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Laryngealized vowels in Yánesha': a phonetic description and subsegmental analysis

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Abstract

This paper addresses the phonetic and phonological status of laryngeals in Yánesha' (Arawakan), showing that they are features associated with vowels, rather than following consonants or free-standing segments. Based on phonetic findings, I propose that [+spread glottis] and [+constricted glottis] are contrastive features associated with the rightmost subsegments of aspirated and glottalized vowels, respectively, within a Q-Theoretic framework. This analysis is supported by distributional and durational patterns and interactions between weight and stress, as quantified in the phonetics description. Yánesha's laryngealized vowels are subsequently considered in light of areal trends, and an analytical extension to closely related Chamicuro is proposed. This paper contributes to our empirical understanding of a typologically rare segment type in an understudied language.

Keywords: laryngeal features; Arawakan; phonetic description; subsegmental phonology

1 Introduction

In Yánesha', an Arawakan language spoken in Peruvian Amazonia, the laryngeal features [+spread glottis] and [+constricted glottis] (hereafter [+sg] and [+cg]) exhibit behavior that is genealogically and typologically unusual. In many Arawakan languages, glottal phones have phonemic status: /h/ and /ʔ/ (Michael et al., 2015). In other language families (e.g., Tukanoan languages), laryngeals occur as a prosodic feature (Silva, 2016; Stenzel, 2007). In Yánesha', however, laryngeals show exceptional distributional patterns and interact with vowels and stress assignment in ways that suggest they are neither segments in the traditional sense, nor solely prosodic in nature. Previous analyses of Yánesha' have recognized a meaningful relationship between laryngeal features and vowels but have not provided substantive phonetic descriptions or explicit phonological assessments of these phenomena (Fast, 1953; Wise, 1958, 2018; Duff-Tripp, 1997, 1998).

This paper investigates the phonetic and phonological properties of laryngeals in Yánesha' to determine their status. As laryngeals consistently surface after vowels and before consonants, three hypotheses are considered:

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- (1) Laryngeals are features associated with the preceding vowel segments, forming aspirated and glottalized vowels (collectively, laryngealized vowels).
- (2) Laryngeals are features associated with the following consonant segment, forming pre-aspirated and pre-glottalized consonants.
- (3) Laryngeals are free-standing glottal segments, /h/ and /ʔ/.

In what follows, I argue for the first hypothesis, in which laryngeals belong to laryngealized vowels. This analysis is supported by distributional and durational patterns, as well as interactions between syllable weight and primary stress, which together rule out the latter two hypotheses in favor of the vocalic association of laryngeals. Furthermore, I show that aspirated and glottalized vowels are phonemic vowel types, which contrast with one another and with short and long modal vowels.

On the phonetic side, I demonstrate that Yánesha' aspirated vowels are segments consisting of a modal voiced portion followed by a breathy voiced portion, and that glottalized vowels are likewise segments consisting of a modal portion followed by a creaky portion. Furthermore, I show that breathy and creaky portions result in the shortening of preceding modal vowels, do not significantly alter vowel formants or pitch, and pattern significantly with intensity, which I suggest as the leading indicator of primary stress assignment in Yánesha'. Phonologically, I posit four contrastive vowel types in Yánesha': short modal, long modal, aspirated, and glottalized. Following Q-theory (e.g., Inkelas and Shih 2014), I propose a subsegmental account of laryngealized vowels, in which [+sg] and [+cg] are contrastive features associated, respectively, with creaky and breathy subsegments of vowels.

1.1 Terminology and organization

Throughout the paper, I retain the descriptive terms 'aspirated' and 'glottalized' vowels, as designated by Duff-Tripp (1997), and shared by geographically related analyses (e.g., Coon, 2010, 2016; Macaulay & Salmons, 1995; Silva, 2016). *Aspirated vowel* here refers to a single vowel segment comprised of a modal portion followed by a breathy portion, and is represented as V^h. *Glottalized vowel* here pertains to a vowel segment comprised of a modal portion followed by a creaky portion, represented as V^ʔ. These two vowel types are collectively referred to as *laryngealized vowels*. *Contrastive vowel type* refers to the combination of phonation and length that define contrastive aspirated, glottalized, short modal, and long modal vowels of any vowel quality, /a, e, o/.

