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LARYNGEAL TIMING AND CORRESPONDENCE IN HUPA

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It is argued that variation in the timing of laryngeal features in Hupa results from a combination of faithfulness constraints requiring that both vowels and laryngeal features be phonetically realized, and correspondence constraints requiring phonological identity between forms belonging to the same paradigm. Inherent differences in the phonetic realization of laryngeal features associated with sonorants and those associated with obstruents produce different realizations of laryngeal features for the two classes of consonants. Cases of surface opacity are argued to result from two types of correspondence constraints: one enforced across forms related to a single lexical entry, and one enforced across members of a single aspectual paradigm. The Hupa data has implications for a number of issues in phonological theory: the role of phonetics in phonology, the articulatory as opposed to the acoustic/perceptual basis of features, timing relations between laryngeal and supralaryngeal features, the relation between syllabic constituency and the realization of laryngeal features, the theory of correspondence constraints, and the issue of rule-based vs. constraint-based grammars. [*]

1. INTRODUCTION

This paper explores laryngeal timing in Hupa, a Pacific Coast Athabaskan language spoken in northwest California by fewer than 25 people (Golla 1996). For the basic description of Hupa phonology, morphology, and the laryngeal alternations, I rely on Golla (1970, 1977, 1985). The phonetic details and some of the phonological observations which form the basis of the analysis developed here are based on fieldwork conducted with three speakers in Hoopa, California in September 1995.

The basic alternation involves the timing of laryngeal features (acoustically realized as voicelessness or glottalization) associated with consonants in different positions. In preconsonantal positions, laryngeal features are realized on the left side of obstruents and the right side of sonorants, e.g. tʃ’eːntɬ’**ḛːt̚**tʰeː ‘it will bulge out (indefinite)’,

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nɪtʃʷʰ**ɪn** ̰tʰeː ‘it will be bad (indefinite)’. In other environments, laryngeal features occur on the right side of obstruents but on the left side of sonorants, e.g. tʃ’eːntɬ’**eːt’ɪ**tʰeː ‘it will bulge out (definite)’, nɪtʃʷʰ**ḛːnɪ**tʰeː ‘it will be bad (definite)’, The data is complicated, however, by the fact that the phonological conditioning factors governing laryngeal timing are often not present on the surface. Consonants which are underlyingly in preconsonantal position sometimes appear in non-preconsonantal position on the surface; nevertheless, the laryngeal timing patterns are those of preconsonantal consonants. Conversely, consonants which underlyingly are not in preconsonantal position may appear in preconsonantal position on the surface; nevertheless, the laryngeal timing patterns are those of non-preconsonantal consonants.

Laryngeal timing is subject to further asymmetries sensitive to the morphosyntactic class of the word containing the affected consonant, the length of the vowel preceding the consonant involved in the timing alternations, the laryngeal feature involved, as well as the place and manner of articulation of the consonant.

Given the complexity of laryngeal timing in Hupa, the analysis developed in this paper is broken down into two phases: one phonetic/phonological in nature, the other morphophonological. Sections 2 and 3 contain some basic information about Hupa phonology and morphology and introduce the laryngeal alternations which are the subject of the paper. Sections 4 and 5 argue that the process of laryngeal spreading is best explained and motivated by phonetic factors which are perceptual in nature and can be formalized in an Optimality-theoretic grammar (Prince and Smolensky 1993).

The second phase of the paper developed in section 6 deals with the opaque cases of laryngeal timing in which the factors which govern timing asymmetries are obscured on the surface. I attribute these cases of synchronic surface opacity to constraints requiring phonetic/phonological identity between morphosemantically or lexically related forms (cf. McCarthy and Prince 1995, Benua 1995, Burzio 1996, Kenstowicz 1996, Steriade 1996, and others).

2. PHONEME INVENTORIES AND THE STRUCTURE OF WORDS IN HUPA

2. 1. *Vowels*

Like other Athabaskan languages, Hupa is characterized by a large number of consonants and a relatively small number of vowels. There are six phonemic vowels, three long and three short, which appear in (1):

(1) Short vowels   Long vowels

ɪ o   eː oː

a   aː

As the transcription indicates, the short and long vowels do not differ markedly in quality for back and low vowels. There is, however, a substantial difference in quality between the short and the long front vowel, with the short vowel being higher and slightly fronter in articulation than the long vowel.

2.2. *Consonants*

The inventory of Hupa consonants is presented in (2). Unless otherwise noted, transcriptions are IPA. Rarely occurring phonemes appear in parentheses. Consonants which do not occur in environments involved in the laryngeal timing phenomena described in this paper are in bold (see section 2.3 for discussion).

Three sets of stops/affricates occur in Hupa: unaspirated, aspirated, and ejective (glottalized). There is also a contrast between plain voiced and glottalized sonorants in certain positions (see section 2.3 for discussion). Palatalized velars are both pre- and post-palatalized. This fact will play an important role in the analysis of place asymmetries in section 5.2. /n/ and /ŋ/ do not contrast underlyingly in syllable final position, though they do contrast on the surface (see section 5.3).

(2) Hupa consonants

		bila-bial	denti-alveo-lar	palato-alveo-lar	velar	uvular	labial-velar	glott
Stop	unasp	(**p**)	t		kʲ	q		ʔ
	asp		**tʰ**		**kʲʰ**			
	eject		t’		kʲ’	q’		
Affr	unasp		ts	tʃ				
	asp		**tsʰ**	**tʃʷʰ**				
	eject		ts’ tɬ’	tʃ’[1]				
Fric	vcl		s ɬ	(**ʃ**)			**x** xʷ ʍ[2]	h
	glott		(s̰)					
Nasal	vcd	**m**	[n]	**ɲ**	[ŋ]			
	glott		[n̰]		[ŋ̰]			
Lateral	vcd		l					
	glott		**l̰**					
Glide	vcd			j			w	
	glott			**j̰**			**w̰**	

2.3. *The structure of Hupa words and morphemes*

Most words in Hupa are based on a monosyllabic root of the form CV(:)C which may be expanded with prefixes and suffixes. All words begin with a consonant in Hupa, which may be either oral or glottal. The first consonant of the root and word can be any consonant except for glottalized sonorants. The final consonant of the root and word can be any consonant except for aspirated stops, affricates or /ɳ/. We know that the laryngeally neutralized final stops are unaspirated rather than aspirated by virtue of their realization when a vowel-initial suffix is added. Additionally, there are certain consonants {q, x, xʷ} which are attested in stem-final position only in a single word or in a few words.[3]

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[1] /t͡ʃ’/ has an optional archaic realization as a labialized palato-alveolar affricate /t͡ʃʷ’/ (Golla 1970: 29).

[2] Note that the contrast between the segment transcribed as /ʍ/ and the segment transcribed as /xʷ/ could be transcribed as a contrast in degree of rounding rather than in the location of the primary constriction, with /xʷ/ more rounded than /ʍ/. For purposes of this paper, nothing crucial hinges on this decision. See Gordon (1996) for discussion of the phonetic aspects of this contrast.

[3] Final /x/ is attested only in the word **nḁːx** (underlying /nḁːxɪ/)‘two’. Final /q/ occurs in the adverbial expression **yinaq** (underlying /yinaqɪ/) 'upstream on this bank, southeast'

In contrast to the glottalized non-nasal sonorants which are, with a couple of exceptions, limited to final position of nouns, glottalized nasals are relatively common in final position of both nouns and verbs.

For purposes of the discussion of laryngeal timing, morphemes may broadly be broken down into two groups: those in which laryngeal timing is a completely transparent phenomenon, and those in which it is not. In prefixes, laryngeal timing is transparent.[4] The set of consonants occurring in prefixes in positions targeted by laryngeal timing alternations is relatively small compared to suffixes and roots.

For morphemes other than prefixes, laryngeal timing is a more opaque phenomenon, as will be discussed in section 6, though the basic phonetic/phonological principles driving the alternations are the same as for prefixes. These morphemes include roots as well as morphemes which I will broadly categorize as suffixes. Suffixes fall into several morphosemantic and syntactic categories which include postpositions and time, place and manner adverbial elements; these morphemes may be grouped together with roots for purposes of the discussion of laryngeal features.[5] The crucial phonological property shared by roots and morphemes which I term suffixes is that their laryngeal alternations are subject to correspondence conditions. Morphosemantically, they have in common that they are non-inflectional unlike the prefixes displaying timing alternations. Phonotactically, they display a much larger set of consonants affected by timing alternations than prefixes. In the discussion which follows “roots” will often be used as a blanket term for both “roots” and “suffixes” except at points in which differentiation of the two classes of morphemes is necessary.

Roots and suffixes may be further divided into two groups according to the degree of opacity they display. The greatest degree of opacity is seen in verb roots which also include the class of words which in English would be considered adjectives. In verb roots, laryngeal timing in certain environments is morphologically contrastive, conveying an aspectual contrast. The set of consonants occurring in environments subject to timing alternations is larger in verbs than in other morphemes. It is also much easier for verbs than for other morphemes

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and **yitaq** (underlying /yitaqɪ/) 'uphill, northeast', and in the postposition **tʰaq** (underlying /tʰaqɪ/) 'between'. /xʷɪ/ occurs as a prefix and a locative suffix. /m/ is attested as a final only in a single numeral.

[4] Prefixes which occur in environments subject to laryngeal alternations are inflectional in nature, conveying concepts such as aspect, agreement and valency. There are other prefixes which do not occur in environments subject to laryngeal spreading. Many of these prefixes are adverbial in nature and most (but not all) occur farther from the root than the inflectional prefixes. See Golla (1970) for discussion of verb structure in Hupa.

[5] The classification of suffixes and enclitics is a difficult matter. Many cannot occur independently of a noun or verb root and belong to the same phonological word as the noun or verb root for purposes of laryngeal timing. However, at the same time, they are not fully attached phonologically to the noun or verb root, since they do not count toward a disyllabic minimum observed by verb (but not noun) roots.

to find minimal and near minimal pairs differing only in the laryngeal feature of the final consonant or the timing of laryngeal features associated with these consonants. This is attributed to the relatively large number of verb roots in Hupa and the fact that the final vowel which plays an important role in laryngeal timing (see section 3.2 below) is an aspectual morpheme in verbs but not in other lexical classes.

Suffixes and roots other than verbs, i.e. nouns and adverbial elements, also display opacity though not to as great an extent as verb roots.[6] In non-verb roots and suffixes, laryngeal timing contrasts lexical items but does not contrast morphological categories belonging to the same lexical entry. Henceforth, I will use the blanket term, “non-verb roots” to refer to suffixes and roots other than verb roots.

The different classes of morphemes are classified as in Table 1 according to the range of consonants occurring in environments affected by laryngeal timing alternations, the degree of opacity they display, and the type of contrasts conveyed by laryngeal timing.

Table 1 shows that the best class of morphemes for observing the purely phonological and phonetic aspects of the laryngeal alternations is prefixes, for which the phonological phenomenon is completely transparent. However, prefixes also have a relatively impoverished set of consonants. The morphemes which display the greatest range of consonants in positions displaying timing alternations are the verbs, which, unfortunately for expositional purposes, also constitute the class of morphemes for which laryngeal timing is most opaque.

Table 1. Range of consonants, degree of opacity and type of contrasts conveyed by laryngeal alternations in different morphemes

Morpheme Class	Range of consonants	Transparent laryngeal timing	Lexically contrastive on surface	Morphol. contrastive on surface
Prefixes	Smallest	Yes	No	No
Non-verb roots, suffixes	Medium	No	Yes	No
Verb roots	Greatest	No	No	Yes

Given this situation, we will begin discussion of the phonological and phonetic basis for laryngeal timing by examining prefixes in section 3.1; discussion will then turn to verb roots in section 3.2. The discussion of non-verb roots and suffixes, which contribute little to the

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[6] Though many suffixes may not appear to be on the same footing as nouns, they share certain crucial properties with nouns. Structurally, suffixes, like roots but unlike prefixes, can occur in word-final position. Furthermore, like verb and noun roots but unlike prefixes, suffixes may end in a full range of stops, affricates, fricatives, or glottalized sonorants.

understanding of the purely phonological and phonetic aspects of laryngeal spreading, will be postponed until the discussion of opacity in section 6.

3. THE LARYNGEAL ALTERNATIONS

3.1. *Prefixes*

In prefixes, laryngeal features associated with obstruents which are preconsonantal overlap with the latter portion of an immediately preceding long vowe. For example, the latter portion of the vowel preceding the /s/ is voiceless in the form **nḁːstaʔaʔ** ‘We carried it about' (root **-taʔ-**; Golla 1970:63). Compare this form with **kʲ’eːseːjaj** ‘I climbed up on it' (root **-jaj-;** Golla 1970: 63), in which laryngeal features associated with the prevocalic /s/ are not overlapped with the preceding long vowel. Because of the impoverished inventory of prefixal consonants appearing in positions in which spreading occurs, we are dealing almost exclusively with voiceless fricatives in this position.[7] I assume that the relevant feature spreading from fricatives is [-voice] or [spread glottis]; the featural specification of voiceless obstruents will be discussed further in section 7.2.

Phonetically, overlap of laryngeal features from a non-prevocalic fricative results in a long vowel whose latter portion is voiceless; this voiceless phase constitutes approximately 40% of the total duration of the vowel (typically about 60-70 milliseconds). The voiceless phase of a voiceless vowel is typically preceded by a short period of breathy voiced phonation. Henceforth, the combination of the breathy voiced and the voiceless phase will often be referred to by the cover term "voiceless" for expository purposes. The term "non-modal" will be used as a blanket term to refer to voiceless, breathy, or glottalized portions of vowels (see below in section 3.2).

Crucially, laryngeal features from prevocalic obstruents do not overlap with a preceding long vowel, as we saw above in the form **kʲ’eːseːjaj**. Furthermore, they do not overlap with a preceding short vowel even if the consonant with which the laryngeal features are associated is not prevocalic: e.g. **ts’ɪslḛːnɪmaːn** ‘because he became’, in which laryngeal features fail to spread from the preconsonantal /s/.

In summary, examination of laryngeal timing in prefixes indicates two asymmetries. First, laryngeal features associated with preconsonantal obstruents, but not laryngeal features associated with prevocalic obstruents, overlap with a preceding long vowel. Second, laryngeal features do not overlap with a short vowel even if the

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[7] There is one prefix /t/ which basically expresses valency (termed a “classifier” in the Athabaskanist literature) and may occur in preconsonantal position. I return in section 5.2 to the behavior of this morpheme with respect to laryngeal features.

following obstruent is in preconsonantal position. These two asymmetries also hold of morphemes other than prefixes at some level as well, though not necessarily on the surface.

3.2. *Verb roots*

Like prefixes, verb roots also display similar laryngeal alternations motivated by the same phonological factors motivating the alternations in prefixes. One difference between prefixes and verb roots is that verb roots display a much larger inventory of consonants occurring in environments subject to timing alternations.

An important difference between prefixes, on the one hand, and verbs (and also non-verb roots and suffixes), on the other hand, is that the structural descriptions which govern laryngeal timing are sometimes not met on the surface: i.e. laryngeal timing often is sensitive to the underlying rather than the surface position of obstruents. Crucially for present purposes, however, the phonological and phonetic basis for the laryngeal alternations are the same for all morphemes and all prefixes at some level, either underlyingly or on the surface, or both. Laryngeal features associated with preconsonantal obstruents overlap with a preceding vowel, but only if this vowel is long.

As in many other Pacific Coast Athabaskan languages,[8] most Hupa verb roots assume two different phonetic shapes, termed light and heavy, which express nuances which would fall under the rubric of aspect in many languages.[9] In Hupa, the contrast basically appears to be one of definiteness (heavy roots) vs. indefiniteness (light roots), though the semantics of the alternation are not thoroughly understood (Golla 1977,1985). Henceforth, for expository purposes, the light roots will be termed “indefinite roots” while the heavy roots will termed “definite roots”.

Laryngeal timing in verb roots is a function of several factors, two of which we have already seen operative in prefixes: vowel length and position of the consonant involved. Additionally, the larger inventory of consonants in verb roots relative to prefixes reveals new dimensions along which laryngeal timing patterns may differ: the aspect of the root (indefinite vs. definite), the manner of articulation of root-final consonant (obstruent vs. sonorant), the place of articulation of the root-final consonant (alveolar vs. other positions), and the laryngeal feature associated with the root-final consonant ([constricted glottis] vs. [-voice]/[spread glottis]). Thus, laryngeal timing is a much richer (and more complex) phenomenon in verb roots than in prefixes.

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[8] See, for example, Li (1930) for discussion of the Mattole data, Goddard (1911) for Kato, and Golla (1976) for Tututni.

[9] In the Athabaskanist literature, the term aspect is traditionally reserved for a different set of morphosemantic relations marked by prefixes. "Aspect" in this traditional Athabaskanist sense will not play a role in the present paper.

The factors involved in laryngeal timing in Hupa verb roots are summarized in (3). Factors which will be discussed in later sections appear in brackets along with the section in which they will be examined.

