboring vowel, which, recall, are most important in cueing nasal place of articulation. Moreover, Dantsuji (1984) reports that he could not find significant differences in the spectral characteristics within the voiceless portion of voiceless nasals in Burmese made at the labial, alveolar, and velar places of articulation (although nasal manner cues were still in evidence). Without their distinctive spectral characteristics, place of articulation may be indiscriminible (see also Ohala 1975, Dantsuji 1986, 1987). This, of course, is an undesirable result, because the functional gain of having the aspiration as a linguistically significant contrast here is obviated by the loss of oral place contrasts. Therefore, a voiced transition between a so-called voiceless nasal and a neighboring vowel serves to better cue the articulatory transitions, thus increasing the likelihood of conveying place-of-articulation information.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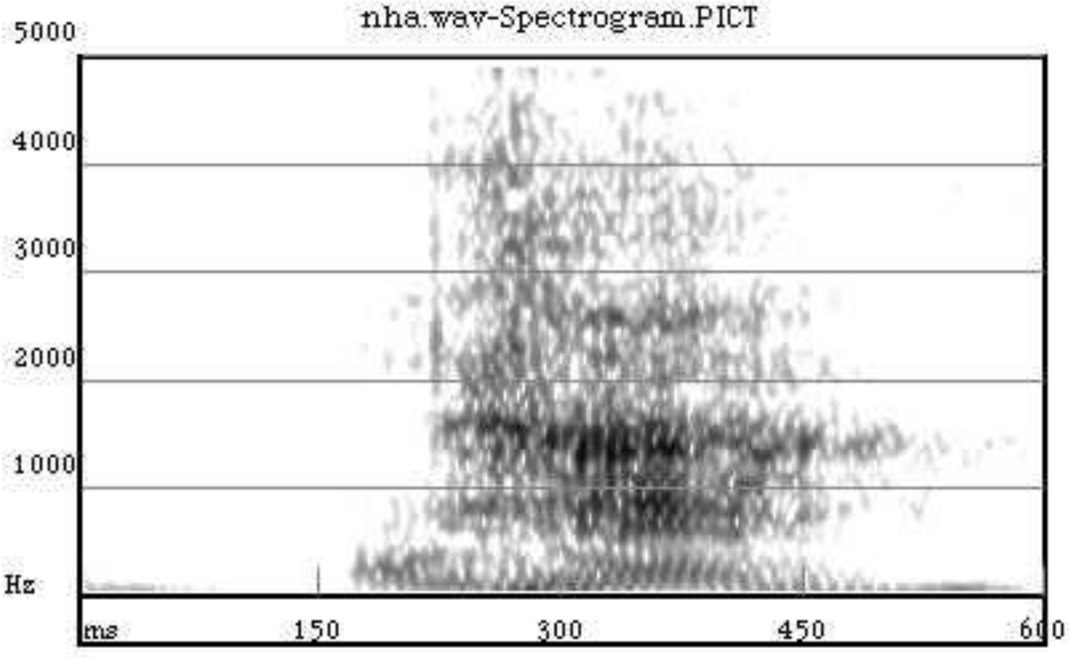
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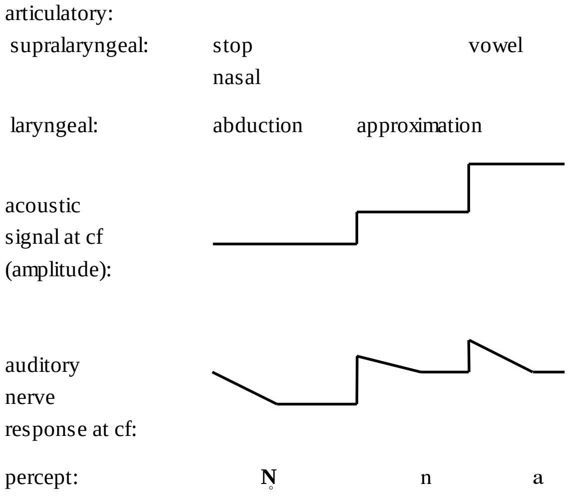
As it turns out, the spread glottis of voiceless nasals is normally timed to the early portion of the nasal stop. In Burmese for example, we find N̥͡**ma**, N̥͡**na**, and N̥͡**ŋa** (where N̥ represents nasally-channelled noise, lacking place cues). In this fashion, a partial nasal murmur survives, and most importantly, CV transitions survive as well, and so place information is recoverable. Indeed, Henderson (1985) as well as Ladefoged and Maddieson (1996) report that voiceless nasals of the Burmese type are cross-linguistically more common than others, for example, **n͡n̤**.