The paper is organized in seven parts. Section 2 provides relevant background, including an overview of Yánesha', previous analyses, syllable weight and stress patterns, and an overview of phonation types. The dataset and methods of analysis are outlined in Section 3. Section 4 presents the phonetic findings, including descriptions of phonation types, phonotactics, duration, formants, intensity, and primary stress effects. Section 5 is concerned with the phonological status of Yánesha' laryngeals, arguing for their vocalic association and subsegmental nature. In Section 6, Yánesha' laryngealized vowels are considered in light

of relevant laryngeal analyses, and an analytical extension to closely related Chamicuro is proposed. Conclusions follow in Section 7.

2 Background

2.1 Overview of Yánesha'

Yánesha' (historically known as Amuesha) is spoken at the tropical–alpine intersection of the eastern Andean foothills and the western Amazon basin in central Peru (INEI, 2017). Its grammatical profile is typically Arawakan: head-marking, head-initial, and polysynthetic, with rich verbal morphology and nominative-accusative alignment. However, Yánesha' is typologically unusual among Arawakan languages due to intensive contact with Panoan and, especially, Quechuan languages, which shrouded the language's genealogical identity in mystery until the 1970s and altered its grammatical structure and sound system (Wise, 1976; Adelaar, 2007). For example, Yánesha' has a three-vowel system, at odds with a typical Arawakan five-vowel system (Wise, 1976; Adelaar, 2007). Additionally, while many Arawakan languages exhibit CV(V) syllable structures and allow vowel hiatuses, Yánesha' constrains vowel hiatuses but permits complex codas across morpheme boundaries (Duff-Tripp, 1997). Genealogically, Yánesha' is most closely related to Chamicuro (currently verging on dormant), and they together form the Western Maipuran subgroup of the Arawakan family (Michael, 2020; Payne, 1991). The two languages' consonant inventories largely overlap, with the notable exception of palatalized counterparts of stops in Yánesha', as influenced by Quechua. Both Yánesha' and Chamicuro exhibit vowel length contrasts, and both treat laryngeals *h* and *ʔ* as special categories with some contrastive quality (see Section 2.2 on Yánesha' and Section 6.2 on Chamicuro for further details). In Section 6.2, I suggest the extension of the current analysis to Chamicuro.

Yánesha' has 22 phonemic consonants and 12 phonemic vowels, presented in Tables 1 and 2, respectively.² These inventories build on the analyses of Fast (1953), Wise (1958), and Duff-Tripp (1997), with updates based on the current data and analysis. Yánesha' exhibits a series of stops that contrast in palatalization, including plosives and nasals. Retroflex affricates and fricatives also occur, likely incorporated from Quechua (Adelaar, 2007). Infrequent phonemes are indicated in parentheses.

Yánesha' has three contrastive vowel qualities, /e, o, a/, whose respective short, long, glottalized, and aspirated counterparts exhibit further contrast. All phonemes are mid to low in height, although mid phonemes are sometimes realized as high vowels corresponding in backness. While nasality is a non-contrastive feature in Yánesha' vowels, nasal vowels are highly common – particularly when adjacent to nasal consonants – and nasal allophones of all phonemic vowels and their allophones are attested, across all phonation types.

²Common allophones of consonants: /p/ [b, p^h]; /t/ [t^h]; /k/ [g, k^h]; /pʲ/ [p^w]; /tʲ/ [tʃ]; /kʲ/ [k^w]; /n/ [ɲ]; /w/ [ɣ, β, v]; /z/ [s]. Common allophones of vowels (across all phonations): /a/ [ae, ə, ʌ]; /o/ [u, ɵ]; e [i, ɪ, ɛ]; nasalization.