(3) Factors involved in Hupa laryngeal spreading in verb roots
  a. aspect of the root (indefinite or definite)
  b. position in which the root occurs (prevocalic or not)
  c. length of vowel in the root (long or short)
  d. laryngeal features associated with the root-final consonant ([constricted glottis] or [-voice]/[spread glottis])
  [e. place of articulation of root-final consonant (denti-alveolar or other); see section 5.2]
  [f. manner of articulation of root-final consonant (sonorant vs. obstruent); see section 5.3]

In the next section, we consider the first four factors: aspect, position, vowel length, and laryngeal features.

3.3. *Aspect, position, vowel length, and laryngeal feature as factors*

Let us first consider the obstruent-final roots in Table 2. Forms in which the observed laryngeal timing patterns are opaque are shaded. These will be considered in detail in section 6.1; for now, focus will be on the forms in which laryngeal timing is transparent on the surface. The forms in bold will be discussed below.

Roots ending in palatalized velars will be taken as representative of other places of articulation.[10] The roots in Table 2 are as follows: **ʧ’eːkʲ’** ‘be hot, peppery’, **tʰɪkʲ’** ‘extend’, **ʧʷʰoːkʲ** ‘brush away’, and **tʰɪkʲ** ‘pinch’, and the suffixes are: **-tʰeː** future marker and **-ɪɬ** progressive mode. Subscripted / ̥/ indicates a vowel whose latter portion is breathy voiced or voiceless. Subscripted / ̰/ indicates glottalization on the latter portion of the vowel. / ̚/ indicates an unreleased stop. Recall that we need not consider roots ending in an aspirated stop, since they do not occur in root-final position.

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[10] Differences dependent on place of articulation will be considered in section 5.2.

Table 2. Realization of root-final obstruents in Hupa

Root-final consonant=ejective

	Long vowel root ‘be peppery’	
	Definite	Indefinite
word-final, preconsonantal[11]	1 tʃ’eːkʲ˺	5 tʃ’ḛːkʲ˺
phrase-final	2 tʃ’eːkʲ’	6 tʃ’ḛːkʲ’
before consonant initial suffix	3 **tʃ’eːkʲ’ɪ-tʰeː**	7 tʃ’ḛːkʲ˺-tʰeː
before vowel initial suffix	4 tʃ’eːkʲ’-ɪɬ	8 tʃ’ḛːkʲ’-ɪɬ
	Short vowel root ‘extend’	
	Definite	Indefinite
word-final, preconsonantal	9 tʰɪkʲ˺	
phrase-final	10 tʰɪkʲ’	
before consonant initial suffix	**11** **tʰɪkʲ’ɪ-tʰeː**	13 tʰɪkʲ˺-tʰeː
before vowel initial suffix	12 tʰɪkʲ’-ɪɬ	

Root-final consonant=voiceless

	Long vowel root ‘brush away’	
	Definite	Indefinite
word-final, preconsonantal	14 tʃʷʰoːkʲ˺	18 tʃʷʰo̥ːkʲ˺
phrase-final	15 tʃʷʰoːkʲ	19 tʃʷʰo̥ːkʲ
before consonant initial suffix	16 **tʃʷʰoːkʲɪ-tʰeː**	20 tʃʷʰo̥ːkʲ˺-tʰeː
before vowel initial suffix	17 tʃʷʰoːkʲ-ɪɬ	21 tʃʷʰo̥ːkʲ-ɪɬ
	Short vowel root ‘pinch’	
	Definite	Indefinite
word-final, preconsonantal	22 tʰɪkʲ˺	
phrase-final	23 tʰɪkʲ	
before consonant initial suffix	24 **tʰɪkʲɪ-tʰeː**	26 tʰɪkʲ˺-tʰeː
before vowel initial suffix	25 tʰɪkʲ-ɪɬ	

A number of important differences between forms are apparent in Table 2. We consider them here in turn.

The first difference between forms in Table 2 concerns the presence of a vowel /ɪ/ following the root-final consonant in definite aspect forms

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[11] Recall that all words in Hupa begin with a consonant; thus, word-final position is also preconsonantal unless word-final position is also phrase-final.

followed by a suffix beginning with a consonant initial suffix (cells 3, 11, 16, 24 in boldface). The vocalic enclitic, which together with the root proper forms what I will term the “extended root”, is historically an extension of the relativizing enclitic /-ɪ/ (Golla 1970) and is not found in the indefinite aspect. Following Golla (1970, 1977), I assume that the enclitic /-ɪ/ is a morpheme marking definiteness and is found underlyingly in all definite aspect forms.

On the surface, the definite vowel enclitic is not found in word-final (or phrase-final) position in the definite aspect (cells 1, 2, 9, 10, 14, 15, 22, 23). This is due to a general process of final short vowel deletion which is fully regular in Hupa: there are no words with final short vowels. This loss of final short vowels is one of the primary sources of laryngeal opacity, as will be discussed in section 6.1.

Note that the only vowel initial suffixes occurring after verb roots begin with /-ɪ/ and /-eː/. In the case of /-eː/, which triggers deletion of the enclitic /-ɪ/, loss of the /-ɪ/ could be due to a more general process in Hupa whereby the first vowel in a hiatus context is lost: **ʍɪ-aːt** → **ʍaːt** ‘my older sister’. In the case of /ɪ/, it is of course impossible to know whether the /ɪ/ belongs to the extended root or to the suffix.

The presence of the enclitic vowel in the definite aspect and the absence of the enclitic vowel in the indefinite is tied in with another important alternation, parallel to the one already seen in prefixes. Glottal features on the root vowel are uniform within each column in Table 2. In all indefinite aspect forms, i.e. in all roots which underlyingly are not followed by the vowel enclitic, the laryngeal feature of the consonant ([constricted glottis] from a root-final ejective and [-voice] or [spread glottis] from a root-final unaspirated obstruent) overlaps with the latter portion of a preceding long vowel. Laryngeal features associated with root-final consonants in the definite aspect, i.e. consonants which are followed by an enclitic underlyingly, do not overlap with a preceding vowel. Thus, the definite aspect in verb roots behaves identically to prevocalic instantiations of prefixal consonants, while the indefinite aspect parallels the behavior of preconsonantal instances of prefixal consonants. Furthermore, as in prefixes, laryngeal features do not overlap with a preceding short vowel regardless of the position of the consonant involved. As Golla (1970, 1977) shows, the behavior of laryngeal features in prefixes and other morphemes, including verb roots, becomes uniform if we assume that the purely phonetic and phonological aspects of laryngeal timing behave in parallel fashion in both roots and prefixes: laryngeal features associated with obstruents which are underlyingly preconsonantal overlap with a preceding long vowel, while laryngeal features associated with obstruents which are underlyingly not-preconsonantal do not overlap with the preceding vowel. This is the approach taken in this paper: that the phonetic and phonological motivation for laryngeal timing is the same for all morphemes, and that surface discrepancies are due to correspondence conditions on morphologically and lexically related forms which are operative in roots and suffixes but not prefixes.

Because laryngeal features do not overlap with short vowels and word-final short vowels are deleted, for verbs containing short vowels, there is no phonetic manifestation of the contrast in aspect in most environments (cells 9, 10, 12, 22, 23, 25). The only position in which the contrast in aspect is manifested phonetically in roots containing short vowels is word-internally before a consonant-initial suffix.

There is another important phonetic property evident in Table 2: stops are typically not released in preconsonantal position, either within the word or across a word boundary at normal speaking rates (cells 1, 5, 7, 9, 13, 14, 18, 20, 22, 26). The lack of a release for preconsonantal consonants leads to neutralization of lexical contrasts in root-final laryngeal features in word-final position which is not phrase-final (cells 1 vs. 14, 9 vs. 22). For short voweled roots in word-final position which is not phrase-final, there is double neutralization of both aspectual and lexical contrasts (cells 9 vs. 22).

To summarize, laryngeal timing in verb roots shares important properties with laryngeal timing in prefixes. Laryngeal features associated with preconsonantal, but not obstruents in other environments, overlap with a preceding long, but not short, vowel. In the case of verb roots but not prefixes, the presence of the underlying definite enclitic, which surfaces before a consonant-initial suffix, is sufficient to inhibit laryngeal overlap with the preceding vowel *for all definite forms in the paradigm*. In the next section, we focus discussion on the purely phonological aspects of laryngeal spreading and return in section 6 to the issue of opacity and the shaded forms in Table 2.

Before proceeding further, a short excursus on the characterization of the positional asymmetries between root-final consonants in the definite and indefinite aspect is appropriate. Thus far, I have described the position of root-final consonants in terms of their linear position (e.g. prevocalic, preconsonantal, word-final, phrase-final) rather than in terms of syllabic constituency, i.e. coda vs. onset position. Although there is nothing incompatible in the Hupa data with an analysis expressed in terms of syllable position, in sections 4 and 5, it will be argued that an analysis of laryngeal spreading is more explanatory if expressed in terms of linear position rather than syllable affiliation. In section 7.1, the relative merits of an approach couched in linear terms as compared to one based on syllable structure will be further considered.

4. THE “LICENSING BY CUE” APPROACH: AN INTRODUCTION

The basic approach adopted here, one developed in the work of Steriade (1997) and Silverman (1995), is that features are more likely to be "licensed" if they occur in an environment which renders them maximally perceptible. The important role of perception in the grammar has been explored by Jakobson, Fant and Halle (1953) and more recently by Flemming (1995), Jun (1996), Steriade and Silverman. Steriade shows that the desire for maximally salient realization of features provides an explanation for a number of laryngeal neutralization processes in languages of the world. For example, laryngeal features associated with an obstruent are most saliently realized when the obstruent occurs next to a vowel, particularly a following vowel, where laryngeal features possess the largest number of and most salient cues to their identity, e.g. voice-onset-time, burst amplitude, consonant duration, pitch and formant information in adjacent vowels. In contrast, laryngeal features associated with an obstruent are less salient in preconsonantal position where their set of available acoustic cues is smaller and perceptually suboptimal. For example, voice-onset-time which plays an important role in the perception of laryngeal features associated with consonants can only be realized on an obstruent in prevocalic position and not on an obstruent in preconsonantal position. Furthermore, burst amplitude is not available as a potential cue in stops which are unreleased, as is typically the case with preconsonantal position in many languages including Hupa. Finally, closure duration is only available as a cue to laryngeal features for a stop which is released or for a stop followed by a segment differing in manner of articulation or voicing. The difference in the availability of acoustic cues to obstruents in prevocalic positions as opposed to preconsonantal position is schematized in (4).

(4) Availability of acoustic cues to laryngeal features associated with obstruents in different positions

	Prevocalic	Preconsonantal
VOT	yes	no
duration	yes	for stop only if released or before segment with different voicing or manner of articulation features
burst	yes	for stops only if released

As Steriade shows, the determination of what constitutes a sufficiently perceptible feature in a given environment is a language specific matter, but follows an implicational hierarchy ranging from environments where a feature is maximally salient to environments where the same feature is least salient. Languages draw various cutoff points for licensing features. For example, languages with the strictest licensing requirements on laryngeal features only tolerate laryngeal contrasts before a vowel (e.g. Totontepec Mixe). Other languages are slightly less stringent, and allow laryngeal features to be licensed before vowels and sonorant consonants (e.g. Lithuanian). Finally, still other languages license laryngeal features before vowels and both sonorant and obstruent consonants (e.g. Khasi).

Requirements on licensing of laryngeal features can be captured in an Optimality-theoretic grammar (Prince and Smolensky 1993) using an implicational hierarchy of phonetically grounded constraints. Steriade proposes that constraints prohibiting laryngeal contrasts in environments where they are less salient are universally higher ranked than constraints against laryngeal features in environments where they are more salient. This account makes the powerful and empirically correct, prediction that a language will not license laryngeal contrasts in an environment in which they are inherently less salient but not in environment in which they are more salient. For example, no language will license laryngeal contrasts in preconsonantal position but not in prevocalic position.

Another important result of Steriade’s work is the conclusion that neutralization sites in many languages, e.g. Klamath, Lithuanian, Hungarian, Kolami, etc.) cannot be explained in terms of syllable position. For example, ejectives and aspirated stops in Klamath (Barker 1964) neutralize before obstruents, but may occur before sonorants, including sonorant consonants. In Klamath , this neutralization pattern cannot be explained solely in terms of syllable position, since all preconsonantal consonants, including those before sonorant consonants, are codas (Blevins 1993). Similarly, voicing contrasts in obstruents are lost word-finally and before obstruents in Lithuanian, but voicing is not neutralized in coda obstruents appearing before a sonorant.

5. A PHONETICALLY-BASED OPTIMALITY-THEORETIC ACCOUNT OF HUPA LARYNGEAL TIMING

In this section, I develop a phonetically-based analysis of laryngeal timing formalized in a constraint-based framework. The examples are drawn from verb roots which display the largest inventory of obstruents occurring in environments in which spreading occurs. The analysis, however, extends to other morphological classes which display laryngeal timing alternations. In sections 5.1 and 5.2, we focus on the laryngeal features associated with obstruents, turning in section 5.3 to laryngeal features associated with sonorants.

5.1. *Laryngeal timing as cue preservation in Hupa*

Hupa, unlike the languages discussed by Steriade (1997), does not crucially bear on the issue of whether laryngeal licensing should be expressed using syllable structure or not. However, given the greater empirical coverage and explanatory power offered by Steriade's approach, an analysis presented in terms of linear position rather than syllable structure will be developed here. The decision to adopt a linear based approach, however, does not preclude the existence of syllable structure or constituency. Indeed, certain aspects of the analysis developed herein appeal to syllable structure: a restriction against long vowels in syllables closed by a sonorant (section 5.3) and an alternation between velar and alveolar nasals which appears to be determined by syllable position (section 5.3). The relative merits of a syllable-based vs. a linear-based approach to laryngeal timing and other phonological phenomena will be discussed further in section 7.1.

Crucially, the analysis assumes that the overlap of a consonant's laryngeal features with a preceding long vowel occurs if that consonant is in a position where its release cues are absent (i.e. preconsonantal position) and does not occur if the consonant is in a position where its release cues are present (i.e. prevocalic and phrase-final position). As discussed in section 3, the conditioning factors governing laryngeal timing are most transparent in prefixes, but are also present at some level in other morphological categories. Opacity cases in these morphological categories will be argued in section 6 to result from constraints on morphological correspondence.

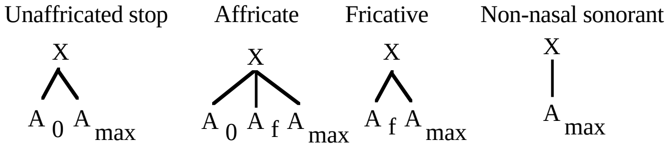
The relative timing of laryngeal and supralaryngeal features of obstruents following a long vowel can be formalized using representations which encode information about different articulatory phases of a consonant, including closure and release. The formalism which will be employed for this purpose is a slightly modified version of Steriade's (1993) aperture theory of segments, though any sufficiently rich set of representations could be substituted.

In Steriade's theory, segmental root nodes are represented according to the degree of oral constriction or aperture involved in their articulation. Vowels and glides have the greatest oral aperture, or least constriction, and are thus designated as A_{max}. Fricatives are characterized by lesser aperture (greater constriction) and are A_f, where $_f$ stands for fricative. Unaffricated stops (both oral and nasal) consist of a complete closure, A_0, followed, if audibly released, by a release phase designated A_{max}. Affricates consist of an A_0 phase followed by an A_f phase for the fricative release.

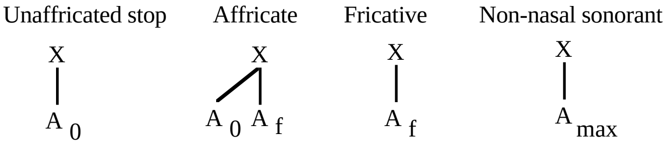
I deviate from Steriade's approach in certain respects. First, I assume that fricatives, also have a release phase, i.e. an A_{max} phase, following their constriction. An extension of this assumption is that affricates contain three phases, a closure phase (A_0), followed by a fricative phase (A_f), followed by a release phase (A_{max}). The view that fricatives and affricates contain a release phase, just like unaffricated stops, is compatible with the observation that these segment types can also manifest laryngeal contrasts on their release. A second assumption adopted here is that all obstruents in preconsonantal position lack an A_{max} phase, capturing the fact that obstruents have a reduced potential to support laryngeal contrasts in preconsonantal position. Sample representations for different segment types appear in (5).

(5) Some sample representations assumed in this paper

Preconsontal Position



Elsewhere



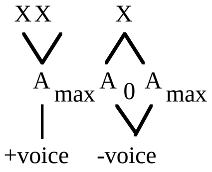
We are now in a position to examine the timing of laryngeal features in Hupa. Before examining actual representations, note the following assumptions concerning the representations. First, the representations will assume that all segments are laryngeally specified and that, when an aperture node associated with a long vowel is linked to two laryngeal features, these features are realized in the order in which they appear; thus, if [+voice] and [-voice] are linked to the same aperture node in that order, [+voice] is realized on the first timing position and [-voice] is realized on the second timing position. Second, [constricted glottis] will be treated as a privative feature, since it is not involved in contrasts which cannot be expressed in terms of voicing. Voicing will be assumed to carry two values, [+voice] and [-voice]. Evidence for the importance of [-voice] will be discussed in section 7.2. Finally, aperture nodes will be specified for only a single laryngeal feature. All of these assumptions, with the exception of both positive and negative voicing features, are not crucial to the analysis which follows but are merely made for the sake of providing explicit representations.