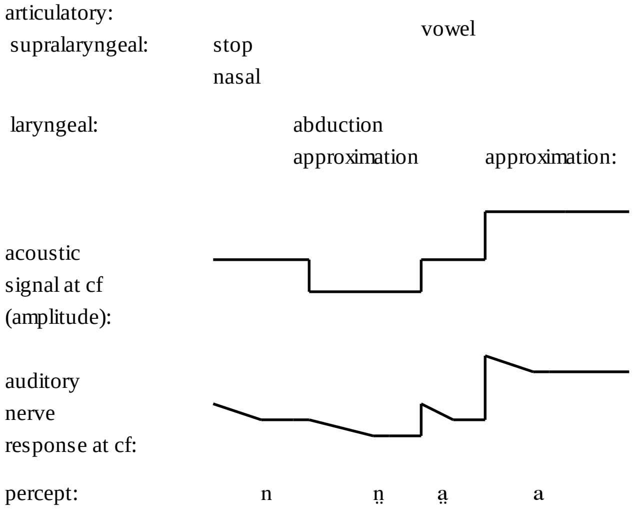
(5)

<u>Gross schematic of articulatory, acoustic, and auditory characteristics of early voicelessness in nasals</u>:



(7)

Gross schematic of articulatory, acoustic, and auditory characteristics of late breathiness in nasals



3. Survey of system types

Consider now the consonant inventory of Oriya (Dhall 1966), shown in (33).

(33) Oriya consonant inventory:

p	t	c	ʈ	k
p^h	t^h	c^h	ʈ^h	k^h
b	d	ɖ	ɟ	g
	s	ʃ	ʂ	
m	n	ɲ	ɳ	ŋ
	l,r		ɭ	
w		j		
h				

As in Mandarin, Oriya contrast plain and aspirated stops. But unlike Mandarin, in Oriya both aspirates and breathy vowels are attested. It is significant, however that breathy vowels are only allowed after sonorants, and never after stops. Onsets disallowed with breathy vowels are shown in (34).

(34) onsets disallowed with breathy vowels:

p	t	c	ʈ	k
p^h	t^h	c^h	ʈ^h	k^h
h				

In (40) are some examples of both aspirates and breathy vowels. According to Dhall's instrumental studies, breathy phonation pervades the domain of the syllable, overlapping with pre-vocalic sonorants.

(35)

aspirated stops:		breathy vowels:	
p^hi	each	**r̥͡r̤i̤**	shame
t^ho	place	**r̥͡r̤ṳ**	(a radical meaning to steal)
c^hu	gone	**n̥͡n̤ṳti**	stealing
ʈ^{h}a	royal meal		
k^hã	(a Muslim surname)		

That is, all plain stops allow aspiration—but never breathy phonation—even though breathy vowels are elsewhere allowed. Thus, while **ta**, **t^ha** and **na̤** are fine, **ta̤** and **t^ha̤** are unattested.

1.

Fasu:	**ta**		
Mandarin:	**ta**	**t^ha**	
Oriya:	**ta**	**t^ha**	(but **na̤**, *t**a̤**)

In this sense then, Oriya is just like Mandarin, in permitting only the optimally recoverable timing pattern of stops, vowels, and vocal fold spreading. And so, given these and only these gestures, the pattern is the same as in Mandarin, and the recoverability of cues may be viewed as the primary determinant of timing here.

As discussed in great in detail by Fischer-Jørgensen (1970) Gujarati possesses breathy vowels with any and all vowel qualities, and most consonant qualities.

In (36) is the Gujarati consonant inventory (from Taylor 1985).

(36) Gujarati consonant inventory:

p	**t**	**tʃ**	**ʈ**	**k**
pʰ	**tʰ**	**tʃʰ**	**ʈʰ**	**kʰ**
b	**d**	**dʒ**	**ɖ**	**g**
bʰ	**dʰ**	**dʒʰ**	**ɖʰ**	**gʰ**
	s	**ʃ**	**ʂ**	
v				
m	**n**	**ɲ**	**ɳ**	**ŋ**
	r,l		**ɭ**	
		j		
h				

In (37) are some examples of breathy vowels (from Fischer-Jørgensen 1970) (no glosses provided).

