Evolutionary Phonology and The Life Cycle of Voiceless Sonorants[1]

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ABSTRACT

In this chapter I examine the phonetic origins of voiceless sonorants cross-linguistically within the general framework of Evolutionary Phonology (Blevins 2004, 2006, 2008b, 2014). In terms of a general hierarchy of contrast, we observe that: voiceless obstruents are common; voiceless sonorant consonants are uncommon; voiceless vowels are extremely rare. One phonetic source of voiceless sonorants is coarticulation in RH and HR and clusters, where R is a sonorant and H is a segment produced with a spread glottal gesture . Voiceless sonorants may also arise when laryngeal spreading gestures are associated with prosodic domains. In this second case, voiceless sonorants can arise as allophones of their voiced counterparts. While a fair number of languages show voiceless sonorant glides, liquids and nasals phonologized as a consequence of RH/HR coarticulation, voiceless vowels resist phonologization despite their high frequency as phonetic variants of modal vowels. In some cases, voiceless vowels are lost before phonologization can occur. In other cases, resistance to phonologization may be due to effects of analogy, /h/, word phonotactics, or lexical competition.

Keywords: voiceless vowels, voiceless sonorants, sound change, phonologization, phonetic explanation.

1. Introduction

Evolutionary Phonology is the study of synchronic sound patterns as partial reflections of their evolution or history (Blevins 2004, 2006, 2014). Central to Evolutionary Phonology is the goal of explaining why certain sound patterns have the specific properties and typological distributions they do. More specifically, we may ask why some sound patterns are extremely common while others are rare. In the realm of segment inventory and contrast, cross-linguistic hierarchies are in evidence. All spoken languages appear to have segments that might be described as voiceless oral stops, whether or not voicing is contrastive. Contrastive voiceless sonorant consonants, on the other hand, are uncommon cross-linguistically, occurring in less than 5% of the world's languages. Even rarer are contrastively voiceless vowels. The central goal of this study is to document this asymmetry, and to offer an explanation for it.

The chapter is structured as follows. In section 2, we review facts related to the distribution of contrastively voiceless sonorant consonants and contrastively voiceless vowels. Since some have questioned whether contrastively voiceless vowels exist at all, the discussion is non-trivial. Once it is established that contrastively voiceless vowels do exist, we turn, in section 3 to the historical sources of voiceless sonorants. In section 4 we address the central analytical problem: voiceless sonorant

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consonants and voiceless vowels are common allophones of their voiced counterparts cross-linguistically, but voiceless vowels resist phonologization, while voiceless sonorant consonants show less resistance. In other words, some factor or group of factors appears to inhibit the phonologization of voiceless vowels. What factors may play a role in inhibiting the evolution or maintenance of contrastively voiced vowels? Before turning to these phonological issues, we offer brief remarks on the phonetics of voiceless sonorants.

As *phonetic* segment types, voiceless sonorant consonants are extremely common in the world's languages, though often overlooked as allophones of their voiced counterparts. As an example, consider the fully or partially voiceless sonorants in initial clusters like English [sn̥æk] 'snack', [sl̥æk] 'slack', [sm̥æk] 'smack'. Voiceless vowels are also common contextual variants of phonologically voiced vowels in many languages. Again, we see examples in English, where, between voiceless consonants, unstressed vowels are often fully devoiced, as the initial vowel of English *potato, pastrami, cathartic,* etc. In order to understand what exactly a voiceless sonorant is, we must first have a clear definition of what a sonorant is.

Chomsky and Halle (1968:302) define sonorant sounds ([+sonorant]) as those produced with a vocal tract cavity configuration in which spontaneous voicing is possible, while obstruents ([-sonorant]) have cavity configurations which make spontaneous voicing impossible. Stevens (1983:254) ammends these definitions by referring directly to the aerodynamic pressure increase in obstruents and associated turbulent noise (during closure or release), and the absence of this intraoral air pressure and associated noise in sonorants. In later work inhibition of vocal fold vibration is noted as a mechanical effect of air pressure increase in obstruents (Stevens 1997:490). With these definitions in place, we can turn more specifically to voiceless sonorants.

The articulation of voiceless sonorants, like modal voiced sonorants, involves approximately equal air pressure above and below the glottis, with no significant increase of intra-oral air pressure. However, since vocal folds are not in their neutral position, there is no modal voicing. Instead, vocal folds are widely spread at the arytenoid cartilages, or there is some other glottal devoicing gesture. Modally voiced sonorants do not involve these spreading gestures. In general, no vocal cord vibration is present and longitudinal tension, medial compression and adductive tension are minimal, though, in some cases, vocal cords vibrate at low amplitude despite glottal aperture. Depending on glottal area and transglottal airstream turbulence, frication can arise (Ladefoged 1971; Gordon and Ladefoged 2001; Bombien 2006; Tucker and Warner 2010).

Acoustic properties associated with voiceless sonorants include: greater duration of voiceless sonorants than voiced sonorants; increased spectral noise at higher frequencies; decrease in overall acoustic intensity; fall off of energy at higher frequencies (negative spectral tilt, in contrast to modal voice with intermediate values, and positive values for creaky voice); possible raising of fundamental frequency; and possible shifts in formant frequencies (Maddieson & Anderson 1994; Gordon and Ladefoged 2001; Turnbull et al. 2011). In one of the few acoustic and perceptual studies of voiceless vowels, Gick et al. (2012) found final voiceless vowels in Oneida and Blackfoot to be completely inaudible, as measured acoustically and perceptually.

2. Voiceless Sonorants as contrastive segment types

Speech sounds of the world's languages make use of a limited number of laryngeal contrasts that can be classified in terms of the following three parameters: (i) whether or not the vocal folds are vibrating; (ii) whether or not the vocal folds are constricted; (iii) whether or not the vocal folds are spread. While the precise phonological feature system used to express these contrasts is not critical, we adopt three standard features for this purpose: [+/- voiced], [constricted glottis], and [spread glottis]. A minimal system of three laryngeal features is necessary to distinguish modal voice in sonorants from voicelessness, creaky voice, and breathy or murmured voice, and two values for voicing appear necessary for a range of assimilatory processes (Blevins 1993; Gordon and Ladefoged 2001; Wetzels and Mascaró 2001; Blevins 2004, 2006).