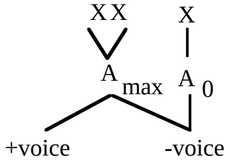
Now let us consider in (6) obstruent-final roots containing a long vowel; the case illustrated in the representations is that of unaffricated stops. Sonorants are discussed in section 5.3. Note that in (6) and henceforth, -C indicates preconsonantal position, whether word-internal or phrase-internal.

(6) Timing of laryngeal and supralaryngeal features in roots containing long vowels

Voiceless obstruents

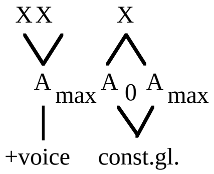
prevocalic, phrase-final: **tʃʷʰoːkʲ** preconsonantal: **tʃʷʰo̥ːkʲ̚ -C**

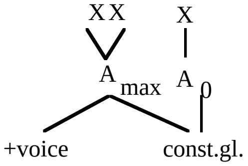




Glottalized obstruents

prevocalic, phrase-final: **tʃ’eːkʲ’** preconsonantal: **tʃ’ḛːkʲ̚ -C**





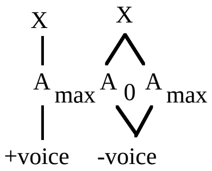
For obstruents following a long vowel, there is in all environments at least a portion of the laryngeal feature which is realized on an A_{max} phase in addition to the A_0 phase. In prevocalic and phrase-final position, the laryngeal feature is realized on the release phase, while, in preconsonantal position, where there is no release and thus no A_{max} phase after the closure, the laryngeal feature is realized on the latter timing position of the the preceding vowel.

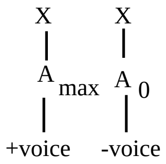
It is not always the case that laryngeal features overlap with the supralaryngeal features of an associated consonant, as shown in (7) which illustrates the timing of laryngeal features associated with obstruents following a short vowel.

(7) Timing of laryngeal and supralaryngeal features in roots containing short vowels

Voiceless obstruents

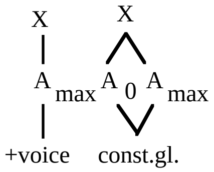
prevocalic, phrase-final: **tʰɪkʲ -V** preconsonantal: **tʰɪkʲ̚ -C**

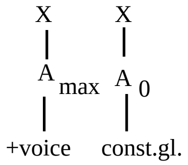




Glottalized obstruents

prevocalic, phrase-final: **tʰɪkʲ’-V** preconsonantal: **tʰɪkʲ̚ -C**





Unlike when the obstruent follows a long vowel, laryngeal features are never realized on a short vowel preceding the obstruent. This means that preconsonantal obstruents realize their laryngeal features only on the closure phase in roots containing a short vowel. Because, the contrast between voiceless and ejective obstruents cannot be phonetically realized on the closure, the result is phonetic neutralization of laryngeal features: **tʰɪʲkʲ̚ -C** vs. **tʰɪkʲ̚ -C**

The asymmetric timing of laryngeal features relative to supralaryngeal features has a basis in terms of licensing by cue and can be formally expressed in McCarthy and Prince's (1995) Correspondence Theory by a set of constraints sensitive to input-output correspondences (e.g. MAX, DEP, IDENT) in conjunction with a series of perceptually motivated constraints requiring features to be phonetically realized.

As discussed in section 4, many of the salient cues to laryngeal features in obstruents reside on the right edge of an obstruent, i.e. on the A_{max} phase. In preconsonantal position, where obstruents are characteristically unreleased, laryngeal features do not have a salient phonetic realization, since they lack an A_{max} phase. In order to enhance their salience, laryngeal features associated with obstruents overlap with the preceding vowel whenever other independent constraints allow it, i.e. when the preceding vowel is long. (I return below to the vowel length asymmetry.) Under this reasoning, laryngeal overlap results from a requirement that laryngeal features associated with obstruents be sufficiently salient. Formally, we may say that, in Hupa, laryngeal features are sufficiently salient if they are realized on an A_{max} phase. For an obstruent preceding a vowel, the A_{max} release phase provides a backdrop for the realization of laryngeal features. Laryngeal features associated with a preconsonantal obstruent lack this A_{max} release phase. As a result, laryngeal features associated with obstruents in these positions must be realized on the A_{max} preceding the obstruent, i.e. on the preceding vowel.

Laryngeal features fail to overlap with the preceding vowel in all forms containing obstruents following short vowels, as shown in (7). It thus appears that an avoidance of non-modal voiced short vowels conflicts with laryngeal spreading. Formally, this conflict can be expressed by means of a few relatively simple constraints.

First, there is a licensing constraint that laryngeal features be realized on an A_{max} phase. I will term this constraint *HIDDEN LARYNGEAL FEATURES (abbreviated *HIDDEN LAR F). It is formulated in (8).

(8) ***HIDDEN LAR F**: Laryngeal features are realized on an A_{max} phase.

The realization of a laryngeal feature on either a release burst or on a vowel adjacent to an obstruent satisfies *HIDDEN LAR F.

The constraint which requires underlying laryngeal features to be realized on the surface belongs to the MAX-IO family of constraints (McCarthy and Prince 1995) which require that underlying features have a correspondent in the output. The relevant MAX-IO constraint in Hupa is MAX-IO (Lar F).

(9) **MAX-IO (Lar F)**: A laryngeal feature in the input has a correspondent in the output.

Other constraints conflict with MAX-IO (Lar F) and *HIDDEN LAR F. These perceptually-based constraints prohibit non-modal vowels, i.e. vowels which are either breathy/voiceless or glottalized. Non-modal vowels have less energy than modal voiced vowels cross-linguistically (Ladefoged and Maddieson 1996), including in Hupa, as informal measurements of Hupa indicate. The reduction in energy in non-modal voiced vowels reduces their perceptibility relative to the modal voiced vowels. Short vowels in Hupa average between approximately 60-80 milliseconds; this is the approximate duration of the non-modal voiced phase in long vowels associated with non-modal voicing for their latter phase. We may assume that the duration associated with non-modal voicing in long vowels is the amount of time necessary to guarantee sufficient perceptual salience of the [constricted glottis] or [-voice]/[spread glottis] phase. If laryngeal features from the following consonant were to overlap with a preceding short vowel for the same duration as on long vowels, virtually the entire short vowel would be obscured by non-modal voicing. Hupa thus assigns higher priority to the salience of the short vowel than the preservation of the laryngeal feature associated with the following obstruent.

Given the perceptual dispreference for non-modal vowels, we may assume a family of constraints against non-modal voiced vowels. In the case of Hupa, two constraints are necessary: one which requires that a vowel must be associated with at least one [+voice] timing position, and one which requires that a vowel be associated only with [+voice] timing positions. These constraints are formulated in (10) and (11), respectively.

(10) ***FULLY NON-MODAL VOWEL**: A vowel is associated with at least one [+voice] timing position.

(11) ***PARTIAL NON-MODAL VOWEL**: A vowel is associated only with [+voice] timing position.

We may assume that *FULLY NON-MODAL VOWEL is ranked above *PARTIAL NON-MODAL VOWEL as evidenced by the Hupa timing patterns. This ranking is also perceptually grounded: the salience of a short vowel is reduced to a greater extent by the introduction of non-modal phonation than the salience of a long vowel is affected by glottalization or voicelessness/breathiness.[12]

Another constraint is needed: a coarticulation constraint which requires that gestures between two adjacent consonants be overlapped (cf. Flemming's 1995 Coarticulation constraint). This constraint, which I term OVERLAP following Cho (1997) is grounded in the important pragmatic requirement that speech occur at a reasonably fast rate. In Hupa, as in many languages, OVERLAP requires that a stop occurring before another consonant, whether word-internally or phrase-internally, not be released, i.e. not have an A_{max} phase.

(12) **OVERLAP**: Preconsonantal stops lack an A_{max} node.

Conflicting with OVERLAP, but lower ranked, is a constraint requiring that stops be released in all positions.

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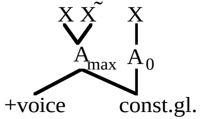
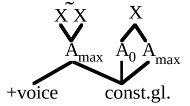
[12] Articulatory constraints often conflict with these perceptually grounded constraints, as evidenced by the occurrence of languages which devoice short but not long vowels (see Gordon 1999 for discussion).

(13) **RELEASE:** Stops have an A_{max} node.

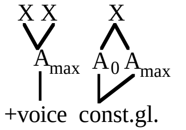
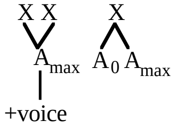
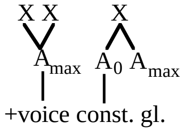
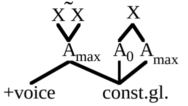
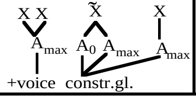
The interaction between OVERLAP and RELEASE is shown for a preconsonantal stop in the indefinite aspect (14); the root is **tɬ’ḛːt’** ‘to bulge’. Note that only the mapping between underlying and surface laryngeal features associated with root-final consonants will be considered in the tableaux which follow. Representations of the root-final consonant and the immediately preceding vowel appear in the same cell as each candidate. Root-initial consonants will merely be represented in the input as they occur in the output. Note that -C and -V indicate any instantiation of the root occurring before consonants or vowels, respectively, whether across a word boundary or not; +C indicates the instantiation of the root before a consonant-initial suffix word-internally, #C indicates word-final position which is not phrase-final, $]_{P}$ indicates phrase-final position.

(14)

Input: tɬ’eːt - C [+cg]	**OVERLAP**	**RELEASE**
☞ a. tɬ’ḛːt̚ - C 		*
b. tɬ’ḛːt’ - C 	*!	

In (15), we see how the constraints other than OVERLAP and RELEASE rule out other possible candidates for a definite root preceding a consonant-initial suffix. Note that a capital T indicates a /t/ with unspecified laryngeal features.

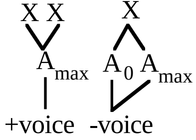
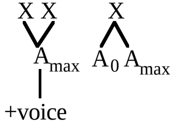
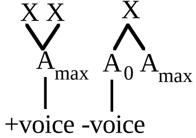
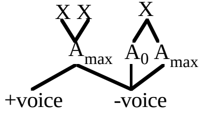
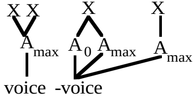
(15)

Input: tɬ’eːtɪ +C | [+cg]	*FULLY NON-MODAL V	*HIDDEN LAR F	MAX-IO (Lar F)	*PARTIAL NON-MODAL V
☞a. tɬ’eːt’ɪ +C 				
b. tɬ’eːTɪ +C 			*!	
c. tɬ’eːtɪ +C 		*!		
d. tɬ’ḛːt’ɪ +C 				*!
e. tɬ’eːt’ɪ̰ +C 	*!			

Candidate (b) violates MAX-IO (Lar F), since its root-final stop is unspecified for laryngeal features. Candidate (c), which contains an ejective stop whose [constricted glottis] feature is realized only on the closure, violates *HIDDEN LAR F. Candidate (d) violates *PARTIAL NON-MODAL VOWEL because it contains a partially glottalized vowel; it is thus eliminated from consideration. Candidate (e) violates *FULLY NON-MODAL VOWEL which requires that a vowel be associated only with [+voice] timing position(s). This leaves candidate (a), with a release burst and no spreading of laryngeal features onto adjacent vowels, as the winner. Note that the phonetic realization of the root-final stop in candidate (b) is a function of its surrounding environment and aerodynamic considerations, since it lacks a laryngeal specification of its own (cf. Rice 1994 on Athabaskan laryngeals). Laryngeally unspecified stops have been shown to be phonetically voiced between voiced segments in Taiwanese (Hsu 1999), with some occasional passive devoicing due to aerodynamic factors in tokens characterized by long stop closure durations.

A form analogous to the one in (15) but containing a voiceless stop is shown in (16).

(16)

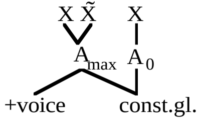
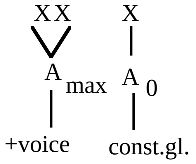
Input: tʃʷʰoːkʲɪ +C [+cg]	***FULLY NON-MODAL V**	***HIDDEN LAR F**	**MAX-IO (Lar F)**	***PARTIAL NON-MODAL V**
☞a. tʃʷʰoːkʲɪ +C 				
b. tʃʷʰoːKʲɪ +C 			*!	
c. tʃʷʰoːkʲɪ +C 		*!		
d. tʃʷʰo̥ːkʲɪ +C 				*!
e. tʃʷʰoːkʲɪ̥ +C 	*!			

Candidate (b) with its laryngeally unspecified stop violates MAX-IO (Lar F). Candidate (c) with its [-voice] feature associated with the closure but not the release phase violates HIDDEN LAR F. Candidate (d) contains a long vowel which is partially overlapped by voicelessness in violation of *PARTIAL NON-MODAL VOWEL. The short vowel after the root-final consonant in candidate (e) violates *FULLY NON-MODAL

VOWEL, since it is completely voiceless. This leaves candidate (a) as the winner.[13]

Thus far, we have not established any crucial rankings of constraints other than the ranking of OVERLAP above RELEASE (see tableau (14)) and the inherent ranking of *FULLY NON-MODAL VOWEL over *PARTIAL NON-MODAL VOWEL on perceptual grounds. Next we turn to a slightly more complicated case, that of obstruents in preconsonantal position. In (17) we consider a preconsonantal instantiation of an indefinite long-voweled root which demonstrates that *HIDDEN LAR F must be ranked higher than *PARTIAL NON-MODAL VOWEL.

(17)

Input: tɬ’eːt -C | [+cg]	***HIDDEN LAR F**	***PARTIAL NON-MODAL V**
☞ a.tɬ’eː̰t˺ -C  		*
b. tɬ’eːt˺ -C  	*!	

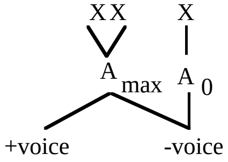
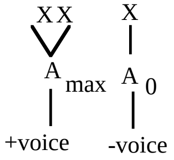
The winning candidate (a) is the form in which [constricted glottis] is overlapped with the preceding vowel thereby satisfying *HIDDEN LAR F, but violating lower ranked *PARTIAL NON-MODAL VOWEL. The losing candidate (b) violates *HIDDEN LAR F since it fails to overlap its [constricted glottis] with an adjacent vowel and it lacks an ejective release preceding a vowel.

The comparable form to (17) except ending in a voiceless obstruent is shown in (18).

---

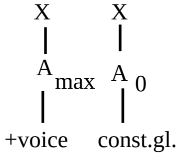
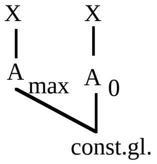
[13] The phonetic difference between a voiceless stop with a [-voice] release (a) and a voiceless stop with a laryngeally unspecified release (b) is uncertain. One might speculate that a laryngeally unspecified release has no voicing lag (voice onset time), unlike a [-voice] release which has a short voicing lag.

(18)

Input: tʃʷʰoːkʲ -C [+cg]	***HIDDEN LAR F**	***PARTIAL NON-MODAL V**
☞ a.tʃʷʰo̥ːkʲ˺ -C 		*
b. tʃʷʰoːkʲ˺ -C 	*!	

If we take a form similar to (17) except containing a short vowel rather than a long vowel, as in (19), we see that *FULLY NON-MODAL VOWEL must be ranked above *HIDDEN LAR F.

(19)

Input: mat -C [+cg]	***FULLY NON-MODAL V**	***HIDDEN LAR F**
☞ a. mat˺ -C 		*
b. ma̰t˺ -C 	*!	

Candidate (b) has its laryngeal features realized on the short vowel preceding the obstruent in violation of *HIDDEN LAR F. The winning candidate (a) does not realize its laryngeal feature on an A_{max} phase; it thus violates lower ranked *HIDDEN LAR F, since its [constricted glottis] feature is neither realized on a vowel or as an ejective burst immediately preceding a vowel.

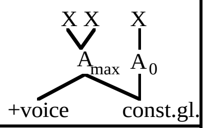
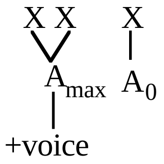
We also have phonetic evidence for ranking MAX-IO (Lar F) above *HIDDEN LAR F. Recall from the discussion earlier that laryngeally unspecified stops receive their phonetic interpretation from their surroundings and aerodynamic factors. Hupa does not voice its stops, even between voiced segments. The absence of environmentally conditioned voicing of stops indicates that all stops are laryngeally specified in Hupa, even if they lack a release burst and fail to spread their laryngeal features onto an adjacent vowel. Thus, in an indefinite short voweled root in prevocalic position, the root-final stop carries a laryngeal specification, as shown in (20).

(20)

Input: mat -C | [+cg]	**MAX-IO (Lar F)**	***HIDDEN LAR F**
☞ a. mat̚ -C X X | | A_{max} A_0 | | +voice const.gl.		*
b. maT̚ -C X X | | A_{max} A_0 | +voice	*!	