(37) examples of Gujarati breathy vowels:

po̤r	**ta̤ro**	**tʃi̤r**		**ko̤ɽ**
bi̤	**dṳd**	**do̤ɽ**		
	se̤dʒ			
mo̤r				
wa̤li				

According to Patel and Mody (1961) breathy vowels are limited in their distribution to the first syllable of the word, although this is only a trend. More importantly, any consonant may precede a breathy vowel except those listed in (38).

(38) onsets disallowed with breathy vowels:

pʰ	**tʰ**	**tʃʰ**	**ʈʰ**	**kʰ**
bʰ	**dʰ**	**dʒʰ**	**ɖʰ**	**gʰ**
		ɲ	**ɳ**	
			ɭ	
h				

Breathy vowels may thus follow any onset except aspirates. Moreover, class-internal coronal sonorants (nasals and laterals) do not contrast before breathy vowels. In Gujarati then, any stop, either plain or voiced, may be followed by either aspiration or a breathy vowel, but never both. This represents a more complicated system than either Mandarin or Oriya, in that both optimal and sub-optimal timing patterns are observed.

2.

Fasu:	**ta**			
Mandarin:	**ta**	**tʰa**		
Oriya:	**ta**	**tʰa**		(but **na̤**, *ta̤)
Gujarati:	**ta**	**tʰa**	**ta̤**	(but ***tʰa̤**)

The Huautla dialect of Mazatec (Pike and Pike 1947, Kirk 1966, Steriade 1994, Silverman 1995), along with the Mazatlán de Flores, Santa María Jiotes, and San Jerónimo Teocatl dialects (Kirk 1966), is similar to Gujarati in allowing both optimal and sub-optimal timing patterns of the involved gestures. However, Huautla Mazatec departs from Gujarati in employing pre-aspirates as its sub-optimal timing pattern, as opposed to stop-breathy vowel sequences. The Huautla Mazatec native consonant inventory is presented in (40).

(40) <u>Huautla Mazatec native segment inventory</u>:

	t				**k**
		ts	**tʃ**	**ʈʂ**	
	s		**ʃ**		
v					
m	**n**		**ɳ**		
	ɾ (marginal)				
	l				
			j		
h,ʔ					

Observe that both oral stops and pre-nasalized stops may be either post-aspirated or pre-aspirated.

(41)

<u>post-aspirated stops</u>:						<u>pre-aspirated stops</u>:					
tʰ	**tsʰ**	**tʃʰ**	**ʈʂʰ**	**kʰ**			**ʰt**	**ʰts**	**ʰtʃ**	**ʰʈʂ**	**ʰk**
	ntʰ	**ntsʰ**	**ɲtʃʰ**	**ɳʈʂʰ**	**ŋkʰ**		**n̥nt**	**n̥nts**	**ɲ̥ɲtʃ**	**ɳ̥ɳʈʂ**	**ŋ̊ŋk**
						m̥m	**n̥n**		**ɲ̥ɲ**		

Some examples of both pre-aspirated and post-aspirated stops in Huautla Mazatec words are presented in (42) (from Pike and Pike 1947).

(542) <u>examples</u>:

<u>post-aspirated stops</u>:		<u>pre-aspirated stops</u>:	
tʰa^{4}	light in weight	**ʰti**^{4}	fish
tsʰe^{43}	clean	**ʰtse**^{13}	a sore
tʃʰa^{4}	brother-in-law	**ʰtʃi**^{4}	small

Here, unlike in Gujarati, aspirated stops do not contrast with post-plosive breathy vowels, but they *do* contrast with *pre*-aspirated stops. How might the timing contrasts in Huautla Mazatec versus those in Gujarati be motivated? Specifically, why does Gujarati expand its system of timing patterns by allowing stop-breathy vowel sequences (**ta̤**) to the exclusion of pre-aspirates (***ʰta**), while Huautla Mazatec expands its system of timing contrasts by allowing pre-aspirates (**ʰta**) to the exclusion of stop-breathy vowel sequences (***ta̤**)? The answer to this question requires a somewhat deeper exploration of the two languages' diverging systems of morphology, and systems of contrasts. I turn to these issues now.