In Table 1 voiceless sonorants as contrastive segment types in the world's languages are exemplified and described in terms of these features, as well as prosodic properties. Cover symbols used in the following discussion are also presented. In addition to these symbols, we use H to indicate any segment specified as [spread glottis], including aspirated oral stops.

DESCRIPTION	COVER SYMBOL	SAMPLE SEGMENTS	FEATURE MAKE-UP	σ -POSITION
Voiceless laryngeal glide	h	/h/	[+son, -cons, spread glottis, -voiced] (no PLACE features)	free (see below)
Other voiceless glide	W̥	/w̥, j̊/	[+son, -cons, spread glottis, -voiced] (with PLACE features)	typically non-nuclear
Voiceless sonorant consonant	R̥	/l̥, m̥/	[+son, +cons, spread glottis, -voiced] (with PLACE features)	typically non-nuclear
Voiceless vowel	V̥	/i̥, u̥/	[+son, -cons, spread glottis, -voiced] (with PLACE features)	nuclear

TABLE 1 Voiceless Sonorants as Contrastive Segment Types: 4 Basic Types

It is important to distinguish between the voiceless laryngeal glide /h/, which is common in the world's languages, and other voiceless glides and voiceless sonorant consonants, which are uncommon. It is also important to distinguish between voiceless sonorant consonants, which are rare, but nevertheless found in a small percentage of the world's languages, and voiceless vowels which are extremely rare. In Table 2, frequencies for these segment types are drawn from Maddieson (1984), and combined with information regarding genetic/areal distribution and potential implicational relations for segment inventories. While the languages Maddieson (1984) classifies as having distinctive voiceless vowels may be disputed, the general frequencies remain unchanged. Contrastive voiceless sonorants are more than twice as common as contrastively voiceless vowels. It is this asymmetry that we seek to explain.

Implicational relations are evident in the distribution of voiceless sonorants in the world's languages, though these are not often remarked upon. If a language has voiceless sonorants (consonants, glides or vowels), it also has the corresponding modal voiced sonorant.[2] In addition, if a language has a contrast between voiced and voiceless sonorant consonants (nasals, liquids, or glides), it also has /h/. While both of these implicational relationships may be attributed to synchronic markedness hierarchies, I suggest below that they are simple consequences of the limited pathways by which voiceless sonorants arise.

TYPE	FREQUENCY (MADDIESON 1984)	GENETIC/AREAL DISTRIBUTION	GENERAL CONTRASTIVE STATUS	IMPLICATIONS FOR SEGMENT INVENTORY?
h	279/317 88%	all major language families*	very common	none
W̥, R̥	11/317 3.5%	South-East Asia; American Northwest; Meso-America	uncommon	if W̥ then W; /h/ if R̥ then R; /h/
V̥	2/317 .6 %	Teso-Turkana (E. Nilotic) Comanche (C. Numic)**	rare	If V̥ then V

*Pama-Nyungan and other Australian languages lack /h/ (and /s/, *s)

**Maddieson (1984) lists Ik (Nilo-Saharan) and Dafla (Sino-Tibetan) as having contrastive voiceless vowels. Teso-Turkana languages and Comanche are not included in his count.

TABLE 2 Contrastive Voiceless Sonorants and Linguistic Typology

An interesting observation regarding voiceless sonorant consonants is that they appear to be areal features. In the Northwest Coast "zone" of North America, voiceless sonorants are found in at least five unrelated language families or isolates: Aleut (Eskimo-Aleut), Koyukon (Athabaskan), Klamath (Klamath-Modoc), Takelma (Isolate) and Kashaya (Pomoan). In South-East Asia, voiceless sonorant consonants are also found in distinct language families in a more-or-less continguous geographic area, attested in : Sedang (Austro-Asiatic); Lakkia (Tai-Kadai); Burmese (Sino-Tibetan/Tibeto-Burman); Angami (Sino-Tibetan/Naga) and Hmong (Miao-Yao). Blevins (to appear) suggests that one recurrent property of areal sound patterns is their relatively high perceptual saliency. While voiceless sonorant consonants may not be loud sounds, like /h/, they may be contextually salient, contrasting with surrounding voiced sounds, and giving an overall "whispered" effect. This saliency may distinguish them from truly voiceless vowels which are both extremely rare, and

[2] The only exceptions are sounds that may vary between sonorant and obstruent production, like the noisy <ř> rhotic in Czech. See footnotes 3 and 4 for further discussion.

which, in the recent acoustic study of Blackfoot and Oneida by Gick et al. (2012), have been found to be, in many cases, altogether silent.

The existence of contrastively voiceless vowels is widely debated, as summarized in Blevins (2004:199-201). The clearest documented contrast between modally voiced vowels and their voiceless counterparts is in the Teso-Turkana subgroup of Eastern Nilotic. This subgroup includes: Karimojong, Dodos Nyakwai, Toposa, Nyangatom, Teso, Turkana, and Jie, and the languages are spoken primarly in eastern South Sudan, northwestern Kenya, southwestern Ethiopia, and northeastern Uganda. Synchronic descriptions of the phonology of Teso-Turkana languages include: Heine (1978) and Dimmendaal (1982, 1983) on Turkana; Schroeder and Schroeder (1987a,b) on Toposa; and Novelli (1985) on Karimojong. In addition to these studies, Vossen (1982) details the historical phonology of this group with reconstructions of Teso-Turkana and Eastern Nilotic.

In Toposa (Schroeder and Schroeder 1987a,b), there is a contrast between voiced and voiceless vowels, but the contrast is restricted to pre-pausal contexts, making it highly suspect. Nevertheless, in exactly this context, as illustrated in (1), underlyingly voiced vowels are realized as voiced, while underlyingly voiceless vowels are realized as either whispered vowel, or as zero (with possible devoicing effects on preceding consonants). On the left, I give reconstructions of these roots following Vossen (1982).

(1) Contrastive voiced vs. voiceless vowels in Toposa (Eastern Nilotic)

{~1000 AD)	Toposa	
*-rruk- 'hump of cow'	/ruku̥/	…nya-ruku̥//
		…nya-ruku na//
*-kamei-u 'dry season'	/kamu/	…nya-kamu//
		…nya-kamu na//

A similar pattern is described for Turkana (Dimendaal 1982, 1983) and other Teso-Turkana languages.