Tableau (21) which contains a long voweled root in the indefinite shows that MAX-IO (Lar F) must be ranked above *PARTIAL NON-MODAL V.

(21)

Input: tɬ’eːt -C | [+cg]	**MAX-IO (Lar F)**	***PARTIAL NON-MODAL V**
☞ a.tɬ’ḛːt̚ -C 		*
b. tɬ’eːT̚ -C 	*!	

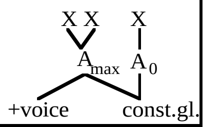
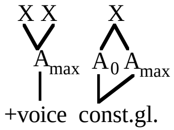
The losing candidate (b) fails to realize its underlying [constricted glottis] feature thereby violating MAX-IO (Lar F). The surface form (a) wins even though it violates the lower ranked *PARTIAL NON-MODAL V.

There are a few additional candidates in the above tableaux which must be ruled out by other constraints not yet introduced. First, we need a constraint which penalizes the insertion of epenthetic vowels: DEP-IO (V) (McCarthy and Prince 1995).

(22) **DEP-IO(V)**: Every vowel of the output has a correspondent in the input.

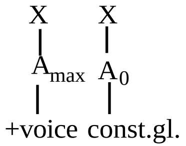
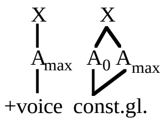
DEP-IO(V) is inviolable in Hupa and is crucially be ranked above *PARTIAL NON-MODAL V as shown in tableau (23) for a long-voweled root in the indefinite.

(23)

Input: tɬ'eːt -C | [+cg]	**DEP-IO (V)**	***PARTIAL NON-MODAL V**
☞ a. tɬ'ḛːt˺ -C 		*
b. tɬ'eːt'ɪ -C 	*!	

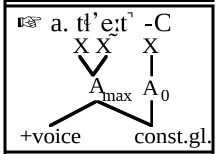
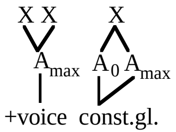
In tableau (24), we see that DEP-IO (V) must also be ranked above HIDDEN LAR F.

(24)

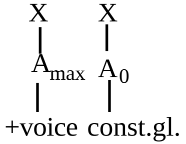
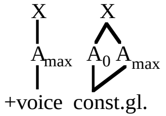
Input: mat -C | [+cg]	**DEP-IO (V)**	**HIDDEN LAR F**
☞ a. matˀ -C 		*
b. mat'ɪ -C 	*!	

OVERLAP is also ranked above both *PARTIAL NON-MODAL VOWEL and HIDDEN LAR F, as shown in tableaux (25) and (26), respectively.

(25)

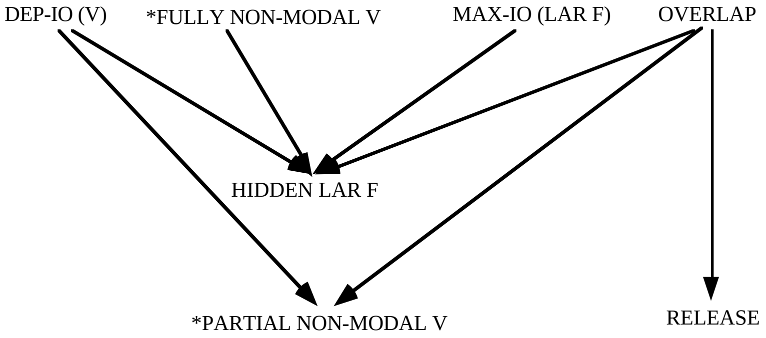
Input: tɬ’eːt -C | [+cg]	**OVERLAP**	*PARTIAL NON-MODAL VOWEL
☞ a. tɬ’ḛːt̚ -C 		*
b. tɬ’eːt’ -C 	*!	

(26)

Input: mat -C | [+cg]	**OVERLAP**	**HIDDEN LAR F**
☞ a. mat̚ -C 		*
b. mat’ -C 	*!	

At this point, we have seen most of the constraints and rankings which are necessary to account for the strictly phonological aspects of laryngeal timing in Hupa. The rankings demonstrated thus far are summarized in (27)

(27) Summary of constraint rankings



5.2. *The loss of supralaryngeal features for /t/ following a voiceless vowel*

One complication in the data not yet considered is that the oral closure for final unaspirated /t/ is lost in the indefinite form of the root following a voiceless vowel, as indicated in Table 3. Final unaffricated stops at other places of articulation are not lost. Note that “other” in this context refers to palatalized velar /kʲ/, the only other stop occurring in a position where /t/ is lost. There are no bilabial obstruents in the native vocabulary and the uvular /q/ does not occur finally in verb roots; it only occurs in adverbs and suffixes which underlyingly end in a vowel, a position where its laryngeal features would not be expected to overlap with a preceding vowel (see section 6.2 for discussion of non-verb morphemes). Furthermore, the closure for unaspirated /t/ is lost *only* following a voiceless vowel. It is never lost in the definite form which does not display overlap of laryngeal features onto a preceding vowel. Nor is the closure for /t/ lost following a short vowel which is not laryngeally overlapped. Ejective /t’/ always preserves its closure, as do all affricates. The realization of unaspirated /t/ is shown in Table 3, with opaque cases of laryngeal timing indicated by shading as earlier in Table 2. The roots shown in Table 3 are **tsʰaːt** ‘sit down’ and **kʲɪt** ‘be afraid’.

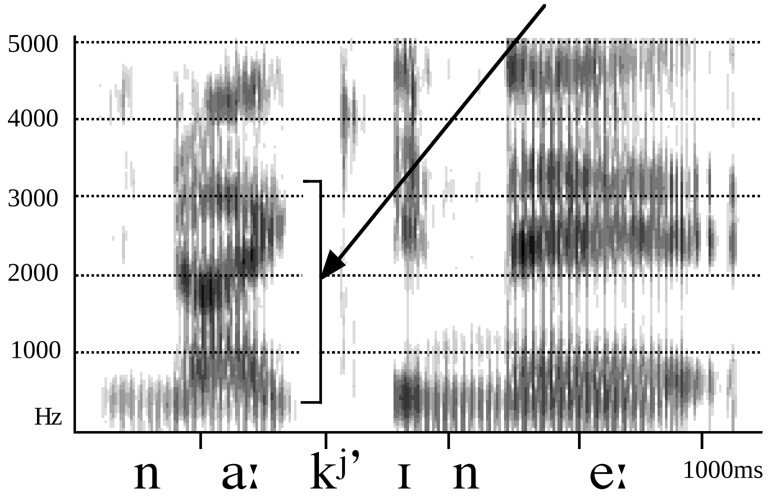
Table 3. Realization of root-final /t/ compared to ejective /t’/

	Long vowel root	
	Heavy	Light
word-final, preconsonantal	tsʰaːt̚	**tsʰḁː**
phrase-final	tsʰaːt	**tsʰḁː**
consonant initial suffix	tsʰaːtɪ-tʰeː	**tsʰḁː-tʰeː**
vowel initial suffix	tsʰaːt-ɪɬ	**tsʰḁː-ɪɬ**
	Short vowel root	
	Heavy	Light
word-final, preconsonantal	kʲɪt̚	
phrase-final	kʲɪt	kʲɪt
consonant initial suffix	kʲɪtɪ-tʰeː	
vowel initial suffix	kʲɪt-ɪɬ	

This asymmetry between /t/ following a voiceless vowel on the one hand, and all other stops, affricates and fricatives, on the other hand, has a phonetic explanation related to the decrease in acoustic energy associated with a breathy or voiceless vowel. Voiceless and breathy vowels are characterized by relatively little acoustic energy compared to both glottalized and modal voiced vowels.

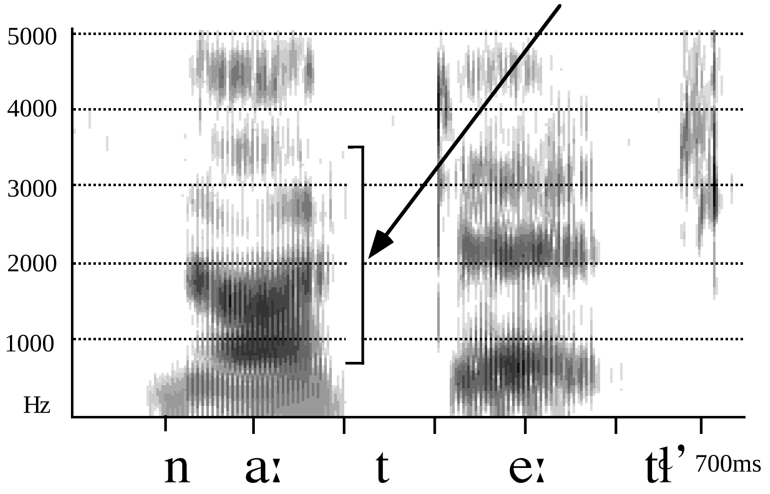
Given the reduction in energy in a voiceless or breathy vowel preceding an obstruent, the transition from the vowel into an obstruent would not be as perceptually salient as the transition from a modal voiced or glottalized vowel into an obstruent. Obstruents following a voiceless or breathy vowel would thus be in danger of being unrecoverable from the acoustic signal. However, not all obstruents would be equally endangered. Fricatives and affricates benefit from having a period of frication from which the place and manner of articulation can be recovered. In the case of fricatives, the manner of articulation is directly recoverable from the frication; in the case of affricates, the stop phase is recoverable from the transition from the closure into the frication phase. The place of articulation is also recoverable from the frication phase. For unaffricated stops, on the other hand, the only right edge cue available is the release burst. However, because unaffricated stops lack a release in preconsonantal position, the only remaining cue to place and manner of articulation is the transition from the preceding vowel into the stop (see the diagram in (4)). Following a voiceless vowel, this transition is obscured by the lack of energy in the vowel. Those transitions which are least salient are in greatest danger of being lost. Palatalized velar stops, the only other stops occurring in environments subject to loss of supralaryngeal features in Hupa, possess more dramatic, and hence more salient, formant transitions than denti-alveolar stops. Recall from section 2.2, that palatalized velars in Hupa are produced with a distinctive palatal on-glide into the closure in addition to an off-glide coming out of the closure. This onglide, physically manifest as a rapid rise in the second and fourth formants and a fall in the third formant, renders the transition from the voiceless vowel into the stop salient enough for the stop to be recovered, despite the overall reduction in acoustic energy. The salient transitions into the palatalized velar can be seen in (28), a spectrogram illustrating a palatalized velar ejective which displays identical transitions to those of the unaspirated palatalized velar.

(28) Spectrogram illustrating a palatalized velar stop in the word **naːkʲ'ɪneː** 'mountain quail' (transitions into the closure indicated by an arrow)



Denti-alveolar stops like /t/, on the other hand, do not possess such dramatic formant transitions as the pre-palatalized velar, and hence are particularly susceptible to being obscured by the reduction in energy. A spectrogram illustrating transitions into /t/ appears in (29).

(29) Spectrogram illustrating a denti-alveolar stop /t/ in the word **naːteːtɬ’** ‘they come again’ (transitions into the closure indicated by an arrow)



To capture the asymmetrical loss of /t/ following a breathy vowel, I simply assume a constraint: ***t/ V̥ __C**.

(30) ***t/ V̥ __C**: Preconsonantal /t/ may not occur after a voiceless vowel.

***t/ V̥ __C** refers to preconsonantal position both within a word or across a word boundary. Though this is a brute force characterization of the relevant facts, it is grounded in the phonetic considerations discussed above. Furthermore, implicit in the formulation of this constraint and the phonetic motivation behind it is the assumption that this constraint is a member of a hierarchy of constraints, whose ranking follows an implicational hierarchy much like constraints governing the licensing of laryngeal features in different environments or constraints against non-modal vowels. In this context, it is interesting to note that, in the Karasjok and Kautokeino dialects of Norwegian Sámi (Nielsen 1926), the closure for preaspirated stops (i.e. stops preceded by a voiceless vowel) is deleted following an unstressed vowel, leaving just a voiceless vowel. Crucially, just as in Hupa, the oral closure for affricates is not lost in Sámi following a voiceless vowel.

In Hupa, *t/ V̥ __C is ranked higher than other constraints militating against other combinations of non-modal vowels and oral obstruents. *t/ V̥ __C must also be ranked above a constraint requiring that the oral gestures associated with the underlying /t/ surface. This constraint belongs to McCarthy and Prince's (1995) IDENT-IO family of constraints.

(31) **IDENT-IO (t)**: Output correspondents of input [αsupralaryngeal feature(s)] associated with /t/ are also [αsupralaryngeal feature(s)].

The ranking of *t/ V̥ __C over IDENT-IO (t) is illustrated in (32), a preconsonantal instantiation in the indefinite of a long-voweled root ending in /t/.

(32)

Input: xeːt -C | [-voice]	***t/ V̥ __C**	**IDENT-IO (t)**
☞ a. xe̥ː -C		*
b. xe̥ːt -C	*!	

Candidate (b) violates *t/ V̥ __C and thus loses. The winning candidate (a) which lacks the underlying supralaryngeal features of /t/ only violates relatively lowly ranked IDENT-IO (t).

Both MAX-IO (Lar F) and *HIDDEN LAR F are ranked above IDENT-IO (t), as shown in (33).

(33)

Input: xeːt -C | [-voice]	**MAX-IO (Lar F)**	***HIDDEN LAR F**	**IDENT-IO (t)**
☞ a. xe̥ː -C			*
b. xeːt -C		*!	
c. xeːT -C	*!		

The constraint against /t/ following a voiceless vowel interacts with another constraint in prefixes. The morpheme /t/ which is called a “classifier” in the Athabaskanist literature and generally is a valency marker is neither deleted nor triggers laryngeal overlap with a preceding vowel even when followed by a consonant: **jaːt-qot’** ‘they wiggle’. Compare the preservation of preconsonantal /t/ in prefix position with preconsonantal /t/ in roots where it is deleted: **tsʰḁː-maːn** from **tsʰaːt-maːn**. The difference between the classifier prefix /t/ and root-final /t/ is plausibly a functional one, namely that the /t/ in the former case constitutes an entire morpheme, whereas the root-final /t/ in the latter case is only a portion of the morpheme. For semantic reasons, preservation of a morpheme is more important than preservation of a part of a morpheme. In her discussion of Chinese, Lin (1993) has proposed a principle designed to reflect the tendency for morphemes to have an overt realization. In Hupa, this principle may be expressed as an IDENT-IO constraint requiring that morphemes which are associated with a supralaryngeal feature in the input be associated with that supralaryngeal feature in the output.

(34) **IDENT-IO (Morpheme, SLF)**: Every morpheme associated with a supralaryngeal feature [αSLF] in the input must be associated with [αSLF] in the output.[14]

A candidate is penalized if it contains a morpheme which has a supralaryngeal realization in the input but not in the output. IDENT-IO (Morph, SLF) is ranked above *HIDDEN LAR F, as shown in (35). Only the relevant consonant, the bold-faced one preceding the root, is considered.

(35)

Input: ja:**t-**qot’ | [-voice]	**IDENT-IO (Morph, SLF)**	***HIDDEN LAR F**
☞ a. ja:**t-**qot’		*
b. jḁ:-qot’	*!	

This form also demonstrates that *t/ V̥ __C is ranked above *HIDDEN LAR F (36).

(36)

Input: ja:**t-**qot’ | [-voice]	***t/ V̥ __C**	***HIDDEN LAR F**
☞ a. ja:**t-**qot’		*
b. jḁ:**t-**qot’	*!	

5.3. *Obstruent vs. sonorant asymmetries*

The final purely phonological asymmetry left to discuss concerns the difference between roots ending in an obstruent and those ending in a sonorant. Only two types of sonorants occur in Hupa, voiced sonorants and glottalized sonorants.[15] The only glottalized sonorant which occurs

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[14] Note that IDENT-IO (Morph, SLF) is not completely undominated in Hupa, as the subject marker /n/ is regularly lost before the classifier /l/.

[15] The modally voiced sonorants /j, w, n, l/ are also subject to alternations, which are more opaque and colored by historical changes than the alternations affecting the

with any frequency in an environment subject to laryngeal alternations is /n̰/.[16] Nasals at other places of articulation do not occur underlyingly in preconsonantal position. Crucially, vowel length is *not* contrastive in roots ending in a glottalized nasal. However, vowels are phonetically longer in the heavy form of roots ending in a glottalized nasal. This phonetic difference in vowel length is also manifest in qualitative changes in vowels as well: /ɪ/ in the light form corresponds to phonetically longer /eː/ in the heavy form. Roots ending in glottalized /n̰/ are compared to roots ending in ejective /t'/ in Table 4; opaque cases of laryngeal timing are indicated by shading. Roots are **tɬ'eːt'** 'bulge out', **mat'** 'slap' and **tʃʷʰḛːn** 'be bad'.