As in certain other largely monosyllabic languages (for example, Otomanguean languages related to Mazatec), Huautla Mazatec superimposes both tonal and phonatory contrasts on vowel quality. Now, tonal contrasts are optimally realized with modal phonation, that is, concurrently with plain voicing, and away from non-modal phonation (Silverman 1995, 1997, to appear). In Jalapa Mazatec “breathy vowels,” for example, modal phonation is implemented on the latter portion of the vowel, where tone resides, while only the early portion of the vowel possesses breathiness (or creakiness) (Silverman, Blankenship, Kirk, and Ladefoged 1994). Assuming that the same is true in closely related Huautla Mazatec, the timing distinction between an aspirated stop followed by toned modal phonation (**tʰá**) versus a plain followed by breathy phonation, in turn followed by toned modal phonation (***ta̤á**) would be extremely meager indeed. The major distinction between the two would be the presence versus absence of voicing during the release interval. Consequently, the maximally contrastive timing pattern available *within the Huautla Mazatec system* may be pre- versus post-aspiration.

3.

Fasu:	**ta**			
Mandarin:	**ta**	**tʰa**		
Oriya:	**ta**	**tʰa**		(but **na̤**, *ta̤)
Gujarati:	**ta**	**tʰa**	**ta̤**	(but ***tʰa̤**)
Huautla Mazatec:	t**á**	tʰ**á**	**ʰtá**	(but *t**á̤**)

Motivating the presence of pre-aspiration in Icelandic (Liberman 1982) requires an expansion of the ideas discussed up to this point, for Icelandic possesses both *lexically contrastive* as well as *allophonic* aspiration, whereas up until now I have considered only the former. Intervocalically, pre-aspiration here is contrastive with post-aspirated stops, plain singleton stops, and plain geminates (44a).[2] Also, pre- and post-aspiration bear an allophonic relationship in certain contexts (44b).

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[2] Both Thráinsson and Kingston assume that non-alternating pre-aspirates are derived from underlying geminates. As there is no evidence for this abstract representation which never surfaces, I do not make this same assumption.

(44)	a.	V**ʰt**V	contrasts with
		V**ːtʰ**V	contrasts with
		V**ːt**V	contrasts with
		V**tː**V	
	b.	V**ʰt**V	alternates with
		V**ːtʰ**V	(in certain contexts)

Non-alternating pre-aspirates are contrastive in morphologically simple contexts where the involved stop closure immediately precedes an unstressed vowel; the pre-aspiration closes the preceding stressed syllable. In (45) are some examples (all examples are from Thráinsson 1978).

(45)	**ˈkʰaʰpi**	hero
	ˈθaʰka	thank
	ˈhaʰtyr	hat

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

(46)	**ˈɛʰplɪ**	apple	**ˈɔʰpna**	open
	ˈajʰtla	intend	**ˈvɛʰtnɪ**	hydrogen
	ˈɛʰkla	lack	**ˈvaʰna**	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.

(47)	**majtʰ+a**	→	**ˈmajːtʰa**	meet (inf.)	
	majtʰ+tʰ+ɪ	→	**ˈmajʰtɪ**	meet (past)	(*ˈ**majttʰɪ**)
	vejtʰ+a	→	**ˈvejːtʰa**	grant (inf.)	
	vejtʰ+tʰ+i	→	**ˈvejʰti**	grant (past)	(*ˈ**vejttʰi**)
	nitʰ+a	→	**ˈniːtʰ+a**	utilize (inf.)	
	nitʰ+tʰ+a	→	**ˈniʰta**	utilize (past)	(*ˈ**nittʰa**)

Rather, I assume that non-alternating pre-aspirates are indeed lexical pre-aspirates, thus adopting Thráinsson's "weak-**h**" hypothesis.

Additionally, pre-aspirated alternants appear upon attaching an **l**- or **n**-initial suffix to an aspirate-final root.

(48)	**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	→	**ˈkʰaʰka**	cake (gen. pl.)

Finally, sonorants vary with their devoiced counterparts. When devoiced, a plain stop follows; when not devoiced, an aspirate follows.

(49)	**ul̥pa**	~	**ulpʰa**	coat
	hejm̥ta	~	**hejmtʰa**	demand
	van̥ta	~	**vantʰa**	lack
	viŋ̊ka	~	**viŋkʰa**	wave

Generalizing about pre-aspirated alternants, as well as lexical pre-aspirates which precede a coronal sonorant, two points are especially important. First, pre-aspirates arise only when the stop is not followed by a morphologically ordered vowel. Second, pre-aspiration gravitates toward stress. In all cases of pre-aspiration as an alternant, its realization is coordinated with a stressed syllable, and away from unstressed syllables. As stress increases acoustic energy through increased aerodynamic force, as well as overall lengthening and sometimes hyperarticulation (de Jong 1991), aspiration quite naturally is optimally implemented in stressed domains. When aspiration would not be realized under stress, it may delete, as in English, or it may migrate to a stressed position, as in Icelandic.