Schrock (2011:7-8) contests the contrastive status of voiceless vowels for Ik (Kuliak) and other languages of the northeast Uganda and northwest Kenya region. His reasons for skepticism include the following: voiceless vowels are limited to word-final position, and are voiceless only phrase-finally before pause; voiceless vowels are voiced when in non-final position of a phrase; in some languages, like Ik, the phrase-final reduced vowel variant can be voiceless or a short (voiced) schwa; in some languages, like Teso and Turkana, vowels may not be pronounced at all in phrase-final position; in some languages, like Turkana, a phrase-final RV̥// sequence is pronounced … R̥] with a final voiceless sonorant consonant allophone; in Ik and Toposo, nominal case-endings are often, but not always, voiceless when phrase-final, independent of their underlying voice features; and, finally, there are no minimal pairs distinguished only by final voiced/voiceless vowel pairs. While all of these observations appear to be sound, contrasts like the one illustrated in (1) constitute near-minimal pairs. Further, the devoicing of a preceding sonorant, if the voiceless vowel is lost, is a further indication of a contrastive feature carried by the vowel.

While it appears to be extremely limited in its distribution, the contrast between modally voiced vowels and voiceless or whispered vowels appears to be a feature of this small group of Eastern Nilotic languages spoken by close to two million people in this part of Africa.

In contrast, voiceless vowels do not appear to be contrastive in Dafla (aka Nishi, Nyishi), contra Maddieson (1984). Dafla is a Sino-Tibetan language of the Tani/Miric subgroup, spoken on the eastern edge of the Himalayas, bordering Tibet, Assam, Bhutan and Myanmar. Though Ray (1967) reports word-final voiceless vowels, these are suspect phonemes for several reasons. First, and most importantly, their distribution is predictable: short /i/ is voiceless word-finally, and voiced elsewhere, while short /u/ is only voiceless word-finally when preceded by a voiceless consonant. Second, more recent descriptions including DasGupta (1969), Tayeng (1990), Goswami (1995) and Abraham (2005) do not include voiceless vowels as basic (or derived) sounds. Finally, as illustrated in (2), there is historical evidence for final vowel devoicing/reduction and loss, but not of contrastive voiceless vowels (Abraham 2005).[3]

(2) Nishi dialect evidence for historical final vowel loss

Lower Region	Upper Region	
at, atə	a:te	‘elder sister’
ix	ixi	‘dog’
ab	abu	‘father’
an	ane	‘mother’

We are left with an interesting conundrum. Contrastive voiceless sonorant consonants appear to be much more frequent than contrastive voiceless vowels in the world’s languages. This is true, despite the fact that voiceless vowels are described as allophones of voiced vowels in a wide range of languages across the world. Some of these languages are listed in (3), arranged alphabetically by language name.

(3) 56 languages with phonetically voiceless vowels

Acoma (Miller 1965); Ainu (Shiraishi 2003); Ashéninka Perené (Mihas 2010:44-46); Awadhi (Saksena 1971); Bagirmi (Gaden 1909); Blackfoot (Gick et al. 2012); Bulu (Alexandre 1962); Cheyenne (Davis 1962); Chickasaw (Gordon and Munro 2007); Cocama (Faust and Pike 1959); Comanche (Armagost and Miller 2000); Cora (Kim and Valdovinos 2014:4); Dafla (Ray 1967, Das Gupta 1969); French, Montreal (Gendron 1966, Cedergren and Simoneau 1985); Gadsup (Frantz and Frantz 1973:408); Galla (Vine 1981); Goajiro (Holmer 1949:49-51); Greek (Dauer 1980); Hopi (Bright 1976: 236); Hupa (Golla 1970, Gordon 1998a); Ik (Heine 1975, Schrock 2011); Island Carib (Taylor 1952); Japanese (Han 1961, Beckman 1982, Tsuchida 1994); Japhug (Jacques 2004:343); Kawaiisu (Zigmond et

[3] A reviewer notes that the data on Nishi may be unreliable.

al. 1990); Kinyarwanda (Myers 2005); Korean (Jun and Beckman 1993, 1994, Jun et al.1997, 1998); Lezgi (Chitoran and Iskarous 2008); Malagasy (Kikusawa 2006); Mandarin (Shirai 2011); Mbay (Caprile 1968); Mixtec (Gerfen 1999); Mokilese (Harrison 1976); Nyangumarta (O'Grady 1964); Oneida (Gick et al. 2012); Oromo, Boraana (Voigt 1984, Stroomer 1995); Papago (Saxton et al. 1983); Portuguese, Brazilian (Mateus and d'Andrade 2000; Mendes and Walker 2012); Quechua (Delforge 2009); Saami (Nielsen 1926); Sara (Vine 1981); Shina (Masica 1991); Shoshoni, Big Smokey Valley (Crapo 1976); Southern Paiute (Sapir 1930); Tarascan, aka Purépecha (Foster 1969, Friedrich 1975); Ticuna (Anderson 1959); Tongan (Feldman 1978); Totonac, Filomena Mata (McFarland 2009); Tubu (Lukas 1953); Tunica (Haas 1946); Turkana (Dimendaal 1982, 1983); Turkish (Jannedy 1995); Uyghur (Hahn 1991); Woleaian (Sohn 1975);Yupik (Miyaoka 2012); Zuni (Bright 1976:236).

In order to solve this problem, we adopt the general explanatory mechanisms first proposed by Greenberg (1966, 1969, 1978) for synchronic distributions of linguistic features.

In the context of what he called "The State-Process Model", Greenberg observed that for any state of a natural human language there must be (i) at least one process leading to that state; and (ii) at least one process leading from it to a different state. If this is the case, then synchronic distribution of linguistic features offers insight into rates of diachronic innovation and transmission. High frequency features may be frequently innovated, robustly transmitted, or both. Rare features may be rarely innovated, poorly transmitted, or both. Genetic and areal distribution of linguistic features can be highly suggestive of innovation and transmission rates. If a feature clusters within related languages or in language areas, especially where there is thought to be significant time depth, the feature shows diachronic fitness, persisting over time, and (in cases of areal features) spreading to unrelated languages. If, on the other hand, there is random distribution of a feature within a language or area, this suggests poor transmission, genetically and/or laterally. Since we have ample evidence that voiceless sonorant consonants and vowels are common allophones of their voiced counterparts, the differential rates of contrastiveness do not appear to be related to innovation. Rather, differences in frequencies of contrastively voiceless sonorant consonants versus voiceless vowels must be related to differential rates of phonologization. Though languages like those listed in (3) show phonetically voiceless vowels, voiceless vowels appear to resist phonologization. In contrast, as demonstrated below, allophonically voiced sonorant consonants like the voiceless nasal of English [sm̥æk] 'smack' do undergo phonologization under the appropriate circumstances.