Table 1: Consonant inventory of Yánesha’

	Labial	Alveolar	Post-alveolar	Retroflex	Palatal	Velar
Plosive	p p ^j	t t ^j				k k ^j
Affricate		ts	tʃ	ɬʂ		
Fricative		s	ʃ	ʂ		(x)
Nasal	m m ^j	n			ɲ	
Approximant					j	w
Tap/flap		r				
Lateral					ɬ	

Table 2: Vowel inventory of Yánesha’

	Front	Central	Back
Mid	e e ^ɾ e ^h e:		o o ^ɾ o ^h o:
Low		a a ^ɾ a ^h a:	

2.2 Previous assessments of Yánesha’ laryngeals

Since the 1950s, a handful of linguists and anthropologists have contributed to research on Yánesha’, resulting, among other things, in a grammar (Duff-Tripp, 1997) and dictionary (Duff-Tripp, 1998). Phonological description of Yánesha’ has been carried out by Peter Fast, Mary Ruth Wise, and Martha Duff-Tripp. Fast (1953) proposes the phonemic status of voiceless velar fricative /x/, which is realized as [h] when followed by a consonant. In contrast with this segmental approach to the [+spread glottis] laryngeal feature, he associates the [+constricted glottis] feature to the preceding vowel. Fast notes a three-part vowel contrast among “basic”, “long”, and “laryngealized” vowels, substantiated by minimal pairs. His main descriptive points concerning this last category is more or less affirmed by the current data: (1) word-final laryngealized vowels entail a “rather fortis glottal closure”, (2) pre-final laryngealized vowels, which are somewhat longer than short vowels, show varying degrees of laryngealization, and (3) laryngealized vowels may surface as “slightly rearticulated” vowels, or – when followed by a nasal – a “somewhat syllabic quality of the nasal”.

In response to Fast’s velar /x/ analysis, Wise (1958) asserts a phonemic distinction between voiceless velar and glottal fricatives, proposing the latter category’s association to vowels. Notably, /x/ never occurs adjacent to other consonants, whereas /h/ always precedes a consonant. Although not fully departing from a segmental analysis for the laryngeals, she toes the line, including them in the phonemic inventory as “? (following vowels, only)... h (following vowels, only)”. “Length” is listed in a similar fashion.

The distinction between [h] and /x/ are corroborated in Duff-Tripp (1997) and (1998),

in which the voiceless velar fricative is written as <j>. The velar fricative occurs rarely and either intervocalically or vowel-adjacent at root edge. Its velar (not glottal) nature has been confirmed by the current data. As for /h/, Duff-Tripp (1997) proposes aspirated vowels (written <Vh> and described as vowels “followed by aspiration”) and glottalized vowels (<V’>, vowels “followed by a glottal stop”). Minimal pairs in the 1998 dictionary substantiate contrast between modal, aspirated, and glottalized vowels (in addition to modal short and long contrast); for example, *tsoh* ‘species of edible tuber’ versus *tso’* ‘consecutively’, and *ahṭsa:n* ‘bite’ versus *aṭsa:n* ‘something vinegary’. Wise (2018) affirms Duff-Tripp’s analysis, asserting four contrastive syllable nucleus patterns: “short vowels, vowel plus aspiration, long vowel, and vowel plus glottal stop” (160).

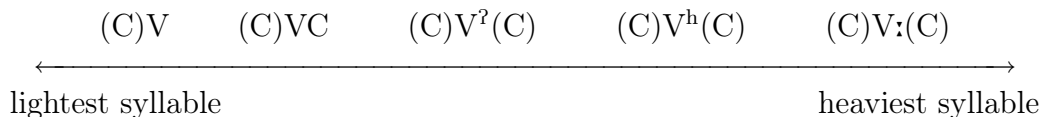
In summary, previous analyses have recognized a meaningful relationship between laryngeal features and vowels but have stopped short of an in-depth phonetic description or non-segmental approach to these phenomena. Similarly, no account acknowledges the intriguing symmetry in the [+sg] and [+cg] features and their parallel roles in vowel contrast.