Table 4. Comparison of roots ending in /n̰/ and roots ending in /t'/

Root-final consonant=/t'/

	Long vowel root	
	Definite	Indefinite
word-final, preconsonantal	tɬ'eːt˺	tɬ'ḛːt˺
phrase-final	tɬ'eːt'	tɬ'ḛːt'
consonant initial suffix	tɬ'eːt'ɪ-tʰeː	tɬ'ḛːt˺-tʰeː
vowel initial suffix	tɬ'eːt'-ɪɬ	tɬ'ḛːt'-ɪɬ
	Short vowel root	
	Definite	Indefinite
word-final, preconsonantal	mat˺	
phrase-final	mat'	
consonant initial suffix	mat'ɪ-tʰeː	mat˺-tʰeː
vowel initial suffix	mat'-ɪɬ	

Root-final consonant=/n̰/

	No vowel length contrast	
	Definite	Indefinite
word-final, preconsonantal	tʃʷʰḛːn	tʃʷʰɪŋ̰
phrase-final	tʃʷʰḛːn	tʃʷʰɪŋ̰
consonant initial suffix	tʃʷʰḛːnɪ-tʰeː	tʃʷʰɪn̰-tʰeː
vowel initial suffix	tʃʷʰḛːn-ɪɬ	tʃʷʰɪŋ̰-ɪɬ

Similar to /t'/, the timing of glottalization and the nasal is different in the definite and indefinite forms. The ordering of laryngeal and

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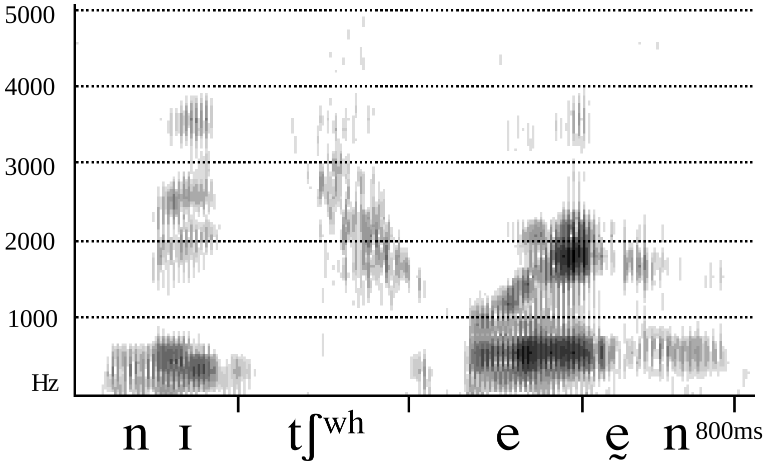
obstruents and glottalized sonorants. These alternations are discussed in Golla (1970, 1977). Most of the alternations affecting the modal voiced sonorants are the result of historical processes of lenition and intervocalic voicing in Hupa. The reader is referred to Leer (1979) and Hoijer (1960) for more on the historical phonology of Hupa and other Pacific Coast Athapaskan languages.

[16] There are a few nouns containing an underlying glottalized non-nasal sonorant, e.g. **ʌɪtaːw̰** 'my beard', **ʌɪtsʰḛːl** my wrist. Because virtually all are either inalienable nouns which always occur in the possessed form or contain a short vowel, they do not undergo laryngeal alternations.

supralaryngeal features, however, is different for glottalized nasals than for glottalized obstruents. In roots ending in a glottalized nasal, glottalization is realized on the *left* edge of the nasal in the definite, shared between the end of the stem vowel and partially on the beginning of the nasal: **nɪ-tʃʷʰḛːnɪ-maːn** ‘because it is bad’. Occasionally, there is a complete glottal closure between the vowel and the nasal. A spectrogram illustrating a prototypical preglottalized sonorant appears in (37).

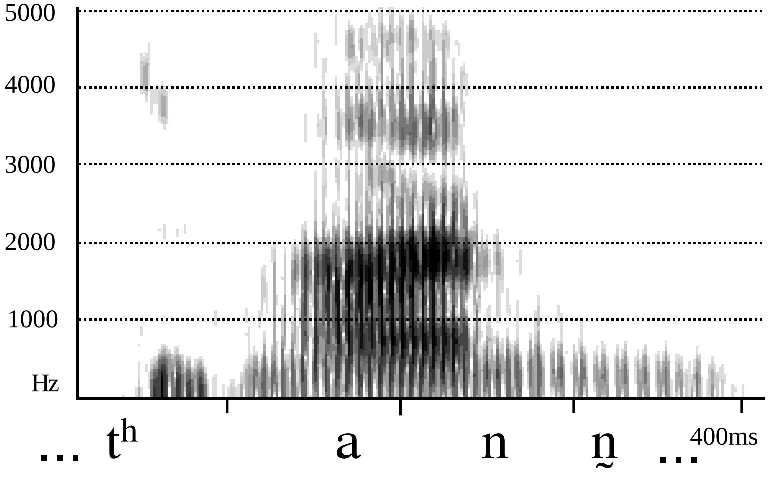
(37) Spectrogram illustrating a pre-glottalized sonorant in the word **nɪ-tʃʷʰḛːn** ‘it is bad’



The increased distance between the vertical striations which represent pitch periods is indicative of glottalization on the end of the vowel and the beginning of the nasal.

In the indefinite, glottalization is realized most strongly on the end of a nasal, though glottalization often encompasses virtually the entire duration of the nasal: **nɪ-tʃʷʰɪn̰-tʰeː** ‘It will be bad.’ Also, the alveolar nasal is realized as a velar nasal in final position and before a vowel or a non-alveolar consonant in the indefinite. This fact is irrelevant for present purposes. An example of a post-glottalized nasal appears in (38).

(38) Spectrogram illustrating a postglottalized nasal in the word **tʃ’oːn-tʰan̰-tʰeː** ‘he will hold on to it’



The increased duration between the pitch periods (indicated by vertical striations) for approximately the last 2/3 of the nasal is indicative of glottalization. Unlike in the heavy form, glottalization does not overlap with the vowel preceding the glottalized nasal in the light form.

The realization of glottalization associated with sonorants is different from glottalization associated with obstruents. Recall that in forms in the definite aspect ending in a glottalized obstruent, glottalization is realized as an ejective release at the *right* edge of the obstruent. In the corresponding forms in the indefinite, glottalization is realized as preglottalization with an ejective burst in phrase final position and preceding a vowel.

We thus have two differences to account for between the definite and indefinite forms of roots ending in glottalized nasals. First, there is a different timing relationship between supralaryngeal and laryngeal features in the two aspects. Second, there is a difference in vowel duration between the definite and indefinite aspect: the vowel is longer in the definite than the indefinite.

First, we will tackle the difference in vowel length. At first glance, one plausible explanation for the vowel length asymmetry is that it is attributed to a general constraint against short vowels preceding glottal features or segments. This analysis would be supported by the fact that there is a general process in Hupa which lengthens vowels before glottal consonants: for example, underlying /ɪ/ surfaces as a phonetically longer [e] before glottal stop and /h/. Thus, the longer vowel in the definite could be due to a process of vowel lengthening to allow for realization of laryngeal features. We saw a similar avoidance of short vowels modified by laryngeal features in roots and prefixes ending in obstruents: **mat̚** and not **ma̰t̚**.

However, unlike in roots ending in glottalized /n̰/, the vowel *does not lengthen* to accommodate laryngeal features in obstruent final roots; rather, the laryngeal feature fails to spread onto the short vowel. If the lengthening of vowels before glottalized /n̰/ in the definite were due to the constraint against laryngeally modified short vowels, we would not be able to explain the different response of obstruent final roots and those ending in glottalized /n̰/ to the constraint against non-modal short vowels.

There is, however, an independent reason for the difference in vowel length between the definite and indefinite in roots ending in a glottalized /n̰/ which is not related to the constraint against non-modal short vowels. There is a general restriction in Hupa against long vowels preceding *all* sonorants in the indefinite, both glottalized and modal voiced: **tɪmeːn** ‘it is sharp’ definite, **tɪmɪn-tʰeː** ‘it will be sharp’ indefinite. Here unlike before glottalized sonorants there is a contrast in length in the definite aspect which is neutralized in the indefinite: cf. **ɬɪʌɪn** ‘it is black’ definite, **ɬɪʌɪn-tʰeː** ‘it will be black’ indefinite. On the basis of these facts we may presume that the definite aspect is the underlying form of the root. We may thus assume that the longer realization of the vowel preceding glottalized nasals in the definite aspect is also underlying.

The shortening of the long vowel in the indefinite can thus be reduced to a restriction against long vowels in syllables which are underlyingly closed by a sonorant, under the assumption that the root-final sonorant is underlyingly in onset position in the definite aspect but in coda position in the indefinite. Restrictions against long vowels in syllables closed by a sonorant are attested in other languages, including Lithuanian, and Early Greek (Steriade 1991). This constraint in Hupa appears to operate only morpheme internally; long vowels may occur in sonorant closed syllables in certain prefixal syllables.

This restriction may be represented in any one of a number of ways depending on one’s theory of weight. I will simply state the relevant constraint as in (39).

(39) *__VːR]__σ_{M}: Long vowels may not occur in syllables closed by a sonorant morpheme internally.

The constraint against long vowels in sonorant-closed syllables is higher ranked than a constraint which requires that underlying long vowels retain their length on the surface. I will state this an IDENT constraint on vowel length.

(40) **IDENT-IO(V-length)**: Output correspondents of a long vowel in the input are also long.

The ranking of *VːR]σ_M above IDENT-IO (V-length) is illustrated in (41) for an indefinite root.

(41)

Input: tʃʷʰeːn -C | [+cg]	***VːR]σ_M**	**IDENT-IO (V-length)**
☞ a.tʃʷʰɪn̰ -C		*
b. tʃʷʰḛːn -C	*!	

IDENT-IO(V-length) is otherwise ranked very highly; it is ranked above MAX-IO (Lar F) as shown in (42) for the indefinite aspect form of a root containing a short vowel followed by a preconsonantal obstruent. In (42), the root vowel does not lengthen to accomodate the [constricted glottis] feature of the following consonant.

(42)

Input: mat -C | [+cg]	**Ident-IO(V-length)**	**MAX-IO (Lar F)**
☞ a. mat` -C		*
b. ma̰ːt` -C	*!	

Another crucial difference between the definite and indefinite forms of sonorant-closed roots involves the timing of laryngeal and supralaryngeal features; the timing in sonorants is basically the opposite of that in obstruents. The constraints posited thus far to account for the obstruents will account for most of the patterns affecting glottalized nasals, if we consider the phonetic differences between [constricted glottis] associated with sonorants and [constricted glottis] associated with obstruents. In the case of obstruents, [constricted glottis] is optimally realized as an ejective burst. For nasals (and other sonorants as well), [constricted glottis] is realized as creak on the nasal and, in many languages, on an adjacent vowel shared between a vowel and the nasal. The phonetic asymmetry between obstruents and sonorants is found in a large number of American Indian languages (e.g. Klamath, Montana Salish; see Steriade (1997) for others).

An issue arises in the formal representation of [constricted glottis] when it is associated with a sonorant. Recall that laryngeal features associated with oral obstruents can be realized either on the closure (A_0)

or the release (A_{max}) phases or on both. By analogy with the oral stops, one might also assume, as we have in fact done, that nasal stops have both a closure and a release phase. In fact, this is exactly the representation proposed by Steriade (1993) to account for languages with prenasalized oral stops and preoralized nasal stops. Prenasalized oral stops have a nasal closure phase and an oral release, whereas preoralized nasal stops have an oral closure phase and a nasal release. Interestingly, unlike for oral releases, laryngeal features appear never to be contrastive on nasal releases. Thus, we do not find any languages, as far as I know, where a contrast between a voiced nasal and a creaky voiced or a voiceless nasal is realized only at the nasal release and not on the nasal closure. Rather, laryngeal features other [+voice] are realized at least partially on the nasal closure itself and on adjacent vowels. This contrasts with certain laryngeal features on oral stops which are realized only on the release and not during the closure. This difference can be made clear by considering the realization of the feature [constricted glottis], which is realized on the release burst of non-preconsonantal stops in many languages, including Hupa, but as creak on sonorants, including nasal stops. The reason for the different realization of [constricted glottis] for the two classes of consonants lies in aerodynamic considerations. In a nasal stop, air continues to escape through the nose during the oral closure preventing the build-up of sufficient oral pressure for a loud and salient release burst. Thus, [constricted glottis] must be realized in another way, by constricting the glottis while maintaining a sufficiently large opening to allow for voicing. The result is a nasal realized with creaky voice for part or its entire duration, encompassing not only the release phase. In contrast to nasal stops, air does not escape during the closure for an oral stop. Pressure thus mounts behind the oral closure, creating a loud burst upon release. This burst is much shorter than the creaky voicing associated with [constricted glottis] nasals.

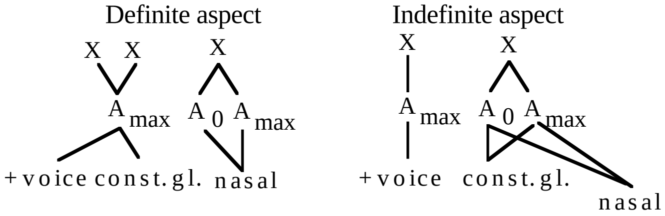
The upshot of this discussion is that a release associated with a nasal stop is fundamentally different from a release associated with an oral stop. While an oral release can support the realization of [constricted glottis], a nasal release cannot. To capture the different realization of [constricted glottis] between nasal stops (and more generally, sonorants) and oral stops, I will assume a second Hidden Lar F constraint which refers specifically to laryngeal features associated with sonorants. This constraint, which is formulated in (43), requires that a laryngeal feature associated with a sonorant be coextensive with an entire timing position.

(43) **HIDDEN LAR F (Son)**: A laryngeal feature must minimally be associated with (via the intermediary of aperture nodes) an entire timing position.

This constraint requires that a laryngeal feature associated with a nasal be realized on both the A_0 (closure) and the A_{max} (release) phases, or on an adjacent vowel. For non-nasal sonorants which lack an A_0 phase, Hidden Lar F (Son) requires that the laryngeal feature be realized on an A_{max} node.

Let us now consider in (44) the representations of glottalized nasals in Hupa.

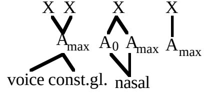
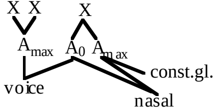
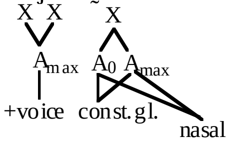
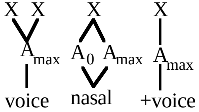
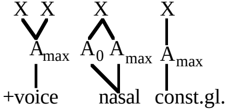
(44) The representation of glottalized nasals



In the definite aspect, we may assume that [constricted glottis] is realized on the second timing position of the long vowel preceding the nasal. This representation accords with the phonetic observation that glottalization is realized primarily on the vowel though it may overlap with the beginning of the nasal. In the indefinite aspect, [constricted glottis] is realized on both the A_{max} and A_0 the nodes of the nasal in keeping with its phonetic realization on most of the nasal. Both the definite and indefinite forms thus satisfy HIDDEN LAR F (Son), since the temporal domain of [constricted glottis] is an entire timing position.

Let us now consider how HIDDEN LAR F (Son) ensures the correct realization of [constricted glottis] in the definite and indefinite aspects. First, in (45), a definite form is considered. The rankings demonstrated earlier also hold of roots ending in a glottalized nasal. Evidence for the ranking of HIDDEN LAR F (Son) above HIDDEN LAR F and below MAX-IO (Lar F) (and thus below *FULLY NON-MODAL V by transitivity) will be considered in the indefinite form in (46).

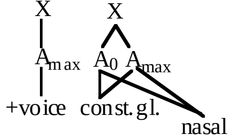
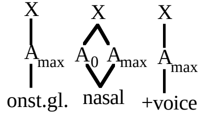
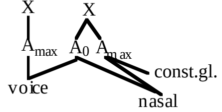
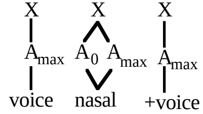
(45)

Input: tʃ^{wh}eːnɪ +C | [+cg]	***Full Non-mod V**	**Max-IO (Lar F)**	**Hid Lar F (Son)**	***Hid Lar F**	***Part Non-mod V**
☞ a.tʃ^{wh}ḛːnɪ +C 					*
b. tʃ^{wh}eːn̰ ɪ +C 			*!		
c. tʃ^{wh}eːn̰ɪ +C 				*!	
d. tʃ^{wh}eːnɪ +C 		*!			
e. tʃ^{wh}eːnɪ̰ +C 	*!				

Candidate (b) violates HIDDEN LAR F (Son), as its [constricted glottis] feature is realized only on the release phase of the nasal. Candidate (c) violates the more generic HIDDEN LAR F constraint, since its [constricted glottis] feature is realized only on the nasal. Candidate (d) falls out of the running due to the failure of its [constricted glottis] feature to surface. Candidate (e) is eliminated because it realizes its [constricted glottis] feature on the following vowel which is short. This leaves candidate (a), with [constricted glottis] realized on the latter half of the long vowel, as the victor.

In (46), an indefinite root is considered. I will assume the root considered is followed by a suffix beginning in a coronal consonant (indicated by D), in order that the tableau not be complicated by changes in nasal place of articulation which are not germane to the present discussion.