Within Evolutionary Phonology (Blevins 2004, 2006, 2008a, 2008b, 2014), Greenberg's general approach is integrated into a theory of phonetically-based sound change that attempts to predict types and frequencies of sound patterns in synchronic systems. A sound or sound pattern ***S*** may be rare because: (i) there is no sound change X*Z*Y > X***S***Y; (ii) the sound change itself is rare, requiring a rare set of conjunctive conditions; or (iii) there is a change X*Z*Y > X***S***Y, but there is also a common sound change X***S***Y > X*Z*Y, whereby ***S*** is eliminated. An example of type (i) rarity are individual sounds with ingressive pulmonic airflow. There is no known regular sound change that takes a sound with egressive pulmonic airflow (or ingressive/egressive glottalic, ingressive velaric airflow) to ingressive pulmonic. Therefore, we do not expect individual consonants or vowels with pulmonic ingressive airflow to arise. The one reported example of a sound of this type, the ingressive lateral fricative of the ritual language Damin spoken by Lardil initiates (Hale and Nash 1997), appears to be an invented sound, not a sound that has arisen spontaneously through natural phonetic processes. Rarity of the second type might include click sounds – consonants produced with the ingressive velaric airstream mechanism. Clicks appear to be rare because they rarely originate via natural phonetically-based sound change from non-click sounds. However, once evolved, they are relatively stable, and robust, as indicated, for example by their spread via contact (Blevins 2004:194-96; Blevins to appear). An example of the final trajectory would be three-way contrasts in vowel length: V vs. V: vs. V::. While these can arise simply from the juxtaposition of a short and a long vowel in languages with two-way length contrasts, extra-long vowels appear to be rare. The explanation for rarity in this case involves subsequent developments: three-way length contrasts appear to place a strain on the perceptual system, and are typically neutralized to two-way contrasts. Only under extreme conditions of lexical competition do such three-way length contrasts appear to survive (Blevins 2004:201-02; Blevins and Wedel 2009).

The differential distributions of contrastive voiceless sonorant consonants vs. contrastive voiceless vowels may be partially explained by this simple typology, as we highlight below. As a case of the third type, they may evolve in word-final position, and then subsequently, be lost. However, the story is not so simple, as illustrated by the many languages, like those in (3), which appear to maintain voiceless vowels as allophones of voiced vowels, without phonologization. The following summary of the historical sources of voiceless sonorants attempts to provide a deeper understanding of why voiceless vowels rarely phonologize.

3. Historical sources of voiceless sonorants

There appear to be only two contextually conditioned historical phonetic sources of contrastively voiceless sonorants in the world's languages.[4] Voiceless sonorants may arise via coarticulation with an adjacent sound that is produced with a glottal

[4] Spontaneous devoicing of certain sonorants may be associated with loss of sonorancy, as when a rhotic is produced with slightly greater constriction, yielding a more strident sound. A case of this type might be the Czech <ř>, as described by Ladefoged and Maddieson (1996:228-29): "the frication…has a distinctive whistle-type of relatively narrow-band noise" and "is often partially devoiced". The reverse process, where a voiceless obstruent is weakened, and becomes an approximant is rare, but may have occurred in Tahltan, where *ɬ > l̥ (Shaw 1991) and in some varieties of Maori, where *ɸ > w̥. This kind of context-free weakening would provide one additional source for voiceless (non-nasal) sonorant consonants.

An anonymous reviewer also suggests that voiceless sonorants may arise directly from preglottalized sonorants. According to this source, the Proto-Thai contrast between *ʔm and *hm is preserved in Kam Sui languages such as Sui, while in proto-South Western Thai, *ʔm and *hm merged to /m̥/.

spreading gesture, and voiceless sonorants may arise at phrase boundaries when those phrase boundaries are associated with glottal spreading gestures.

3.1 Voiceless sonorants via RH, HR coarticulation. The first pathway is schematized in (4), where '/' is to be interpreted as "in the environment of", where H may precede, follow, or precede and follow the target segment; (4a) shows the evolution of voiceless sonorant consonants, and (4b) the evolution of voiceless vowels, though the paths are parallel and represent the same general development[5].

(4) Source I: Co-articulation of sonorant and adjacent H

Stage I Allophony	Stage II Phonologization
a. R > R̥ / H	R̥H, HR̥ > R̥
b. V > V̥ / H	V̥H, HV̥ > V̥

The schema in (4) illustrates co-articulation of a sonorant consonant or vowel with an adjacent segment with [spread glottis] specification. Recent work suggests that HR and RH sonorant devoicing is a consequence of gestural overlap or sharing of a single laryngeal spreading gesture (e.g. Gordon 1998; Tsuchida et al. 2000, Bombien 2006, Tucker and Warner 2010). In (4), two idealized 'stages' are illustrated: the stage where the voiceless sonorant is identifiable as a conditioned allophone of a voiced sonorant; and a later stage where the voiceless sonorant is reinterpreted as a single segment. Note that the order of sounds is not specified: voiceless sonorants can arise when a segment with [spread glottis] specification precedes the sonorant in question, or when it follows. In (5) we illustrate the first case, and (6) we illustrate the second.

Data in (5) is from a range of Tibetan languages, where a reconstructed initial *sm cluster gives rise to a contrastive voiceless nasal in Mngaris and Sbathang (Huang et al. 1992; STEDT, 2012). In Labrang we see an /hm/ cluster, but in Sbathang, the same cluster appears to have fused, giving rise to the attested initial voiceless nasal, following the pathway illustrated in (4a). A subsequent development is that of sonorant re-voicing: this appears to have occurred in Chone, where earlier voicing contrasts on sonorants have been phonologized as tonal contrasts on the following vowel.[6]

(5) HR > HR̥ > R̥ in Tibetan

Proto-Tibeto-Burman	*s-man 'medicine'
Written Tibetan	*sman*
Bengni (North Assam)	*si-min*

[5]This evolutionary pathway is meant to include cases where sonorants devoice between voiceless obstruents, as in Japanese, and the history of Japanonic languages (Pellard 2009). The working assumption is that, in these contexts, a spread glottal gesture is responsible for the long-domain absence of voicing.