Note additionally that coordinating the laryngeal abduction with the stressed syllable accounts for its tightest temporal coordination with the *preceding vowel* as opposed to the *following stop*, as shown instrumentally by Kingston (1990). Kingston finds that pre-aspiration bears the most stable temporal relationship with the preceding vowel, and a marginally less stable temporal relationship with the following stop closure. This becomes intuitive when considering that the primary auditory cues for (post-vocalic) pre-aspiration are encoded around the *onset* of aspiration, while *offset* cues are relatively diminished: as auditory nerve response is poor upon the termination of acoustic energy, the diminution of energy involved at the onset of aspiration results in a better cue than at the onset of silence. Recall that in the present approach, the location and temporal stability of particular gestures may be viewed as a consequence of their auditory salience. In the context under investigation, the marginally better cues are at the onset of devoicing, not at the onset of silence. The maintenance of temporal stability of the vowel-aspiration sequence may thus supercede that of the aspiration-stop sequence.

4.					
	Fasu:	**ta**			
	Mandarin:	**ta**	**tʰa**		
	Oriya:	**ta**	**tʰa**		(but **na̤**, *ta̤)
	Gujarati:	**ta**	**tʰa**	**ta̤**	(but ***tʰa̤**)
	Huautla Mazatec:	tá	tʰá	**ʰtá**	(but *tá̤)
	Icelandic:	**ta**	**tʰa**	**ʰta**	

Summary...

3. Fricatives and glottal spreading

Unlike plosive releases, fricative releases are virtual mirror images of their onsets. As air continually flows across the glottis and out the mouth, apart from the marginal case of stridents no appreciable build-up of air pressure takes place, and consequently, there is no burst on to which a laryngeal may "bind." Consequently, modifying a fricative release affords little acoustic payoff. Moreover, fricatives are necessarily accompanied by abducted vocal folds. This laryngeal abduction results in sufficient airflow to induce turbulence at the constriction site, thus giving rise to the fricative's characteristic noise (Ohala 1990). For these reasons, laryngeal contrasts in fricatives are **extremely** rare.

In those rare instances of aspirated fricatives, aspiration usually both occurs with the fricative (in order to maintain frication) and is maintained upon oral release (in order to saliently encode the contrastive aspiration), for example, **sʰ**. Burmese and Korean are languages with post-aspirated fricatives. In both cases, these aspirates contrast with their plain counterparts.

Given that Kingston's binding hypothesis should not should influence the timing properties of laryngeally specified fricatives (since fricatives do not have bursts, and consequently their offsets are virtual mirror images of their onsets), we might incorrectly predict that pre-aspirated fricatives are just as common—or, rather, just as uncommon—as their post-aspirated counterparts. It is telling that—so far as I am aware—*no* language has contrastively pre-aspirated fricatives. Once again, , Bladon's principles of auditory phonetics may motivate this observed asymmetry: post-aspirated fricatives involve incremental increases in overall energy as the sequence of articulatory events unfolds over time.

4. Sonorants and glottal spreading

Nasals

Consider how place of articulation is cued in a plain nasal. Pooling the results of several studies (Fant 1960, Fujimura 1962, Recasens 1983, Dantsuji 1984,86,87, Kurowski and Blumstein 1984, Bhaskararao and Ladefoged 1991), CV formant transitions are primary in conveying place information, VC formant transitions secondary, and steady-state nasal formants tertiary. Regarding the primary and secondary importance of CV and VC transitions, respectively, these findings are consistent with Mattingly's (1981) conclusions regarding the overriding perceptual importance of periods of acoustic modulation in the speech signal: acoustic discontinuities in the speech signal are of especial value to the listener. The tertiary steady state-portion of the nasal, often called the nasal murmur, contains place cues primarily in the form of a nasal zero, or anti-resonance; a frequency range of dampened energy. The farther back in the oral cavity the constriction, the higher in frequency is this reduction in energy. In Burmese and Catalan, for example, studies show that the murmur itself can help to cue place of articulation, more so at some places of articulation; less so at others (Recasens 1983, Dantsuji 1984,86,87). Moreover, nasality as a class may be cued by both a low frequency formant, as well as a mid-range energy plateau. So intervocalic nasals, for example, **ama**, **ana**, **aŋa**, enjoy an abundance of both place and manner cues, and not coincidentally, are not subject to neutralization (see also Jun 1995, Steriade 1996).