(46)

Input: tʃ^{wh}eːnɪ +C [+cg]	*FULL NON-MOD V	MAX-IO (Lar F)	HID LAR F (Son)	*HID LAR F	*PART NON-MOD V
☞ a. tʃ^{wh}ɪn +D 				*	
b. tʃ^{wh}ɪ̰n +D 	*!				*
c. tʃ^{wh}ɪn +D 			*!		
d. tʃ^{wh}ɪn +D 		*!			

The candidates of particular interest in (46) are (a) and (c). Candidate (c) violates the more specific constraint HIDDEN LAR F (Son), as its [constricted glottis] feature is realized only on the release phase. Candidate (a) violates only the more general HIDDEN LAR F which is lower ranked than HIDDEN LAR F (Son).[17]

5.4. *The phonetic basis for laryngeal spreading: a summary*

Thus far, we have accounted for many of the complexities of the Hupa. The asymmetrical overlap of laryngeal features associated with preconsonantal, but not other obstruents onto a preceding long vowel was argued to result from a difference in the availability and salience of acoustic cues to the obstruent's laryngeal features in different environments. Cues to laryngeal features associated with an obstruent are less abundant and less salient in preconsonantal position than in

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[17] Note that it also would be possible to assume another specific HIDDEN LAR F constraint pertaining to obstruents.

other positions. The failure of laryngeal features to overlap with a preceding short vowel was attributed to the greater reduction in perceptibility of non-modal short vowels relative to non-modal long vowels. The loss of /t/ following a voiceless vowel was shown to result from the reduced perceptibility of /t/ in this environment relative to both other obstruents in the same position and to /t/ after a glottalized vowel. Finally, the different behavior of sonorants and obstruents was argued to result from differences in the phonetic manifestation of glottalization for these two classes of consonants combined with a restriction against long vowels in syllables closed by a sonorant. In the next section, we turn to cases in which laryngeal timing is an opaque phenomenon.

6. OPACITY AND MORPHOLOGICAL CORRESPONDENCE IN HUPA

There are two types of surface opacity in Hupa: in some forms, laryngeal features overlap with a preceding vowel even though the environment for overlap is not met on the surface; conversely, in other forms, laryngeal overlap does not occur even though triggering factors are present on the surface. Opacity is found in verb roots and non-verb roots, including suffixes, though the degree of opacity is different in the two cases. The extent of opacity is greater for verbs than for other morphemes, an asymmetry which will be linked to the fact that laryngeal spreading has assumed a quasi-morphemic status as a marker of an aspectual contrast in verbs but not other morphemes.

In section 6.1, we consider verb roots; discussion shifts to non-verb roots and suffixes in section 6.2.

6.1. *Verb roots*

In previous tables illustrating verb roots, certain forms were shaded indicating that the timing of laryngeal features in these forms was unexpected on the basis of surface position. Table 2 illustrating roots ending in an obstruent is repeated below as Table 5.

Table 5. Realization of root-final obstruents in Hupa

Root-final consonant=ejective

	Long vowel root ‘be peppery’	
	Definite	Indefinite
word-final, preconsonantal[18]	1 tʃ’eːkʲ˺	5 tʃ’ḛːkʲ˺
phrase-final	2 tʃ’eːkʲ’	6 tʃ’ḛːkʲ’
before consonant initial suffix	3 **tʃ’eːkʲ’ɪ-tʰeː**	7 tʃ’ḛːkʲ˺-tʰeː
before vowel initial suffix	4 tʃ’eːkʲ’-ɪɬ	8 tʃ’ḛːkʲ’-ɪɬ
	Short vowel root ‘extend’	
	Definite	Indefinite
word-final, preconsonantal	9 tʰɪkʲ˺	
phrase-final	10 tʰɪkʲ’	
before consonant initial suffix	11 **tʰɪkʲ’ɪ-tʰeː**	13 tʰɪkʲ˺-tʰeː
before vowel initial suffix	12 tʰɪkʲ’-ɪɬ	

Root-final consonant=voiceless

	Long vowel root ‘brush away’	
	Definite	Indefinite
word-final, preconsonantal	14 tʃʷʰoːkʲ˺	18 tʃʷʰo̥ːkʲ˺
phrase-final	15 tʃʷʰoːkʲ	19 tʃʷʰo̥ːkʲ
before consonant initial suffix	16 **tʃʷʰoːkʲɪ-tʰeː**	20 tʃʷʰo̥ːkʲ˺-tʰeː
before vowel initial suffix	17 tʃʷʰoːkʲ-ɪɬ	21 tʃʷʰo̥ːkʲ-ɪɬ
	Short vowel root ‘pinch’	
	Definite	Indefinite
word-final, preconsonantal	22 tʰɪkʲ˺	
phrase-final	23 tʰɪkʲ	
before consonant initial suffix	24 **tʰɪkʲɪ-tʰeː**	26 tʰɪkʲ˺-tʰeː
before vowel initial suffix	25 tʰɪkʲ-ɪɬ	

The cases which are unexpected on the basis of the phonological analysis developed in section 5 are those indicated by shading. In definite roots containing long vowels, spreading fails to apply to word-final preconsontal consonants (cells 1, 14), even though conditions which caused laryngeal features to be realized on a preceding vowel in the indefinite aspect are met on the surface: the root vowel is long and the root-final consonant is preconsonantal. Furthermore, in indefinite

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[18] Recall that all words in Hupa begin with a consonant; thus, word-final position is also preconsonantal unless word-final position is also phrase-final.

long-voweled roots before a vowel-initial suffix (cells 8, 21) and phrase-finally (cells 6, 19), laryngeal features overlap with a preceding vowel even though the root-final consonant has a release on which to be realized.

We will deal first with forms in which laryngeal overlap would be expected to be present but is not: the definite form of long voweled roots in word-final preconsonantal position.

To account for these apparently deviant forms a few constraints are necessary. The first of these is a general constraint against word-final short vowels: *SHORT V]$_W$.

(47) ***SHORT V]$_W$**: There are no word-final short vowels.

This constraint is independently confirmed by the absence of words ending in a short vowel in an open syllable in Hupa. It also subsumes phrase-final cases, since phrase-final position is a subset of word-final position. *SHORT V]$_W$ also plays a role in a number of languages in which short vowels are lost in final position, either synchronically or historically, e.g. Indo-Aryan languages (Masica 1991), Estonian (Laanest 1975).

Another constraint is necessary to account for the absence of laryngeal overlap in word-final preconsonantal forms which underlyingly end in an /-ɪ/. In a rule-based approach, the interaction between apocope and laryngeal spreading would be captured by ordering final vowel deletion after laryngeal spreading. Here, working with a constraint-based framework, we will assume a constraint on morphological correspondence (McCarthy and Prince 1995, Benua 1995, Burzio 1996, Kenstowicz 1996, Steriade 1996). In Hupa roots, the surface form in which laryngeal overlap is most transparent is the manifestation of the root before consonant-initial suffixes. In the definite aspect, this form preserves the enclitic vowel which prevents laryngeal overlap with the preceding vowel, while, in the indefinite aspect, this form lacks the enclitic vowel, thereby triggering overlap. Thus, the consonant-initial instantiation of the root is the form which other forms attempt to mirror: in Steriade's terms, roots occurring before consonant-initial suffixes are the "veridical" forms. The tendency for all roots within an aspect to mirror the pre-consonant instantiation of the root is captured by the IDENT constraint in (45).

(45) **IDENT +C/O (lar F) $_{\text{ROOT(ASPECT)}}$**: All output roots correspond with respect to the presence or absence and timing of laryngeal features to their instantiation in the same aspect occurring before a consonant-initial suffix.

IDENT +C/O (lar F) $_{\text{ROOT(ASPECT)}}$ requires that laryngeal features in all instantiations of the root have the same realization as the instantiation of the root in the same aspect which occurs before a consonant initial suffix. It refers only to laryngeal features and their timing. The form which serves as the veridical form is always the form occurring before a consonant initial suffix. However, the definite and indefinite aspect each have their own veridical root. In the case of the definite aspect, the veridical root has laryngeal features realized on the release burst, while, in the indefinite aspect, the veridical root has its laryngeal features realized on the preceding vowel. Violations are cumulative and are incurred for each realization of a laryngeal feature which is not part of the realization of the laryngeal feature in the veridical form. Thus, a candidate form in the definite aspect which either has its laryngeal features on the preceding vowel or lacks a release burst violates IDENT +C/O (lar F) $_{\text{ROOT(ASPECT)}}$. A candidate in the definite which both realizes its laryngeal features on the preceding vowel and lacks a release thus incurs two violations of IDENT +C/O (lar F) $_{\text{ROOT(ASPECT)}}$. An instantiation of the root in the indefinite aspect without laryngeal features on the preceding vowel or with a release burst violates IDENT +C/O (lar F) $_{\text{ROOT(ASPECT)}}$.

Many actual surface instantiations of the root incur at least one violation of IDENT +C/O (lar F) $_{\text{ROOT(ASPECT)}}$. The word-final but not phrase-final instantiation (cells 1, 9, 14, 22) of the definite root incurs one violation, since it lacks a release burst unlike the instantiation of the root before a consonant initial suffix. The phrase-final instantiation of the indefinite root (cells 6, 10, 19, 23) incurs one violation, since it has a release. The existence of these forms indicates that OVERLAP and RELEASE are higher ranked than IDENT +C/O (lar F) $_{\text{ROOT(ASPECT)}}$. This is shown for RELEASE in tableau (49) for an indefinite form in phrase-final position and OVERLAP in tableau (50) for a definite form in word-final position which is not phrase-final.

(49)

Input: tɬ’eːtɪ]$_P$ | [+cg]	**RELEASE**	**IDENT +C/O (lar F) ROOT(ASPECT)**
Veridical instantiation: tɬ’ḛːt̚ +C		
☞ a. tɬ’ḛːt’]$_P$		*
b. tɬ’ḛːt̚]$_P$	*!	

Candidate (b) does not have a released final stop in violation of RELEASE. The winning candidate (a) violates lower ranked IDENT +C/O (lar F)$_{\text{ROOT(ASPECT)}}$, due to its lack of a release unlike the veridical instantiation of the indefinite root before a consonant-initial suffix.

(50)

Input: tɬ’eːtɪ #C | [+cg]	**OVERLAP**	**IDENT +C/O (lar F) ROOT(ASPECT)**
Veridical instantiation: tɬ’eːt’ɪ +C		
☞ a. tɬ’eːt˺ #C		*
b. tɬ’eːt’ #C	*!	

Candidate (b) has a consonant release in preconsonantal position in violation of OVERLAP. This leaves (a) as the winning candidate even though it violates IDENT +C/O (lar F) $_{\text{ROOT(ASPECT)}}$ by virtue of its lacking the release which is present in the veridical form of the definite.

In (51), a word-final phrase-medial instantiation of the definite root, we see that *SHORT V$]_W$ must also be ranked above IDENT +C/O (lar F).

(51)

Input: tɬ’eːtɪ #C | [+cg]	***SHORT V$]_W$**	**IDENT +C/O (lar F) ROOT(ASPECT)**
Veridical instantiation: tɬ’eːt’ɪ +C		
☞ a. tɬ’eːt˺ #C		*
b. tɬ’eːt’ɪ #C	*!	

In (51) we see that the short word-final vowel is not preserved in order to allow the ejective to be released which would make the word-final instantiation of the definite root more similar to the form of the root before a consonant-initial suffix.

IDENT +C/O (lar F)$_{\text{ROOT(ASPECT)}}$ is ranked above *PARTIAL NON-MODAL V, as shown in (52), the indefinite root occurring before a vowel initial suffix.

(52)

Input: tɬ’eːt -V | [+cg]	**IDENT +C/O (lar F) ROOT(ASPECT)**	***PARTIAL NON-MODAL V**
Veridical realization: tɬ’ḛːt˺ +C		
☞ a. tɬ’ḛːt’-V	*	*
b. tɬ’eːt’-V	**!	

Candidate (b) incurs two violations of IDENT +C/O (lar F) ROOT(ASPECT): one for the added release burst not present in the veridical form, and another for absence of the laryngeal feature on the root vowel. The winning candidate (a) incurs only one violation of IDENT +C/O (lar F) ROOT(ASPECT) due to its release burst. It also violates the lower ranked *PARTIAL NON-MODAL V.

IDENT +C/O (lar F) ROOT(ASPECT) must be ranked above *HIDDEN LAR F to account for the absence of spreading in word-final instantiations of the definite aspect, where there no release burst. This is illustrated in (53).

(53)

Input: tɬ’eːtɪ #C | [+cg]	**IDENT +C/O (lar F) ROOT(ASPECT)**	***HIDDEN LAR F**
Veridical realization: tɬ’eːt’ɪ +C		
☞ a. tɬ’eːt˺ #C	*	*
b. tɬ’ḛːt˺ #C	**!	

Candidate (b) differs from the veridical form in two ways, since its laryngeal features are overlapped with the preceding vowel and there is no release. The winning candidate (a) violates the correspondence constraint only once, as well as the lower ranked constraint *HIDDEN LAR F.

Roots ending in a nasal also show that there is another IDENT constraint which requires that the vowel length of the veridical root, the form of the root occurring before a consonant-initial suffix, be the same in all instantiations of the root belonging to the same aspectual paradigm. This constraint is thus identical to IDENT +C/O (lar F) ROOT(ASPECT), except that it refers to vowel length rather than laryngeal features. The relevant constraint is formulated in (54).

(54) **IDENT +C/O (V-length)** $_{\textbf{ROOT(ASPECT)}}$: All output roots correspond with respect to vowel length to their instantiation in the same aspect occurring before a consonant-initial suffix.

This constraint must be ranked above *Vː R]σ_M. This ranking can most clearly be seen in roots ending in a plain voiced sonorant where there is no interaction between glottalization and vowel length. In (55), we see a phrase-final instantiation of a root **tɪmeːnɪ** 'sharp' in the definite aspect ending in a plain voiced nasal.

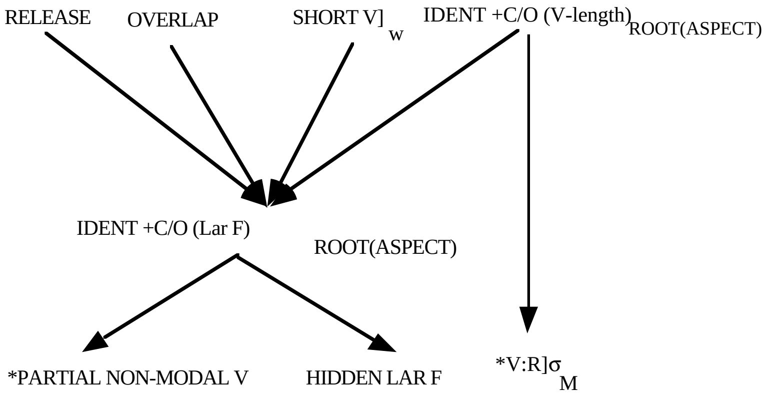
(55)

Input: tɪmeːnɪ]$_P$	**IDENT +C/O (V-length)** $_{\textbf{ROOT(ASPECT)}}$	***Vː R]**σ_M
Veridical realization: tɪmeːnɪ+C		
☞ a. tɪmeːn]$_P$		*
b. tɪmɪn]$_P$	*!	

Candidate (b) violates IDENT +C/O (V-length) $_{\text{ROOT(ASPECT)}}$, because the underlying long vowel is short. The winning candidate (a) violates lower ranked *Vː R]σ_M due to its tautomorphemic long vowel occurring in a closed syllable.

Ranking relations between the correspondence constraints and the phonotactic constraints proposed in section 5 are summarized in (56).

(56) Rankings of correspondence and phonotactic constraints



6.2. *Opacity in non-verb roots and suffixes*

Laryngeal timing alternations are not confined only to verb roots and prefixes, but also occur in roots other than verbs and also in suffixes, which recall from section 2.3 share many properties with roots. In this section, we focus primarily on noun roots though most of what is said about nouns also holds of other non-verb roots and also of suffixes.

Non-verb roots and suffixes are similar in many respects to verbs, but are different in certain crucial respects. Like verb roots, laryngeal timing is often opaque for non-verb roots and suffixes; it may occur where structural conditions are not met on the surface, and conversely may fail to occur where structural conditions on its application are satisfied on the surface. These cases of opacity occur in exactly the same positions as in verb roots. However, unlike verbs but similar to prefixes, laryngeal timing in non-verb roots and suffixes does *not* convey a crucial morphosemantic contrast such as aspect. Rather, the /ɪ/ which appears on verb roots in the definite aspect is synchronically simply part of the lexical entry for certain non-verb roots and suffixes, having originated in many cases historically from the relativizing enclitic. Similar to verb roots, the short /ɪ/ is the only final short vowel occurring on non-verb roots and suffixes. Compared to the enclitic /ɪ/ which can occur as a morpheme on virtually any verb root, there are relatively few non-verbal roots with a final lexical /ɪ/.

The alternations in non-verb roots and suffixes are shown in Table 6 using nouns as examples.[19] Note that roots with identical final consonants and a short vowel could not be found in the available material; this is likely to be an accidental gap due to the general paucity of non-verb roots ending in a final short vowel.