[6] I am grateful to an anonymous reviewer for clarifying details of the Tibetan developments and providing the Chone form.

Labrang (Tibetan)	*hman*
Mngaris (Tibetan)	*rm̥an*
Sbathang (Tibetan)	*m̥ẽ*^{55}
Chone (Tibetan)	*mẽ́:*

In (6), the mirror image sound change is in evidence. Here the data is from two closely related Oceanic languages: Kokota, which shows voiceless sonorants, and Zabana, which does not. Kokota is highly unusual for an Oceanic language in showing clear contrasts between plain voiced and voiceless sonorants in initial and medial position, as in: *nomi* 'our (excl.)' vs. *nom̥i* 'hear (tr.)', *ruta* 'swamp taro' vs. *r̥uta* 'untangle', etc. Palmer (1999, 2009) presents a range of arguments for these voiceless sonorants as single segments as opposed to clusters. The comparative data in (6) allows us to understand this as in instance of (4a). Voiceless sonorants in Kokota are a consequence of a sequence of sound changes: first, syncope of a vowel between a sonorant and /h/; then, merger of the Rh sequence, as in *namaha > namha > *nam̥a* 'love'.

(6) *RH > R̥H > R̥ in Kokota

	Zabana	Kokota	
*namaha	*namaha*	*nam̥a*	'love'
*komuhu	*komuhu*	*kom̥u*	'season, year'
*naroho	*naroho*	*nar̥o*	'rope'

The historical pathway that takes *RH or *HR to a voiceless sonorant explains several phonetic and phonological properties of voiceless sonorants observed by earlier researchers. As observed robustly by Gordon and Ladefoged (2001), voiceless sonorant consonants often have longer durations than their voiced sonorant counterparts. A simple explanation for this fact is that the when an RH sequence is coarticulated, the duration of the sequence is maintained. A second aspect of some voiceless sonorant consonants is that they show contours from voiceless-to-voiced or from voiced-to-voiceless. Voiceless-to-voiced contours are described for some Tibeto-Burman languages, reflecting the original temporal HR sequence in clusters like the one illustrated in (5). The opposite contour of voiced-to-voiceless is described for Kokota, reflecting the historical RH clusters from which the single segments in (6) originated. A final property that is explained by the general development in (4a) concerns distributional restrictions on voiceless sonorants. In many Tibeto-Burman languages, voiceless sonorants are limited to syllable-initial position, reflecting their origins in syllable-initial HR clusters. In Kashaya, a Pomoan language of California, voiceless sonorants are limited to syllable-final position, reflecting historical origins in syllable-final HR clusters.

The same evolutionary pathway is observable for vowels, but, consistent with the facts seen thus far, clear instances of phonologization are difficult to identify. One of the best studied cases is that of Comanche (Central Numic). As detailed by Armagost and Miller (2000), Comanche shows two clear cases of devoicing in its synchronic phonology. In the first case, referred to as "organic" devoicing, illustrated in (7), a short unstressed non-stem-initial vowel obligatorily assimilates to a following /h/ or /s/, becoming voiceless.

(7) VH> V̥H > V̥ in Comanche: Organic devoicing

	Word-initial		Non-word-initial
a.	*kohno* ‘cradle’	c.	*haβi-ko̥no* ‘night cradle’
b.	*tosa* ‘white’	d.	*to-to̥sa* ‘white’ (reduplication)

If word-initial syllables are associated with some kind of prominence, we can view the sound change in (7) as occurring when the historical VH sequence is unstressed or relatively short. However, given the maintenance of initial VH and Vs sequences in word-initial position, there has been no clear reanalysis of voiceless vowels as contrastive sounds in these contexts, and they remain predictable allophones of their voiced counterparts.

However, an independent development could be leading to an incipient contrast between voiceless vowels and Vh sequences in non-initial syllables. As detailed by Armagost and Miller (2000), if a vowel is in a context where it should be devoiced before /h/ and it is preceded by a voiced consonant, the vowel is lost, and there is Dh > hD metathesis (D a voiced consonant). Some examples are provided in (8).

(8) A new source of Comanche Vh sequences: VDVhV> VDV̥hV > VhDV

a. /na-juhu/	[nahju]	‘oil’
b. /wa-waha/	[wahwa]	‘twins’ < ‘two-RED’
c. /ku(h)-tsa(h)-wihi/	[kuhts**a**hwi]	‘to throw in the fire’
	not [kuhtsV̥wi]	

From a synchronic perspective, forms like (8c) suggest that organic devoicing precedes metathesis, since the bolded vowel is in a context for organic devoicing but does not devoice. From a historical perspective, we suggest that the sound change in (7) was regular, and was followed by the metathesis process illustrated in (8). As a consequence, in words like (8c) organic devoicing has become opaque.

The debate over whether or not Comanche has contrastive voiceless vowels centers on the extent to which organic voiceless vowels like those in (7) can all be attributed to underlying /h/, which often does not surface. However, whether or not one analyzes Comanche as having this contrast, the example is extremely useful in illustrating the complex type of system that needs to arise for voiceless vowels to be potentially phonologized. First, there must be a process like (6), whereby voiceless allophones arise in coarticulatory contexts, with loss or absorption of the trigger: either V̥H > V̥ or HV̥ > V̥. In addition, there must be a *new* source for VH or HV clusters *in the same phonological contexts*. If a new source does not arise, there is nothing to force voiceless vowels to be reinterpreted as phonemic, and, given the existence of /h/, they will continue to be interpreted as phonological VH or HV clusters.

3.2 Voiceless sonorants via phrase-final devoicing. The second pathway giving rise to voiceless sonorants originates with phrase-final devoicing, as schematized in (9).