2.3 Syllable structure and primary stress

According to Duff-Tripp (1997), syllables in Yánesha' contain exactly one vowel and may include a monosegmental onset and/or coda. Syllables without onsets only occur root-initially. Complex onsets and codas may arise across morpheme boundaries due to short modal vowel syncope (Duff-Tripp describes but does not provide a motive for syncope). In the event of syncope, three-part consonant clusters are permitted only if the first and third consonants are nasal, while the second consonant is non-nasal; for example, /monkon/ 'reed species' may lose its second vowel in /monkon-ahtʃ/ [monknahtʃ] 'reed stalk', but the cluster constraint prevents syncope in /monkon-maʔ/ [monkonmaʔ] 'reedbed', which would otherwise result in a four-part consonant cluster (Duff-Tripp 1997: 140).

The syllable weight scale, proposed by Duff-Tripp (1997), categorizes short, glottalized, aspirated, and long vowels as bearing distinct weights. She further suggests that, with few exceptions, the heaviest available syllable receives primary stress. Figure 1 shows my proposed adaptation of Duff-Tripp’s scale, which updates the terminology, replaces the binary distinction between strong and weak syllables with a syllable weight continuum, and reverses the placement of (C)VC and (C)V²(C) based on empirical findings (which will be discussed further in Sections 4 and 5). Excepting open versus closed short modal syllables, the scale implies that *vowel* weight, rather than *syllable* weight, dictates stress assignment.

Figure 1: Gradient syllable weight scale in Yánesha'



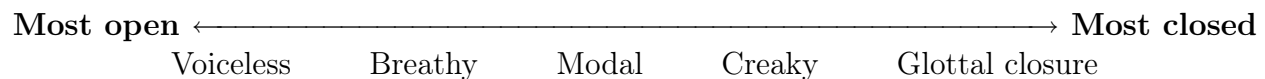
The Yánesha’ weight scale reflects discussions of scalar hierarchies and gradient weight scales that can take many forms cross-linguistically (Gordon, 1999; Ryan, 2011). Yánesha’

upholds the typological trends set forth by Ryan (2011), namely that in determining weight, the rhyme structure takes precedence over the onset structure, and that more “structure” (e.g., timing slots) and greater sonority correspond with greater weight. This last observation about sonority implies that aspiration (i.e., breathy voice) is more sonorous than glottalization (i.e., creaky voice). Miller (2012) observes that both breathy and creaky voices are indeed less sonorous than modal voice but draws no definitive conclusions as to their relative ranking. Finally, as Figure 1 demonstrates, codas do not contribute to weight distinctions between syllables with glottalized, aspirated, or long vowel nuclei.

2.4 Overview of phonation types

The first step in accurately categorizing Yánesha’s laryngeal features is determining their phonational nature. To this end, this section provides a brief overview of phonation as a basis for language-specific description in Section 4.1. Ladefoged (1971) defines the continuum of phonation types in terms of arytenoid cartilage aperture, with creaky voicing toward the closed end of the spectrum and breathy voicing toward the open end. The continuum is shown in Figure 2.

Figure 2: Continuum of phonation types (Ladefoged, 1971)



Gordon & Ladefoged (2001) note characteristic representations of these non-modal phonation types, such as the “relatively jagged appearance” in waveforms of breathy voicing due to turbulent airflow and noisy energy, and the “irregularly spaced pitch periods” that are characteristic of creaky voice (2). The authors also discuss the decreased acoustic intensity, lowered fundamental frequency, and (typically) increased duration of creaky and breathy voices as compared to modal voice, regardless of the duration of surrounding phones. This increased duration is partially attributable to non-modal asymmetrical spreading, in which non-modal voicing is realized in only a portion of an otherwise modal segment. In his examination of Jalapa Mazatec, Hupa, and Quileute, Gordon (1998) identifies the perceptual disadvantages of non-modal vowels, including formant lowering, masking of contrastive place information, and decreased amplitude. He thus suggests that non-modal asymmetrical spreading occurs so as not to impede the segment’s perceptual salience, and that languages with non-modal vowels are sensitive to a constraint requiring that some portion of vowel be modal (94).