In (1) are nasal-initial pairs which minimally contrast for voicelessness (from Dantsuji 1986). Observe that so-called voiceless nasals in Burmese are implemented in canonical fashion, as voiceless nasality precedes the nasal murmur, and so voicing is present at oral release.

(1)

voiced nasals:		voiceless nasals:	
mâ̰	lift up	N̥͡**mâ̰**	from
na	pain	N̥͡**na**	nose
ɲa	right	N̥͡**ɲa**	considerate
ŋâ	fish	N̥͡**ŋâ**	borrow

Far more interesting are the forms in (2), taken from Okell's (1969) grammar.

(2) Morphological aspiration:

a. nasal-initial:

mjin	be high, tall	N̥͡**mjin**	raise, make higher
niʔ	be submerged, sink	N̥͡**niʔ**	submerge, sink
ne	be loose	N̥͡**ne**	loosen (in socket, etc.)
naʔ	be completely cooked	N̥͡**naʔ**	complete cooking

b. obstruent-initial:

pi	be pressed	$\mathbf{p^hi}$	press, compress
pe	break off, be chipped	$\mathbf{p^he}$	break off (a piece)
po	appear	$\mathbf{p^ho}$	reveal
ceʔ	be cooked	**c**$^{\mathbf{h}}$**eʔ**	cook
sowʔ	be torn, shabby	**s**$^{\mathbf{h}}$**owʔ**	tear
suʔ	be damp	**s**$^{\mathbf{h}}$**uʔ**	moisten, make damp
kwe	be split, separated	$\mathbf{k^hwe}$	split, separate

Voicelessness in Burmese is not only phonemic, but is morphemic as well, resulting in anti-passive verbs. These are termed "**h**/non-**h** pairs" by Okell. In (2a) the breath morpheme precedes the plain voiced portion of the nasal, in canonical fashion. In (2b) are plosive-final roots. Note that aspiration here is realized at stop release, after the oral occlusion, which, we now know, is the best realization of oral stops modified by aspiration. So, whether nasal-initial or plosive-initial, the breath morpheme is optimally timed with respect to its affiliated supralaryngeal configuration: the most straightforward account of the observe patterns is that phonological ordering here is a consequence of phonetic optimality.

By contrast, in Sukuma (Maddieson 1991), the involved gestures are timed rather differently. Instead of early *voicelessness*, we see late *breathiness*, that is, simultaneous voicing and glottal spreading: **m͡m̤**, **n͡n̤**, **ŋ͡ŋ̤**. In (3) are some examples.

(3) "Aspirated nasals":

ⁿdɪːn͡n̤ɔ̤͡ɔ	ladle
m͡m̤a̤͡ala	gazelle
m͡m̤a̤͡ala n͡n̤a̤͡ale	small gazelle
m͡m̤a̤͡ajɔ	word

Maddieson reports that the production of so-called "aspirated nasals" in Sukuma usually involves the sequence of events listed in 4.

(4) Sukuma aspirated nasals:

a. Voicing, oral closure, and velic lowering. This results in a plain nasal stop: **n**.

b. Intraoral pressure and nasal airflow increase, along with continued voicing. This indicates that a glottal abduction has been added to the configuration: **nn̤**.

c. Oral closure is released, while nasality and breathy phonation persist into the following vowel: **nn̤ã̤**… .

Were voicing not present during the so-called "aspirated" portion, the all-important offset formant transitions might be fully obscured by voicelessness. Consequently, when, for whatever historical reason, a language possesses this alternative timing pattern—that is, late timing of the laryngeal opening gesture—this additional articulatory asymmetry is almost always present, and so all contrastive information retains recoverability.[1]

At the auditory level, the sequence of acoustic events in Sukuma aspirated nasals, from nasal murmur to breathy nasal to vowel, is perhaps somewhat inferior to the incremental rise in energy found in Burmese, thus perhaps contributing to the rarity of the pattern. Nonetheless, all contrasts are recoverable here as well.[3]

Finally, consider the case of Comaltepec Chinantec (Anderson 1989, Anderson, Martinez, and Pace 1990, Pace 1990). As in Burmese, Chinantec has voiceless nasals with early voicelessness. Some examples are provided in (5).

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[3] Angami possesses an otherwise unknown pattern: **nn̥** (Bhaskararao and Ladefoged 1991). Here, airflow records indicate that no voicing whatsoever is present at oral release, and so CV formant transitions do not contribute to cueing oral place. However, the authors do report that oral release is often accompanied by a moderate burst. Despite nasal venting, there might be a moderate build-up of oral pressure as a consequence of increased transglottal flow due to the wide open glottis, and so perhaps burst frequencies help cue the place of articulation here.