(9) Source II: Phrase-final devoicing[7]

	Phrase-final	Word-final	Lexicalization
a.	R > R̥ / __//	R > R̥ / __#	R̥ #
b.	V > V̥ / __//	V > V̥ / __#	V̥ #

In some languages, phrase-final position may be associated with a laryngeal spreading gesture, while in others it may be associated with a laryngeal closing gesture (Blevins 2006; 2008b).[8] In languages where there is a laryngeal spreading gesture, one finds phrase-final devoicing of both obstruents and sonorants, though cases of obstruents are much more widely studied. As suggested by Blevins (2006), reanalysis in the course of language acquisition, may result in final-devoicing patterns shifting from phrase-based to word-based generalizations. If there are words that are canonically phrase-final, and others that are canonically phrase-medial, a contrast between word-final voiced vs. voiceless sonorants may evolve via lexicalization.

One well known case of final sonorant devoicing like that in (9a) is that found in Angas (aka Ngas), a West Chadic language of Nigeria.[9] As described by Burquest (1998:68-70), Angas has utterance-final devoicing, which results in voiceless liquids and nasals. Utterance-final words from this language include those shown in (10), with their non-final counterparts. While allophonic alternations of this kind are not uncommon, it is difficult to identify cases where this kind of phrase-final devoicing has resulted in contrastive voiceless sonorants. I return to this issue below.]

(10) Phrase-final devoicing in Angas: *R > R̥ / __//

Phrase-final	Non-final	
[sir̥]	*sir*	'to forgive'
[k^{w}al̥]	*k^{w}al*	'joint'

[7] The phrase/word-initial context is not illustrated, as there are no clear cases of sonorant devoicing in this position. Ancient Greek initial <rh>, a voiceless or aspirated rhotic, reflects word-initial *sr or *wr. In the first case, the spread-glottal gesture may be attributed to *s; in the second, the development may be analogical, or due to fortition associated with the *wr cluster (cf. sounds like Czech <ř>, as described in footnote 2).

[8] Devoicing before pause has also been attributed to coarticulation: if the vocal folds are wide apart during pause or relaxed breathing, this position can be anticipated, resulting in phrase-final devoicing (Myers 2005; Myers and Hansen 2007). It is difficult to understand how this coarticulatory explanation can be extended to languages that show vocal fold constriction at phrase boundaries (Blevins 2008b).

[9] The data is well known since it appears in a problem set in Halle and Clements (1983). Since the words are presented out of context, the "solution" for the problem is that sonorants are devoiced word-finally. However, the original source, Burquest (1998:68-70), makes it clear that Angas has phrase-final, not word-final, devoicing.

[fʷan̥]	*fʷan*	'to rain'
[ntaŋzum̥]	*ntaŋzum*	'wasp'

Parallel processes for vowels are widespread in the world's languages (Myers 2005; Myers and Hansen 2007). For example, in Woleaian (Micronesian) and Oromo (Cushitic) an underlying contrast between long and short vowels is realized as a contrast between voiced and voiceless vowels in word final position. In both languages we can posit the sound changes shown in (11). Though (11i) and (11ii) are formulated as distinct historical processes, they clearly reflect one and the same process of final devoicing. The domain of final devoicing is essentially the last timing unit, which results in devoicing/loss of a short vowel, and devoicing/shortening of a long vowel.

(11) Phrase-final to word-final vowel devoicing

i. Historical Long Vs *VV > VV̥ > V
ii. Historical short Vs *V > V̥

Recent work by Gick et al. (2012) looks at the acoustic and perceptual properties of devoiced or whispered vowels in two languages that have undergone a similar process: Oneida and Blackfoot. In both languages, while there was clear evidence from the articulatory record that the vowels are pronounced, the vowels are acoustically and perceptually silent. Given this, it should not be a great surprise that many languages with final vowel devoicing show a subsequent stage of development where final voiceless (short) vowels are lost. For example, in comparing Woleaian to Trukese, a closely related language, we find that final short voiceless vowels that are present in Woleaian are absent in Trukese, as illustrated in (12i) (data from Blust and Trussel, 2014). Where final vowels were long (12ii), they have also undergone devoicing and loss, but the consequence is a synchronic short vowel. Recall that though (12i) and (12ii) are formulated as distinct processes, they reflect one and the same historical process of final devoicing.

(12) Micronesian final vowel devoicing and loss

i. *V > V̥ > ø /__#

Proto-form	Woleaian	Trukese	gloss
*pitu	*fitį̥*	*fúús*	'seven'
*kuRiCa	*giusḁ*	*kúús*	'octopus'
*laNiC	*laŋį̥*	*nááŋ*	'sky'

ii. *VV > VV̥ > V/__#

Proto-form	Woleaian	Trukese	gloss
*panapa > *panaa	*pana*	*fela*	'needlefish'
*taRaqan > *taraa	*sera*	*sara*	'kind of fish'

While it might appear that Woleaian has evolved a set of phonologically contrastive voiceless vowels in word-final position, this analysis is difficult to maintain, since final voiceless vowels alternate with voiced medial vowels as in, e.g. *mejḁ* 'feel', transitive *meja-fi*, *fire̥* 'weave', transitive *fire-xi*, etc.

While phrase-final devoicing could, in principle, give rise to contrastive voiceless sonorants, this rarely occurs. In the case of sonorant consonants, this appears to be due to the fact that contextual conditioning would need to become lexicalized, and opaque. What is needed is a language like Angas, where all words are produced with final devoiced sonorants, and where, subsequently, words like /kʷal̥/ enter into compounds where they are non-final, maintaining their devoiced final Cs, and contrast in those contexts with historically non-final voiced sonorants.

In contrast, phrase-final devoicing may give rise to contrastive, or weakly contrastive, voiceless vowels, as in languages like the Teso-Turkana group discussed above. The paucity of languages with phonologized word-final voiceless vowels is not due to the rarity of sound changes producing phonetically voiceless vowels. Rather, it is due to two distinct sets of factors, one phonetic and one structural. The phonetic factors have already been mentioned, but can now be reviewed in comparison with phonetic properties of voiceless sonorant consonants. Voiceless vowels are imperceptible or nearly imperceptible in word-final position (Gick et al. 2012). Therefore, all else being equal, it is expected that they will be lost over time (Blevins 2004:199). This distinguishes voiceless vowels from voiceless sonorants. Though voiceless sonorants are relatively weak sounds, in word-initial position, as they have evolved, for example, in Sino-Tibetan (5), or initial and medial position in a language like Kokota (6), they are audible, with intrinsic cues similar to /h/, and contrast (in their near-silence) with the adjacent vowel(s). In sum, word-final voiceless vowels have the weakest cues of perhaps any segment type, and are expected to disappear as language is transmitted from one generation to the next. In this way, they contrast with pre-vocalic or post-vocalic voiceless sonorants, which are more perceptually salient. Within the Evolutionary model, what needs to be explained are the cases where final voiceless vowels are maintained for more than a few generations. In section 4 this is related to the same factors that may inhibit phonologization.