In non-verb roots and suffixes which have a final /ɪ/ underlyingly, the /ɪ/ only surfaces preceding a consonant initial suffix: **naːq'ɪ-tah** 'gravel also'. It is lost when the root or suffix appears in isolation: **naːq'** 'gravel', though it is interesting to note that in Tututni (Golla 1976), another Pacific Coast Athabaskan language, the final vowel is preserved even in nominal roots in isolation, suggesting that its loss in Hupa is a relatively recent development. The loss of final /ɪ/ in non-verb roots and suffixes is reminiscent of verb roots which also lose the final enclitic /ɪ/ of the definite in word-final position; recall that we attributed this loss to a general constraint against word-final short vowels in Hupa. Another set of lexical nouns do not possess this final /ɪ/: **xḛːq'** 'spit', **xḛːq̚ -tah** 'spit also'.

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[19] It is interesting to note that laryngeal spreading tends to function as a completely transparent process for at least one suffix, perhaps others. Golla (1970: 261) reports that the diminutive enclitic **-tʃɪ** often undergoes laryngeal spreading following a long vowel: **te̥ː-tʃ** (underlyingly **teːtʃɪ**) '(woman's) sister'. We would not expect this on the basis of the underlying final vowel which is sufficient to block spreading on the surface in other roots.

Table 6. Laryngeal spreading in noun roots

	Long vowel roots	
	Underlying /ɪ/	No /ɪ/
word-final, preconsonantal	naːq˺	xḛːq˺
phrase-final	naːq’	xḛːq’
consonant initial suffix	naːq’ɪ-tah	xḛːq˺-tah
vowel initial suffix	naːq’-eʔ	xeːq’-eʔ ~ xḛːq’-eʔ
	Short vowel roots	
	Underlying /ɪ/	No /ɪ/
word-final, preconsonantal	ʍɪŋot͡ʃ	mɪs
phrase-final	ʍɪŋot͡ʃ	mɪs
consonant initial suffix	ʍɪŋot͡ʃɪ-tah	mɪs-tah
vowel initial suffix	ʍɪŋot͡ʃ-tah	mɪs-ɪɬ

Non-verb roots and suffixes which have the /ɪ/ basically function like heavy verb roots and do not display laryngeal overlap between the final obstruent and a preceding vowel in any forms, suffixed or unsuffixed, i.e. they display uniformity across the paradigm with respect to laryngeal overlap just like verbs in the definite aspect. Non-verb roots and suffixes which do not have the underlying /ɪ/ show alternations on the surface. In non-verb roots and suffixes without the /ɪ/, the laryngeal feature of the final obstruent overlaps with the preceding vowel in unsuffixed forms, but only if the root contains a long vowel, parallel to verb roots: e.g. **xḛːq**’ ‘spit’, **hajjoːw tʃ’ɪtuːlje’-tʰe̥ːɬ-tɪŋ** ‘where they are to dance (ceremonially)’ with laryngeal features from the lateral fricative overlapping with the preceding vowel in the penultimate syllable.

The parallel between non-verb roots and suffixes, on the one hand, and verbs, on the other hand, ends when we consider forms which do not underlyingly end in a vowel occurring before a vowel on the surface. In this environment, laryngeal features typically do not spread: e.g. **ʍɪxeːq’eʔ** ‘my spit’, **ʍɪloːteʔ** ‘my scab’.[20] However, note that laryngeal features may optionally overlap with the preceding vowel in this environment though this option appears to be less commonly exercised: e.g. **ʍe̥ːseʔ** or **ʍeːseʔ** ‘my fish dam’ from **e̥ːs** ‘fish dam’.[21] The spreading of laryngeal features in these possessed forms is possible a relative recent development, since Golla (1964) cites several equivalent stems without laryngeal spreading. Non-verb roots and

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[20] The change from /ɬ/ to /l/ in the possessed form of 'scab' is a separate process which is not relevant to the alternations under discussion.

[21] The option of preserving laryngeal spreading in possessed forms derived from unpossessed forms with laryngeal spreading appears not to be available for roots ending in /t/: thus, the possessive of **ɬo̥ː** 'scab' is always **ɬo̥ːdeʔ** and not **ɬo̥ːeʔ**. This option is also not available for glottalized sonorants. Though this is an interesting asymmetry, its analysis lies beyond the scope of this paper.

suffixes without the final /ɪ/ which contain a *short* vowel are never subject to laryngeal alternations, as expected given the behavior of verb roots.

The constraints posited thus far will account for many aspects of the laryngeal phonology of non-verb roots. The constraint against word-final short vowels accounts for the loss of the lexical final vowel in word-final instantiation of words like **naːq’ɪ** and **ʌɪŋot͡ʃɪ**. The constraint against non-modal short vowels accounts for the absence of laryngeal spreading in roots containing short vowels. The paradigm uniformity effects in non-verb roots, however, are not accounted for by the IDENT constraints proposed in section 6.1 to account for opacity in verb roots. The reason for this is that IDENT +C/O (lar F) $_{\text{ROOT(ASPECT)}}$ and IDENT +C/O (V-length) $_{\text{ROOT(ASPECT)}}$ refer to aspectual paradigms which are lacking in nouns and suffixes.

To account for the paradigm uniformity effects in non-verb roots more general IDENT constraints are needed which refer to laryngeal features and vowel length just like the comparable constraints operating on aspectual paradigms. The relevant constraints for non-verb roots and suffixes refer to lexical items independent of aspect. These constraints are formulated below in (57) and (58).

(57) **IDENT +C/O (lar F) $_{\text{ROOT}}$**: All output roots correspond with respect to the presence or absence and timing of laryngeal features to their instantiation occurring before a consonant-initial suffix

(58) **IDENT +C/O (V-length) $_{\text{ROOT}}$**: All output roots correspond with respect to vowel length to their instantiation before a consonant-initial suffix.

These constraints operate over all lexical items, including verbs. However, their application is vacuous in the case of verbs, since verbs do not have a single instantiation before consonant-initial suffixes. Thus, verbs lack a veridical form for interpreting the constraints in (57) and (58). The veridical form in non-verb roots and suffixes is also the instantiation occurring before a consonant initial suffix. However, there is only one veridical form for non-verb roots and suffixes, since they do not contrast in aspect.

IDENT +C/O (lar F) and IDENT +C/O (V-length) $_{\text{ROOT}}$ refer only to roots and suffixes, which behave like roots for purposes of laryngeal spreading. They do not apply to inflectional morphemes, i.e. prefixes. If IDENT +C/O (lar F) $_{\text{ROOT}}$ applied to inflectional prefixes, laryngeal overlap between a consonant and a preceding vowel would incorrectly be expected to occur across the board in all surface manifestations of each prefix, since most prefixes containing an obstruent have at least one surface preconsonantal manifestation in which laryngeal spreading has applied. We may also assume that IDENT +C/O (V-length) $_{\text{ROOT}}$ only affects roots and suffixes and not prefixes, since prefixes do not appear to display any tendency to display the vowel length present in their preconsonantal instantiations.

Given the relatively small number of prefixes subject to laryngeal spreading it is not surprising that they should be exempt from IDENT +C/O (lar F) $_{\text{ROOT}}$ and IDENT +C/O (V-length) $_{\text{ROOT}}$. Assuming that IDENT +C-O (lar F) $_{\text{ROOT}}$ and IDENT +C/O (V-length) $_{\text{ROOT}}$ are motivated by the desire to minimize allophony for purposes of facilitating lexical access, they find less motivation in the case of prefixes. Lexical access is less of an issue for the relatively small set of inflectional prefixes found in Hupa than for the large number of roots and suffixes. Golla (1970) cites hundreds of non-verb roots, not unexpectedly. What is striking is the large number of suffixes in Hupa. Golla (1970) lists 125 suffixes, a figure which includes postpositions, adverbial suffixes, and a few suffixes indicating aspect. Compare the number of nouns and suffixes with the number of inflectional prefixes listed in Golla (1970): only 12. Thus, the set of possible nouns and suffixes which the listener and speaker must choose between is much larger than the set of possible prefixes; lexical access of nouns and suffixes is thus potentially much more problematic than lexical access of prefixes.

The rankings of IDENT +C-O (lar F) $_{\text{ROOT}}$ and IDENT +C/O (V-length) $_{\text{ROOT}}$ are largely the same as the ranking of the IDENT constraints operative in aspectual paradigms of verbs. If we rank IDENT +C-O (lar F) $_{\text{ROOT}}$ above *HIDDEN LAR F we correctly account for blocking of laryngeal spreading in word-final but phrase-medial instantiations of roots which underlying end in a vowel. This is shown in (59).

(59)

Input: naːqɪ #C | [+cg]	**IDENT +C/O (lar F) ROOT**	***HIDDEN LAR F**
Veridical realization: naːq’ɪ +C		
☞ a. naːq˺ #C	*	*
b. na̰ːq˺ #C	**!	

Furthermore, if we assume that IDENT +C/O (lar F) $_{\text{ROOT}}$ is ranked above *PARTIAL NON-MODAL V, one of the prevocalic instantiations of roots which underlyingly do not end in a vowel is accounted for: **xḛːq’eʔ**, as shown in (60).

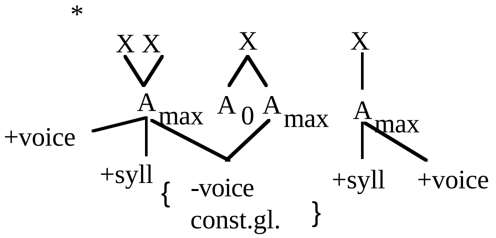
(60)

Input: xeːq -V | [+cg]	**IDENT +C/O (lar F) ROOT**	***PARTIAL NON-MODAL V**
Veridical realization: xḛːq˺ +C		
☞ a. xḛːq’ -V	*	*
b. xeːq’-V	**!	

However, the alternative realization of this form is not yet accounted for: **xeːq’-eʔ**. The question then becomes how does one formally account for this optionality. I propose as is standard in Optimality Theory that optionality is derived by freely ranking constraints. In this case, the relevant constraints are IDENT +C/O (lar F) $_{\text{ROOT}}$ and another constraint which has not yet been determined. A priori it would seem that the relevant constraint would be *PARTIAL NON-MODAL V. By ranking *PARTIAL NON-MODAL V above IDENT +C/O (lar F) $_{\text{ROOT}}$ we would get the variant without laryngeal spreading. However, if we assume optional reranking of *PARTIAL NON-MODAL V and IDENT +C/O (lar F) $_{\text{ROOT}}$ we also incorrectly predict optional lack of spreading in phrase-final instantiations of forms lacking a final vowel, i.e. **xeːq’** alongside **xḛːq’**.

There thus must be a different constraint with which IDENT +C/O (lar F) $_{\text{ROOT}}$ can be freely ranked. This constraint must prohibit laryngeal spreading in intervocalic but not in phrase-final environments. I propose that this constraint is termed *DOUBLY LINKED LAR F and limits the duration of laryngeal features in intervocalic position. This constraint, which is defined in (61), bans the association between identical laryngeal features other than [+voice] and A_{max} nodes associated with adjacent skeletal positions in intervocalic position. The configuration banned by *DOUBLY LINKED LAR F appears below the definition of the constraint in (61). Note that (61) assumes that vowels are differentiated from other segments by virtue of being [+syllabic]. Nothing crucial hinges on this assumption, however, and one could alternatively assume that vowels are differentiated from other segments because they belong to the nucleus.

(61) ***DOUBLY LINKED LAR F**: In intervocalic position, a laryngeal feature other than [+voice] may not be linked to A_{max} nodes associated with adjacent skeletal positions.



*DOUBLY LINKED LAR F has the effect of banning intervocalic voiceless and glottalized consonants which realize their laryngeal features on both their release (the A_{max} phase) and on the preceding vowel. This constraint thus has the effect of an assimilation constraint banning [constricted glottis] and [-voice] in environments which are [+voice] with the added proviso that the environment be intervocalic. Note that *DOUBLY LINKED LAR F crucially refers to A_{max} nodes and not to A_0 nodes since unreleased consonants regularly spread their laryngeal features onto a preceding long vowel.

By ranking *DOUBLY LINKED LAR F above IDENT +C/O (lar F)$_{ROOT}$ the alternative prevocalic instantiation **xeːq’-eʔ** without laryngeal spreading is accounted for as shown in (62).

(62)

Input: xeːq -V | [+cg]	***DOUBLY LINKED LAR F**	**IDENT +C/O (lar F) ROOT**
Veridical realization: xḛːq̚ +C		
☞ a. xeːq’ -V		**
b. xḛːq’-V	*!	*

Candidate (b) incurs a violation of *DOUBLY LINKED LAR F since it contains a released intervocalic stop which has spread its laryngeal feature onto the preceding vowel. The winning candidate is thus (a) which violates IDENT +C/O (lar F) $_{ROOT}$ twice, once for the release burst not present in the veridical form and once for the lack of laryngeal features on the vowel.

If we rank *DOUBLY LINKED LAR F below IDENT +C/O (lar F) $_{ROOT}$ we get the variant with laryngeal spreading shown earlier in (60). This form is considered again in (63).

(63)

<table>
<tr><th>Input:
xeːq -V
|
[+cg]</th><th>IDENT +C/O (lar F) ROOT</th><th>*DOUBLY LINKED LAR F</th></tr>
<tr><td>Veridical realization:
xḛːq˺ +C</td><td></td><td></td></tr>
<tr><td>☞ a. xeːq’ -V</td><td>**!</td><td></td></tr>
<tr><td>b. xḛːq’-V</td><td>*</td><td>*</td></tr>
</table>

*DOUBLY LINKED LAR F is always ranked below IDENT +C/O (lar F) $_{\text{ROOT(ASPECT)}}$, as indicated by the fact that there is no optional spreading of laryngeal features from prevocalic obstruents in the indefinite of verbs.

This leaves a few other rankings which would be predicted on the basis of the behavior of parallel constraints affecting verb roots. One would expect that IDENT +C/O (lar F) $_{\text{ROOT}}$ would be ranked above *FULLY NON-MODAL V, parallel to the ranking of the IDENT constraint in verbs over *FULLY NON-MODAL V. Similarly, one would expect that IDENT +C/O (lar F) $_{\text{ROOT}}$ would be higher ranked than *V:R]σ_M on the basis of the similar ranking of the IDENT constraint over *V:R]σ_M in verb roots. However, forms of the relevant shape to test these rankings in nouns or suffixes are lacking: there are, to the best of my knowledge, no suffixes beginning in a short vowel which attach to non-verb roots, and there are no forms ending in a long vowel + nasal + vowel sequence underlyingly. Thus, we have no evidence either for or against the predicted rankings.

To complete the picture for non-verb roots and suffixes, there are, however, a few other rankings left to discuss for which we do have evidence. First, both OVERLAP and RELEASE are ranked above IDENT +C/O (lar F) $_{\text{ROOT}}$ as shown in (64), a word-final form with an underlying root-final vowel, and (65), a phrase-final form with no underlying root-final vowel.

(64)

<table>
<tr><th>Input:
naːqɪ#C
|
[+cg]</th><th>OVERLAP</th><th>IDENT +C/O (lar F) ROOT</th></tr>
<tr><td>Veridical instantiation:
naːq’ɪ +C</td><td></td><td></td></tr>
<tr><td>☞ a. naːq˺ #C</td><td></td><td>*</td></tr>
<tr><td>b. naːq’ #C</td><td>*!</td><td></td></tr>
</table>

(65)

Input: xeːq]$_P$ | [+cg]	**RELEASE**	**IDENT +C/O (lar F) ROOT**
Veridical instantiation: xḛːq˺ +C		
☞ a. xḛːq’]$_P$		*
b. xḛːq]$_P$	*!	

Finally, *SHORT V]$_W$ is ranked above IDENT +C/O (lar F) $_{ROOT}$ as shown in (66), a word-final form containing an underlying root-final vowel.

(66)

Input: naːqɪ #C | [+cg]	***SHORT V]$_W$**	**IDENT +C/O (lar F)** ROOT
Veridical instantiation: naːq’ɪ #C		
☞ a. naːq˺ #C		*
b. naːq’ɪ #C	*!	

7. IMPLICATIONS OF THE HUPA DATA FOR PHONOLOGICAL THEORY

7.1. *A linear-based approach to laryngeal spreading*

This paper has argued for an analysis of laryngeal timing which does not crucially refer to syllable positions such as onset and coda. While an approach based on syllable position could generate the correct empirical results, there are a few reasons, I believe, why such an approach is not as explanatory as one which does not crucially rely on syllable position.

First, an analysis which stipulates that laryngeal features associated with coda but not onset consonants overlap with an adjacent vowel does not explain why codas rather than onsets induce overlap and why laryngeal features overlap with the preceding rather than the following vowel. It would be just as easy to formulate a hypothetical but unattested rule or constraint which forces the overlap of laryngeal features leftward from an *onset* consonant.

Interestingly, there are cases of leftward laryngeal overlap similar to Hupa but found in other languages. In Chitimacha (Swadesh 1946), glottalized stops are preglottalized in final position, but postglottalized in prevocalic position. Likewise, in Takelma (Sapir 1912), the glottal closure may either precede or occur simultaneously with oral closure in prevocalic glottalized obstruents, but glottalized stops in preconsonantal or final position are consistently and audibly preglottalized (pg. 36). As Sapir suggests, these timing patterns reflect an attempt to render the glottalization feature audible in all environments. Interestingly, in Takelma and Chitimacha, glottalization can overlap with both long and short vowels, unlike in Hupa, in which laryngeal features only overlap with long vowels. Thus, the constraint against non-modal voiced short vowels is lower ranked in these languages than in Hupa.