(5)	**N̥͡mɨː˩**	water
	N̥͡ʔː˩	green beans
	N̥͡ŋajɲʔ˩˨	he kills

However, the language also has voiceless nasals in post-vocalic position, pre-suffixally. Here, strangely enough, we witness the full simultaneity of all gestures, oral stop, velic lowering, and glottal spreading, with no voicing whatsoever: N̥. This pattern certainly seems to contradict my claims, as such a timing configuration fully obscures oral place of articulation. However, it turns out that place of articulation is non-contrastive in such contexts. Anderson, Martinez, and Pace report that the post-vocalic nasal assimilates in place of articulation to a following consonant (and is velar pre-pausally and/or when a plain laryngeal follows). Examples are in (6) (syllable boundaries are indicated by tone marks).

(6)	**ka˩w̥wen̥ʔ˩˨ neʔ˩**		the animal was frightened
	j̊juːn̥˩˥la˥˩		this child
	j̊juːn̥˩˥zeʔ˦		sick child
	pimʔ˥	(<..Nʔ + **p**)	he is tiny
	j̊juːm̥˩˥piŋʔ˥		small child
	j̊juːŋ̊˩˥kʌŋʔ˦		big children
	w̰wiŋ̊ʔ˥		black child
	j̊juːŋ̊˩˥haŋʔ˦		perverse child
	ni˩l̥lejɲ̊˦	(<..N̥ + **ʐ**)	he will tremble
	ʔʌjɲ̊˩˨	(<..N̥ + **ʐ**)	he pulls (him)

So Chinantec does not contradict my claims at all. Instead, since place of articulation is non-contrastive here, voicelessness is free to occur in full parallel with velic lowering, as no contrasts are jeopardized.

4.2 Liquids and glottal spreading

Voiceless laterals may be readily realized in two distinct ways from language to language: the abduction may be implemented strictly simultaneously with a constricted lateral gesture, actually resulting in a lateral fricative (e.g. Zulu **ɬ**; Ladefoged 1975), or the abduction is realized only during the first portion of the lateral gesture (e.g. Chinantec **l̥l**; Anderson, Martinez, and Pace 1990).

Why should languages allow this relative freedom of realization? As I now show, the answer to this question lies in a combination of two factors: first, the relative articulatory and acoustic similarity found within the class of laterals, which explains why languages do not often possess place contrasts within the lateral class, and second, the relative acoustic distinctness between laterals and non-laterals, in particular, the distinctness between voiceless laterals and voiceless nasals. I consider these two factors in turn.

First, unlike, say, nasals or stops, laterals are almost exclusively coronal articulations, for only the tongue tip and blade possess sufficient flexibility to initiate simultaneous central contact and lateral opening—the defining characteristics of a lateral (I ignore velar laterals for present purposes, which are extremely rare (Ladefoged and Maddieson 1996)). Given these articulatory constraints, it is rarely the case that a language possesses more than a single place of articulation here: articulatory similarity within the class of possible laterals results in acoustic similarity, and acoustically similar contrastive values, should they evolve, are likely to merge over time.

Let us then briefly consider the acoustic quality of laterals. Bladon (1979) reports on palatalized dentals (French and Irish **l̪**), pharyngealized alveolars (English **ɫ**), retroflexes (Tamil, Swedish **ɭ**), and palatals (Castilian Spanish **ʎ**). He finds that F1 in laterals is always low, with little difference across places. F2, by contrast, is higher in laterals with a shorter back cavity (e.g., **ɫ**), lower in laterals with a longer back cavity (e.g., **ʎ**). F3 is often obliterated due to a lateral zero present in this spectral range. However, the retroflex and palatal laterals may possess a relatively prominent F3. F4 varies with front cavity length. Between F1 and F2, at about 1000 Hz., is the first lateral zero. This is true for all laterals investigated. Finally, the second zero, which often overlaps with F3, displays only minimal variation across places.

With their often obliterated F3, their similar Z1, and their only minor variability in their other formants and Z2, laterals at distinct places, unlike other classes of constrictions, display comparatively minor acoustic distinctness. Consequently, place contrasts within this class are dispreferred (see Maddieson 1984).