The analysis proposed here is distinct from those based on synchronic markedness constraints. Consider the concrete proposal of Gordon (1998:93) regarding the typological rarity of contrastively voiceless vowels. He suggests that "non-modal vowels are perceptually less robust than modal vowels and are therefore eschewed by many languages." While this much is agreed on, the question is whether the extreme phonetics of these nearly-imperceptible segments is enough, or more is needed. Gordon proposes a universal constraint *NON-MOD V that can be ranked above or below constraints demanding vowel devoicing on the basis of articulatory/aerodynamic ease. But the cross-linguistic data we have examined to this point is clear: very few languages prohibit phonetically voiceless vowels. Therefore *NON-MOD V is typically violable and ranked below constraints valuing articulatory/aerodynamic ease. Despite this synchronic ranking where *NON-MOD V is violable, synchronic grammars with the same rankings and contrastive non-modal vowels are extremely rare. It remains to be seen, then, what the constraint *NON-MOD V explains. It does not explain anything in particular about the 55 languages in (3) that have phonetically voiceless allophones of modal vowels, since it is essentially inert in these grammars. And it does not allow us to explain why over 99% of the world's languages lack contrastively voiceless vowels, because the synchronic constraint has precisely the same status as other constraints like *VOICED or *CODA: the constraint may or may not be highly ranked within a given language. Though it appears to encode a notion of markedness in a particular grammar, and serves a definite function in determining surface forms, there is no direct or indirect relationship between markedness constraints and sound pattern frequency of the world's languages. Most importantly however, synchronic accounts of this kind fail to identify differentials between expected phoneme types, and attested types. If voiceless vowels are fine as predictable allophones of voiced vowels in so many languages, why are they not potential phonemes themselves? What kinds of factors might be at work in the many languages where voiceless vowels are maintained as persistent allophones of their voiced counterparts, without phonologization, and without loss?

Before addressing this question, we summarize the general results of this typological survey. In (13) the common life cycles of voiceless sonorants are outlined.

(13) The life cycles of contrastively voiceless sonorants

	Birth	Life[10]	Death/Reincarnation
Consonants	RH, HR > R̥	R̥V, VR̥	(Revoicing/Loss in CC)
Vowels	VH, HV > V̥	CV̥, V̥C	???
	V > V̥ / __#	V̥#	V̥# > ø

Known cases of contrastively voiceless sonorant consonants arise from RH or HR clusters. Voiceless sonorants with these origins are relatively stable, though in languages like Tamang (5), they may undergo revoicing. In all languages, instability may arise in consonant clusters. I have yet to find a case where contrastive voiceless sonorants have arisen from a final-devoicing process. In contrast, voiceless vowels, as rare as they are, may arise either from coarticulatory effects, as in Comanche, or be a consequence of historical final devoicing, as in Teso-Turkana. There is no data bearing on the potential "next" phase of medial voiceless vowels in Comanche, as it is the only known language with potentially contrastive voiceless vowels in non-final position. The phonetic silence associated with word-final vowels usually leads to their loss, as in Trukic. However, the persistence of final voiceless vowels, whether contrastive or not, is notable in many unrelated languages. We now turn to potential factors underlying this persistence.

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[10]Voiceless sonorants, whether vowels or consonants, may subsequently undergo fortition to fricatives (Pellard 2009) or aspirated fricatives (Jacques 2011), or subsequent weakening to /h/ (Jacques and Michaud 2011).

4. Structural factors in the maintenance of voiceless vowels

Let us return to the original observation inspiring this study. Phonological contrasts between voiceless sonorant consonants and their voiced counterparts may be five to ten times more common than those between voiceless vowels and their voiced counterparts. Further, the areal distribution of voiceless sonorant consonants suggests that these sounds are relatively robust, and can spread via contact. In contrast, the rarity of contrastively voiceless vowels is notable, but cannot be attributed to the rarity of phonetically voiceless vowels. Phonetically voiceless allophones of voiced vowels are cross-linguistically common. The failure to perceive final voiceless vowels predicts their eventual loss in word-final position. Therefore, what is remarkable in the life cycle of voiceless vowels is their maintenance: they are maintained as allophones of voiced vowels, when one might expect them to split into separate phonemes; and they are maintained as ghost-like articulations at the ends of words in many languages, where, due to imperceptibility, their loss is expected.

4.1. The role of analogy. In their concluding remarks Gick et al. (2012:53) summarize their findings:

> The experiments described in this study confirm the presence of systematically "soundless" vowels in two native languages of North America: Oneida and Blackfoot.The vowels are articulatorily distinct despite being inaudible, showing that it is possible for articulations to be phonologically stable in a natural language even in environments where their production consistently lacks acoustic consequences.

They continue, with comments on how such inaudible sounds might be learned:

> The existence of speech sequences where acoustic input is systematically absent suggests that, rather than relying solely on direct acoustics-based evidence, learners must make use of other mechanisms such as multimodal integration and analogy… given that these soundless sequences occur only in utterance-final position, it seems likely that learners rely on analogy based on audible versions of the same words as they appear in non-final contexts.

Quite generally, it does not seem unreasonable that, within an exemplar-based model of phonological learning, non-final vowelful tokens of words will dominate over final vowelless ones, resulting in the kind of analogical learning suggested above. In short, the voiced allophones in non-final position support the continuation of voiceless allophones in utterance-final position. Word-to-word pattern matching both allows soundless sounds to be maintained, and inhibits the evolution of distinct phonemes.

4.2. The role of /h/. The Comanche data reviewed above showed only a few contexts with non-predictable voiceless vowels. Most voiceless vowels in Comanche are either a consequence of word-final devoicing, or can be analyzed as /Vh/. It appears, very generally that, if a language has /h/, a phonetically voiceless vowel will be analyzed as an /hV/ or /Vh/ sequence. As a consequence, phonologization of voiceless vowels is inhibited.