While there are cases of laryngeal features associated with prevocalic and preconsonantal/final consonants overlapping with a preceding vowel (e.g. preaspirated stops in Icelandic-- Thraínsson 1978), crucially I am aware of no cases of prevocalic but not preconsonantal/final stops overlapping their laryngeal features with a preceding vowel. Under the proposed analysis, this asymmetry follows from the relative availability and salience of cues in prevocalic as opposed to other positions (see sections 4 and 5). Although, in many cases, this positional asymmetry coincides with an onset vs. coda asymmetry, expressing the process in terms of codas and onsets offers a less direct and explanatory account of the process. Furthermore, an analysis couched in terms of codas and onsets would not extend to data from other languages like Klamath and Lithuanian as pointed out earlier in section 4.

Furthermore, an analysis stated in terms of coda and onset positions does not explain the different timing relations between laryngeal and supralaryngeal features in sonorants and obstruents in Hupa. The realization of the feature [constricted glottis] demonstrates this asymmetry. [Constricted glottis] is realized on the left edge of prevocalic and phrase-final sonorants as glottalization or creak, but on the right edge of prevocalic and phrase-final obstruents as an ejective burst. Preconsonantal consonants display the opposite pattern. [Constricted glottis] is realized as creak on a long vowel preceding an obstruent, but as creak on the right side of sonorants. While this asymmetry could in principle be stated in terms of onset and coda position, this would not explain the asymmetry between glottalized sonorants and glottalized obstruents. One might expect exactly the opposite pattern to obtain: glottalization on the right side of onset sonorants and coda obstruents, but on the left side of onset obstruents and coda sonorants. That this scenario does not occur in Hupa, or for that matter in any language, to the best of my knowledge, would not be explained in an analysis which crucially refers to onsets and codas. In contrast, under the proposed analysis, the ordering of laryngeal features with respect to supralaryngeal features has a natural explanation in terms of differences in the possibility of realizing laryngeal in different contexts and in terms of differences between sonorants and obstruents in the acoustic manifestations of their associated laryngeal features.

In summary, an analysis couched in terms of linear position rather than syllable constituency offers, I would argue, a persuasive account of laryngeal timing in Hupa. Note, however, that the Hupa facts do not argue against the syllable as a valid constituent in phonology. In fact, I have argued that the syllable plays an important role in certain aspects of Hupa phonology. First, it was argued that a constraint against long vowels in tautomorphemic syllables closed by a sonorant plays an important role in the Hupa alternations. Similarly, a constraint against alveolar nasals in coda position was tacitly assumed to account for the alternation between alveolar nasals in onset position and velar nasals in coda position. Whether an analysis of these facts in terms which do not appeal to syllable structure can be offered is an open question which must be left for future research. However, the behavior of laryngeal features is one area in which an analysis presented in terms of syllable structure does not appear to offer as explanatory an account as an approach referring to linear position.

7.2. *The specification of laryngeal features*

In the proposed account, the complex laryngeal facts were explained in terms of different timing relationships between laryngeal and supralaryngeal features in different positions. The fact that laryngeal features have a different phonetic realization when associated with sonorants from when they are associated with obstruents results in different timing relations between laryngeal and supralaryngeal features in the two class of consonants. In obstruents, there is the possibility of realizing a laryngeal feature on the burst; additionally, in the case of voiceless non-glottalized obstruents, the [-voice]/[spread glottis] feature can also be realized directly on the constriction phase of the obstruent as a voiceless closure. This option is not available for [constricted glottis] obstruents, however, since there is no way of realizing glottalization during the voiceless closure of a stop. In sonorants, on the other hand, [constricted glottis] can be realized directly on the consonant due to the voicing which allows glottalization to be manifested.

Assuming that there is a single feature [constricted glottis] which is realized either by an ejective burst or by glottalization on a sonorant, the laryngeal timing patterns involving [constricted glottis] must be explained in terms of timing differences. However, in the case of voiceless consonants, there are two features which have the same acoustic consequences and could potentially be used to account for the Hupa data: [spread glottis] and [-voice]. Thus far, I have not taken a position as to which of these is the relevant feature involved in the Hupa laryngeal alternations.

[Spread glottis] and [-voice] are not equivalent in terms of the properties to which they refer. [Spread glottis] refers to an articulatory gesture, the opening of the glottis, whose acoustic consequence is voicelessness. The feature [-voice], on the other hand, reflects the acoustic property of absence of voicing. Thus, [spread glottis] refers to an articulatory event, whereas [-voice] refers to an acoustic consequence of an articulatory event (see Flemming 1995 and Steriade 1997a for discussion of the differences between acoustic and articulatory features and their role in phonology).

Strictly speaking, the laryngeal feature involved in the timing alternations in Hupa is both [spread glottis] and [-voice]. It is standardly assumed in recent phonological literature that voicing features are monovalent and that there is no negatively specified [voice] feature (Ito and Mester 1986, Lombardi 1991, 1995, etc.). If we uphold the notion that [-voice] is not a member of the universal set of features, then this forces us to assume that the laryngeal feature overlapping with long vowels preceding voiceless obstruents is [spread glottis]. However, this is problematic if we also assume that [spread glottis] is the feature used to define the aspirated stops which occur in initial position in Hupa. (Recall that there is a three-way contrast between voiceless unaspirated, voiceless aspirated and ejectives in initial position in Hupa.) Final obstruents are unaspirated in Hupa as evidenced by their phonetic realization when a vowel-initial suffix is added in the definite aspect: **tʃʷʰoːkʲ** → **tʃʷʰoːkʲɪ** and not ***tʃʷʰoːkʲʰɪ**. Thus, final obstruents cannot be [spread glottis], nor can the laryngeal feature overlapping with the preceding vowel in cases like the indefinite form **tʃʷʰo̥ːkʲ** be [spread glottis].

This apparent featural conundrum is resolved if we distinguish between the properties to which [spread glottis] and [-voice] refer and the timing relationships between laryngeal and supralaryngeal features in different positions. If [spread glottis] is used in the same sense as [constricted glottis] to refer to an articulatory gesture rather than an acoustic property, both the voiceless unaspirated stops and the voiceless aspirated stops in Hupa are marked as [spread glottis]. The contrast in root-initial position between voiceless aspirated and unaspirated stops is thus one of timing rather than one of different feature specifications. Under this approach, the [spread glottis] feature is present during the closure and persists long into the following vowel for the aspirated stops, while [spread glottis] is present during the closure of unaspirated obstruents in prevocalic and phrase-final position but overlaps onto a long vowel preceding preconsonantal obstruents. It is also likely that the spread glottis gesture perserverates slightly beyond the release of the closure in unaspirated stops on the basis of articulatory measurements from languages like Korean (Hirose et al. 1974) and Mandarin (Iwata and Hirose 1976) in which the glottis remains open slightly past closure release. Studies from these languages suggest that the period after the release of a stop until the beginning of voicing for the following vowel is roughly equivalent to the amount of time the glottis is open after the release of the closure.

The fact that a [spread glottis] gesture is present in both aspirated and unaspirated obstruents is supported by articulatory data on languages with both sets of obstruents: French (Benguerel et al. 1976), Mandarin (Iwata and Hirose 1976), Icelandic (Pétursson 1976), Korean (Kagaya 1974). In all of the languages except Korean, the glottis is open for voiceless unaspirated stops in both initial and intervocalic position. (In Korean, the voiceless unaspirated stops became voiced intervocalically.) Universally, [spread glottis] is acoustically manifested as [-voice] just as [constricted glottis] is manifested either as glottalization/creak on a sonorant and as an ejective burst on an obstruent. Hupa thus provides evidence for the view that timing plays an important role in the phonology of laryngeal features (cf. Kingston 1985, Silverman 1995, Steriade 1997).

7.3. *The short vs. long vowel spreading asymmetry*

The failure of laryngeal features to be overlapped with short vowels in Hupa is not easily captured under conventional theories of phonology which are exclusively articulatory-based. In contrast, the asymmetrical overlap of laryngeal features onto a long but not a short vowel follows straightforwardly in a theory of phonology sensitive to perceptual factors (e.g. Jakobson, Fant and Halle 1953, Flemming 1995). Under the analysis proposed in this paper, the failure of laryngeal features to overlap with short vowels is due to the lack of space on which to realize laryngeal features on short vowels without obscuring the vowel itself. Similar durational asymmetries involving non-modal vowels are found in Jalapa Mazatec in which non-modal vowels (breathy and glottalized) are substantially longer (by approximately 50%) than modally voiced vowel (Kirk, Ladefoged and Ladefoged 1993). Similarly, in Kedang (Samely 1991) in which the only non-modal voiced vowels are glottalized, the glottalized vowels are much longer than their modal voiced counterparts. This increase in duration of non-modal voiced vowels in Jalapa Mazatec and Kedang may be viewed as an attempt to compensate for the reduction in perceptual salience at any one point in time.

The proposed analysis also extend to other non-laryngeal features which can also reduce the perceptibility of vowels: for example, the feature [nasal]. Nasalization has similar acoustic manifestations to laryngeal features; nasalization reduces amplitude and obscures formants (cf. Wright 1986, Beddor 1993). It is thus not surprising that nasalization processes in certain languages apply asymmetrically to long vowels but not short vowels. Instantiations of this asymmetry are found in Athabaskan itself. Short vowels resist nasalization in Tolowa in environments where long vowels undergo it (Collins 1989). Likewise, historically in Navajo nouns, clusters consisting of a long vowel plus nasal consonant became nasalized vowels, but clusters of a short vowel plus nasal consonant did not become nasalized vowels; rather, the nasal consonant was preserved (Leer 1979). The avoidance of short nasalized vowels also has phonetic manifestations synchronically in Navajo, in which phonemically short nasalized vowels are phonetically longer than phonemically short oral vowels of identical phonemic length (Zhang 1997). We may assume that the additional length associated with nasalized vowels is compensating for the reduction in perceptibility of nasalized vowels. Finally, to take an example of asymmetric nasalization in a non-Athabaskan language, in certain Min dialects of Chinese, nasalization is only allowed to spread onto long vowels but is blocked from spreading onto short vowels (Yip 1997). In summary, data from many languages suggest that short vowels are less optimal targets for laryngeal and nasal features than long vowels, a fact which emerges if perceptual factors are assigned an important role in the grammar.

7.4. *The loss of /t/ following voiceless vowels*

One of the most interesting facts about laryngeal spreading in Hupa is the loss of a alveolar stop following a voiceless vowel. What is particularly curious in an exclusively articulatory-based model of phonology, is that the alveolar stop is not lost following a glottalized vowel and that palatalized velar stops are not lost following a voiceless vowel. Furthermore, alveolar affricates are not lost following a voiceless or glottalized vowel. None of these asymmetries are easily captured in terms of conventional features. All instances of /t/ whether occurring after a breathy or a glottalized vowel are identical in terms of place of articulation features, and would thus be expected to be deleted in standard accounts.

Under the present account, it is not surprising that the only sequence of non-modal voiced vowel plus obstruent which triggers loss of the obstruent is a sequence of voiceless vowel plus /t/. The closure is particularly prone to loss in this environment, because the /t/ benefits from no right-edge cues to its place of articulation when in preconsonantal position, where stops are often unreleased. Furthermore, the cues going into the stop closure are obscured by the reduction in energy during the voiceless phase of the preceding vowel. In contrast, fricatives and affricates benefit from a period of frication which provides information about place of articulation. Alveolar stops following a glottalized vowel suffer from a reduction in left-edge cues, but not as severely as alveolar stops after a breathy vowel, because glottalized vowels have more energy than a breathy vowel in Hupa. Finally, the pre-palatalized velar stops in Hupa benefit from salient formant transitions going into the closure which offset the reduction in energy during the breathy/voiceless phase of the preceding vowel.

7.5. *Morphological correspondence*

The paradigm uniformity effects in Hupa have been argued here to result from correspondence constraints referring to two different paradigms: one referring to an aspectual paradigm, the other referring to a paradigm containing forms related to the same lexical entry. For all correspondence constraints, the veridical form, i.e. the form which serves as the target form upon which other instantiations are modeled, is the form occurring before a consonant-initial suffix. The first type of correspondence constraint refers only to verbs, which unlike other morphological categories, possess aspectual paradigms, while the second type of correspondence constraint refers to non-verb roots and suffixes. The correspondence constraints sensitive to aspect are stronger than those referring to lexical paradigms, as evidenced by the fact that those referring to lexical paradigms are optionally ranked either above or below *OVERLONG LAR F. This optional ranking results in two possible surface forms in prevocalic instantiations of non-verb roots and suffixes which underlyingly do not end in a vowel. In contrast, the correspondence constraints referring to aspectual paradigms is obligatorily ranked above *OVERLONG LAR F; the result is a *single* surface form in the prevocalic instantiation of verbs in the indefinite aspect.

The Hupa facts are problematic for a derivational approach which relies on cyclic rule application to get the opacity effects. This can be seen in the paradigm of nouns which do not underlyingly end in a vowel. Let us suppose that there is a rule termed "laryngeal overlap" according to which laryngeal features associated with a non-prevocalic obstruent overlap with a preceding long vowel. Another rule, final short vowel loss, deletes word-final short vowels and applies after laryngeal overlap.

Assuming that laryngeal overlap applies before final short vowel loss, laryngeal overlap will correctly apply vacuously to all instantiations of non-verb roots and suffixes containing an underlying final vowel; after the application of laryngeal overlap, the final vowel will be lost. This is shown in (67).

(67)	Word-final	Phrase-final	Before +C	Before +V
Underlying:	naːqɪ #C	naːqɪ]p	naːqɪ +C	naːqɪ +V
	|	|	|	|
	[+cg]	[+cg]	[+cg]	[+cg]
Laryngeal overlap:	n.a.	n.a.	n.a.	n.a.
Final Short V loss:	naːq˺ #C	naːq’]p	n.a.	n.a.
Surface:	naːq˺ #C	naːq’]p	naːq’ɪ +C	naːq’ɪ +V

But, if we assume that laryngeal overlap is ordered before final short vowel loss, we encounter problems in the prevocalic form of non-verb roots which do not underlyingly end in a vowel. In all forms corresponding to lexical items not ending in a vowel underlying, we expect laryngeal overlap to apply across the board given the proposed rule ordering; this is shown in (68). Yet, the prevocalic instantiation of these nouns may optionally be realized without laryngeal overlap as **xeːq’** in addition to the form correctly produced by the proposed rules.

(68)	Word-final	Phrase-final	Before +C	Before +V
Underlying:	xeːq #C	xeːqɪ]p	xeːqɪ +C	xeːqɪ +V
	|	|	|	|
	[+cg]	[+cg]	[+cg]	[+cg]
Laryngeal overlap:	xe̥ːq #C	xe̥ːq]p	xe̥ːq +C	xe̥ːq +V
Final Short V loss:	n.a.	n.a.	n.a.	n.a.
Surface	xe̥ːq #C	xe̥ːq]p	xe̥ːq +C	**xe̥ːq** +V

While it would be possible to add a rule which "undoes" laryngeal overlap in prevocalic instantations of non-verb roots which lack a vowel underlyingly, this rule would have to be restricted to non-verb roots and could not be allowed to apply to verb roots. There would be no principled explanation why it would apply to non-verb roots but not to verb roots.

Under the proposed account, the asymmetric behavior of non-verb roots and suffixes, on the one hand, and verbs, on the other hand, is due to the fact that non-verb roots and suffixes have different paradigms than verbs. In verb roots, but not non-verb roots and suffixes, there are aspectual paradigms which are sensitive to their own correspondence constraints distinct from those correspondence constraint referring to forms corresponding to a single lexical item. The different correspondence constraints may be ranked differently relative to other constraints, just as expected in Optimality Theory. The different rankings for the two types of correspondence constraints thus yield different realizations of laryngeal features in verbs as opposed to non-verb roots.

9. CONCLUSIONS

In summary, many of the intricacies involved in the spreading of glottal features in Hupa are explained in a phonetically-based version of Optimality-Theory using a series of phonetically-grounded constraints in conjunction with constraints on morphological correspondence. The proposed constraints and the implicational hierarchies which they respect make a number of empirically testable predictions about the nature of laryngeal spreading, the timing of laryngeal features and the preservation of consonants in different environments. The proposed approach offers an explanation for the different timing relations of laryngeal features based on position and based on differences in the class of affected segments, sonorants vs. obstruents. Furthermore, asymmetries in laryngeal timing governed by vowel length also find an explanation when one considers phonetic factors. Finally, the loss of certain consonants but not others following only certain laryngeal features but not others also is sensible given phonetic considerations. The morphological correspondence constraints proposed in this paper also follow simple principles. Morphological correspondence is most stringently enforced where there is an aspectual paradigm, and less strictly enforced where there is no aspectual contrast at stake, i.e. in non-verb roots and in suffixes.

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