However, since laterals *as a class* are articulatorily and acoustically distinct from other classes of constrictions, a given lateral does not run a major risk of being confused with any non-lateral. This holds not so much for plain laterals (which may be confused with alveolar nasals), but does hold for voiceless laterals.[4] In particular, the spectral correlates of voiceless laterality are quite distinct from those of voiceless nasality. Thus, when a system possesses a contrast between a plain and a voiceless lateral, the articulatory and acoustic distinctness of this class remains sufficient so that recoverability of the contrast is readily maintained. Consequently, a voiceless lateral should enjoy a relatively free and varied realization across languages. Indeed this combination of gestures is implemented in at least two ways, yielding two rather different acoustic effects.

First, the lateral gesture may be sufficiently constricted, so that oral frication results, culminating in a voiceless lateral fricative **ɬ**, as in Zulu. Here, it is perhaps the added frication due to increased constriction which helps cue the configuration.

Alternatively, the laryngeal gesture may be truncated relative to the oral gesture, **l̥l**. The non-modal laterals of Otomanguean are implemented in this second fashion. See 17.

Let us briefly compare the system of laterals with the system of nasals. Nasal systems usually possess maximal oral dispersion (**m,n,ŋ**), whether or not laryngeal contrasts are available. With laryngeal cross-classification, three more nasal contrasts become available (**m̥, n̥, ŋ̊**). As just discussed, fully voiceless nasals run a great risk of neutralizing with each other, and so the abduction is obligatorily truncated here so that all contrasts are recoverable. But as the class of laterals rarely possesses oral contrasts, and since, regardless of their implementation, voiceless laterals are acoustically distinct from other classes, the oral constriction here may enjoy a relative freedom of aperture and timing with respect to the laryngeal abduction, and the attested variation results.

Finally, I predict the extreme rarity of systems which cross-classify lateral place contrasts with laryngeal contrasts. Indeed, the only language in Maddieson 1984 to possess such a contrast is Diegueño, which possesses both voiced and voiceless laterals at both the dental and alveolar places of articulation (l̪,l,ɬ̪,ɬ). Tellingly, according to Langdon (1970:31), the acoustic distinction between the apical and laminal lateral fricatives is, "even after long exposure ... still very hard for [her] to differentiate."

4.3 Glides and glottal spreading

Like nasals, non-modal glides normally realize their laryngeal gesture early.

I show in Chapter Five that vowels which possess contrastive non-modal phonation (V̤,V̰) may simultaneously implement their laryngeal and supralaryngeal gestures, provided that tone and non-modal phonation do not cross-classify. I show that breathy and creaky vowels possess sufficient acoustic energy to simultaneously cue both the supralaryngeal gesture and the laryngeal gesture, in parallel fashion. If glides possess a similar degree of stricture as do high vowels, then why should not non-modally phonated glides pattern similarly? That is, why are not the laryngeal and supralaryngeal gestures implemented simultaneously here as well?

The answer lies in both the durational difference between glides and vowels, and the energy difference between glides and vowels. I consider each in turn.

First, as glides are by definition non-syllabic, they are of a shorter temporal duration than their vocalic counterparts. This makes it difficult to saliently cue both oral and laryngeal contrasts simultaneously here. Second, as glides are often implemented with a slightly greater degree of constriction than their corresponding high vowels, the energy level of glides is significantly reduced relative to these vowel: glides show significant reduction in amplitude in their higher frequencies—at the F2 region and above—in comparison to their vocalic counterparts (Bordon and Harris 1984). Thus, indeed, despite a minute increase in degree of constriction between high vowels and glides, amplitude levels may diminish significantly. These decreases in energy, of course, make it difficult to simultaneously transmit oral and laryngeal cues in glides.

With their shorter duration and reduced energy in comparison to vowels, it is less likely that all the contrastive information in non-modally phonated glides is reliably recoverable if produced in parallel. Therefore, in such contexts, truncation of non-modal phonation is observed, so that all contrastive information is recoverable from the speech signal. As in the case of contrastively phonated nasals, the canonical realization of non-modal glides involves the early timing of the laryngeal gesture. In this fashion, salient formant transitions are guaranteed between the glide and a following vowel.

I am unaware of any language which sub-optimally implements contrastively phonated glides to the exclusion of optimally timed contrastively phonated glides; Jalapa Mazatec, in fact, possesses both patterns.

English is an example of a language with early voicelessness in glides (in those dialects in which possess a voiced-voiceless glide contrast). In 21 are some examples of each.

(21)

English palatal voiceless glide:		English labial voiceless glide:	
ˈj̥jumən	human	**ˈw̥wɪtʃ**	which
ˈj̥juːtʃ	huge	**ˈw̥wɛn**	when

Discussion of formalism

7. Concluding Remarks

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