Contrastive breathy and creaky vowels of any vowel quality are rare; by current measures, they are each represented in 1% of languages worldwide (Moran & McCloy, 2019).

3 Methods

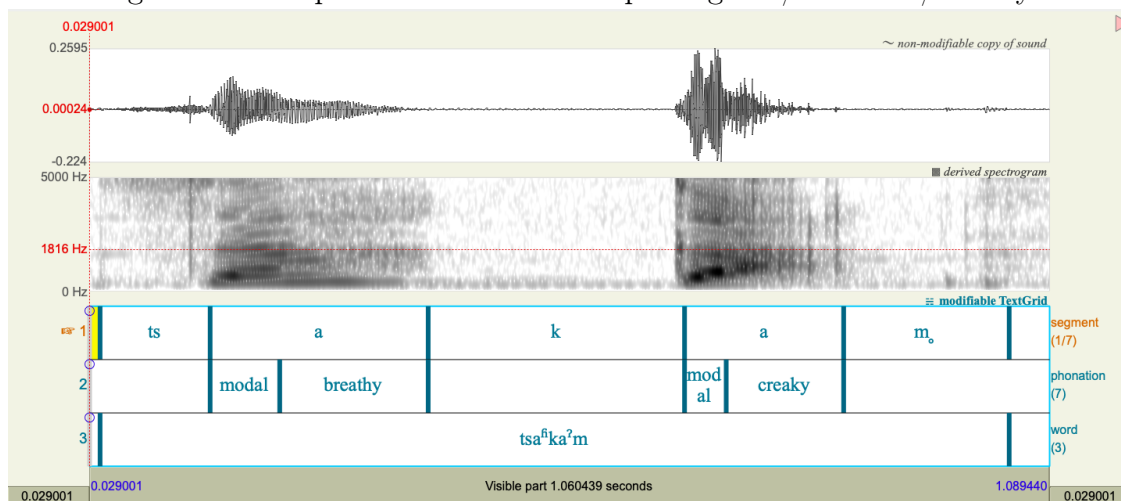
In this analysis, I weigh the evidence for and against three competing hypotheses, as outlined in Section 1. The data used for this analysis come from six recordings of elicited Yánesha' speech, including isolated words and short phrases. These unpublished recordings, ranging in length from 8 to 63 min, contain lexical elicitation conducted in 2011 by Dr. Tammy Stark in Tsachopén, a Yánesha' community near Oxapampa (Pasco region, Peru).³ All utterances are produced by a middle-aged Yánesha'–Spanish bilingual female (here referred to by her initials, JEO). Elicited topics include clothing, animals, body parts, colors, adjectives, and kinship terms.

Using Praat (Boersma, 2001), words from the recordings that contain perceptually salient cases of breathy, creaky, and modal voices were selected first to identify the speaker's range of phonations and compare visible characteristics from their waveforms and spectrograms. These words were manually parsed into segments, based on visual and auditory evidence. Words with less perceptible distinctions in phonation were then identified and segmented accordingly. If available, multiple iterations of the same word were selected to examine lexical consistency and variation concerning laryngeals (e.g., 45 words occur three times in the dataset, and one occurs nine times). Where possible, words were glossed, and contrastive vowel length was labeled according to Duff-Tripp (1998). In total, 298 words, entailing a total of 1,687 segments, were manually parsed and labeled.

Toward the goal of finding evidence for and against the three hypotheses, all vowels were parsed by quality on one tier (segmental tier) and by phonation type on another (phonational tier), and measured for duration, intensity, fundamental frequency, and first three formant frequencies. On the segmental tier, all consonants and vowels were manually segmented and labeled. On the phonation tier, vowels were sub-portioned and labeled by phonation (breathy, creaky, or modal), in accordance with Gordon and Ladefoged's (2001) phonation definitions. This multi-tier approach to vowels, exemplified in Figure 3, enabled the assessment of potentially laryngealized vowel segments, as well as their differing phonation portions. Meanwhile, the phonation tier, on which laryngeals are isolated, enabled the assessment of potentially free segments or consonant-affiliated phases. Contrastive versus natural (i.e., non-meaningful) breathiness and creakiness were later distinguished, based on a combination of phonemic representations in Duff-Tripp (1998), consistency, and contextual effects (e.g., utterance-final breathiness and utterance-initial creakiness).