4.3. Phonotactics and morphotactics. In some languages, all words must end in vowels. A phonotactic of this kind may contribute to the preservation of final voiceless vowels against phonetic odds. A language of this type is Purépecha (aka Tarascan) (Camacho 2013, field recordings; Maldonado 2012; Friedrich 1975; Foster 1963). In Purépecha, all words end in vowels, but word-final vowels are generally devoiced and often completely deleted, resulting in phonetic consonant clusters in phrase-final position, and across word boundaries.

Purépecha is considered an isolate, and one might think, on the basis of descriptions in the 20th and 21st centuries that final voiceless vowels are unstable, and on the path to eventual loss. However, the two earliest descriptions of the language written by Friar Maturino Gilberti, Order of San Francisco, are *Arte de la lengua tarasca de michoacán* (1558) and *Vocabulario en la lengua de mechuacán* (1559). Both works show the same kind of vowel loss in sandhi that is found today, suggesting that the final voiceless allophones of modally voiced vowels have been stable for hundreds of years.

As with the Oneida and Blackfoot examples, the fact that each final morpheme that is produced without a vowel often shows a full vowel when it is non-final, allows the learner to analogize from full forms to vowelless forms. However, several other factors may play a role as well. First, abstracting away from word-final vowel devoicing, all words end in vowels. In a Purépecha word like /terhu-ngarhi-ta-phe-yara-ni/ (cross-face-ACT-PL.IND-MOV-INF) 'to put something in front of others upon arrival' (Maldonado 2012:9), pronounced with all but the final voiceless vowel intact, there is clear evidence that all but the final morpheme (here the infinitive), are vowel-final. As strange as it may sound, the fact that all phonological words end in vowels in Purépecha appears to be the primary factor that allows for final vowels devoicing and loss in the phonetics. In this instance, even when a vowel is not pronounced, it may be present in the mind of the listener. Experimental evidence supports phonotactically motivated perceptual epenthesis in the absence of acoustic vowel cues (Dupoux et al. 1999; Dupoux et al. 2011). If word-final voiceless vowels are found voiced non-finally, and a general phonotactic shows all (non-final) words to be vowel-final, voiceless vowels may be "heard" in final position by Purépecha speakers as a consequence of perceptual illusions, and therefore maintained for long time periods.

4.4 Lexical competition. The distribution of rare features in phonological systems is not uniform. As suggested in Blevins (2004), and detailed further in Blevins and Wedel (2009), there is a strong association between perceptually difficult contrasts and their role as sole exponents of morpho-syntactic contrasts. The model of lexical competition embedded within Evolutionary Phonology invokes "Lexical Character Displacement". Lexical character displacement occurs when contextual overlap between similar words leads to higher error rates for more ambiguous exemplars of these words. This, in turn, leads to accentuation or retention of phonetic differences between similar words.

How does lexical competition play a role in voiceless vowel maintenance? Consider the silent vowels of Blackfoot investigated by Gick et al. (2012). As described by Frantz (1991), all short vowels in Blackfoot are devoiced in utterance-final position, and are typically inaudible. In the Siksiká dialect of Blackfoot, as in other varieties, word-final suffixes *-(w)a*, a proximate suffix, and *-(y)i*, an obviative suffix, are obligatory noun markers used in tracking reference within discourse. When these suffixes are added to consonant-final stems, the glide is lost and all that remains is the final vowel, which is devoiced in utterance final position (Gick et al. 2012:49). Lexical character displacement will occur with proximate/obviative pairs since these elements are in contextual overlap. Higher error rates for more ambiguous exemplars of these suffixes means that the phonetic differences between the suffixes will be accentuated or retained. In this way, loss of final voiceless vowels is inhibited by the fact that these particular suffixes contrast paradigmatically.[11]

5. Concluding remarks

A simple view of the distribution of spread glottal gestures in speech sounds might invoke a markedness hierarchy whereby this gesture is most preferred as an independent segment (/h/), next most preferred with voiceless obstruents (aspirated stops, /s/), much less preferred with sonorant consonants, and strongly dispreferred with vowels. If universal markedness hierarchies of this kind are part of phonological grammars, as argued, for example, in the work of de Lacy (2006), languages with more marked segment types are predicted to have less marked segments. However, sound patterns of the world's languages suggest complexities within these distributions that cannot be handled by a simple hierarchy of this kind. To take just two examples where phonetics studies have been undertaken, Blackfoot has been argued to have pre-aspirated stops and voiceless vowels, but no segmental /h/ (Reis-Silva 2006, Derrick 2006), while Kokota, mentioned earlier, has voiceless sonorants and /h/, but lacks aspiration in the /p, t, k/ series (Palmer 2009:8). Further, though voiceless sonorant consonants are not common, they are well attested in the historic record, with areal properties suggesting spread via contact. This spread is unexpected if voiceless sonorants constitute ill-formed segment types within grammars of languages lacking them. A phonological markedness hierarchy also says nothing of recurrent phonetic properties of voiceless sonorants. Recall that they are often significantly longer than their voiced counterparts, with laryngeal contours. Under the evolutionary alternative offered here, frequencies of aspirates and voiceless sonorants are related, in part, to necessary conditions for their evolution. Since most voiceless sonorant consonants arise from RH or HR clusters, the existence of these clusters is a precondition to their evolution, and it is the rarity of these clusters that becomes the object of study. This same evolutionary pathway explains both the

[11] In Purépecha as well, Maldonado (2012:8) remarks that final vowels carry "vital morphological information." This may be another contributing factor to vowel maintenance in Purépecha.

longer duration of voiceless sonorants in languages as divergent as Tibetan and Kotoka, as well as observed laryngeal contours. The evolutionary account also raises questions that do not arise for proponents of a markedness hierarchy. Given the high frequency of phonetically voiceless vowels in the world's languages, how can we explain the rarity of phonological contrasts between modal and voiceless vowels? Under a markedness hierarchy, voiceless vowels are banned, and allophonic rules should not give rise to them. In contrast, the persistence of allophonic voiceless vowels in languages over long time periods suggests that structural features support perception and production of these vowels, even when acoustic cues are absent.

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