Phonetic measures (intensity, f0, and formants) were extracted from the labeled segments and vowel portions using an original Praat script (Boersma, 2001). These measurements were extracted 20%, 40%, 60%, and 80% of the way through each segment, in addition to overall segment minimum, maximum, and mean. Further visualization with Matplotlib and Seaborn packages (Waskom, 2021; Hunter, 2007) and statistical analysis with lmerTest and lme4 (Kuznetsova et al., 2017; Bates et al., 2015) were conducted in Python and R, respectively. In relevant cases, a parametric t-test was used to compare the means. To

³Respectively, the six recordings are 8, 9, 16, 20, 50, 59, 63 minutes long, rounded to the nearest minute.

Figure 3: Example of multi-tier vowel parsing for /tʰa^hka^ʔm/ ‘firefly’

mitigate the potential effects of syllable structure and word length, a “control” subset of the data, entailing 100 instances of 33 CVCVC words, was examined in parallel to the full dataset. This bisyllabic structure is prevalent in the dataset and facilitates the comparison of two vowels in the same utterance. Results from the control and full datasets are comparable unless otherwise noted, and results from the full dataset are presented throughout the paper, unless explicitly mentioned.

Of course, one person’s elicited speech cannot account for the potential variation in laryngeal usage across Yánesha’. This imbalance in speech type, speaker, and geographical diversity was addressed to the greatest extent possible, provided limited available data at the time of the study.⁴ During a preliminary study, the aforementioned dataset was augmented by natural speech data from two additional recordings: one recording, carried out by Dr. Stark in the same community, features conversational speech by a middle-aged male speaker (LOV); the other recording contains narration by a male and a female speaker (here referred to as YOM and YOF, respectively), who tell the story of an important Yánesha’ ancestor (Bautista et al., 2008). Natural speech was analyzed according to the procedure outlined above. Notably, the natural and elicited data revealed very similar patterns in laryngeal production, across all examined phonetic characteristics. However, the natural speech data are lower in recording fidelity than the elicited speech data and do not amount to a large enough sample size to discern statistically significant patterns in the data. For these reasons, the following description and analysis draws on data from JEO alone. To illustrate the complete analyzed data (amounting to 1,908 segments in 345 words), all speakers are represented in full and control datasets, summarized in Tables 3 and 4, respectively. If, upon future examination of natural speech from a geographically varied speaker pool, laryngeal

⁴The limited available data was an unavoidable effect of stalled fieldwork due to COVID-19. The author has since collected high-quality audio data from native Yánesha’ speakers, during a 2022 field trip, which confirm the presented findings.

phenomena prove significantly different from those presented here, the current description will be duly corrected.

Table 3: Summary of counts in full dataset (data in current analysis are bolded)

Speaker	Speech type	Words	Segments	Asp. V	Glott. V	Modal V
JEO	Elicited	305	1,687	200	84	398
LOV	Natural	15	93	8	7	24
YOM	Natural	19	102	10	6	27
YOF	Natural	6	26	3	3	4

Table 4: Summary of counts in control dataset (data in current analysis are bolded)

Speaker	Speech type	Words	Segments	Asp. V	Glott. V	Modal V
JEO	Elicited	100	540	69	25	107
LOV	Natural	5	25	0	4	5
YOM	Natural	5	26	0	2	9
YOF	Natural	2	11	1	1	1

Lastly, it should be noted that this dataset was first compiled for aspirated vowels and later expanded to include glottalized vowels as well, so the greater quantity of aspirated vowels as compared to glottalized vowels reflects this earlier priority rather than any actual frequency discrepancy between the laryngeals.

4 Phonetic description

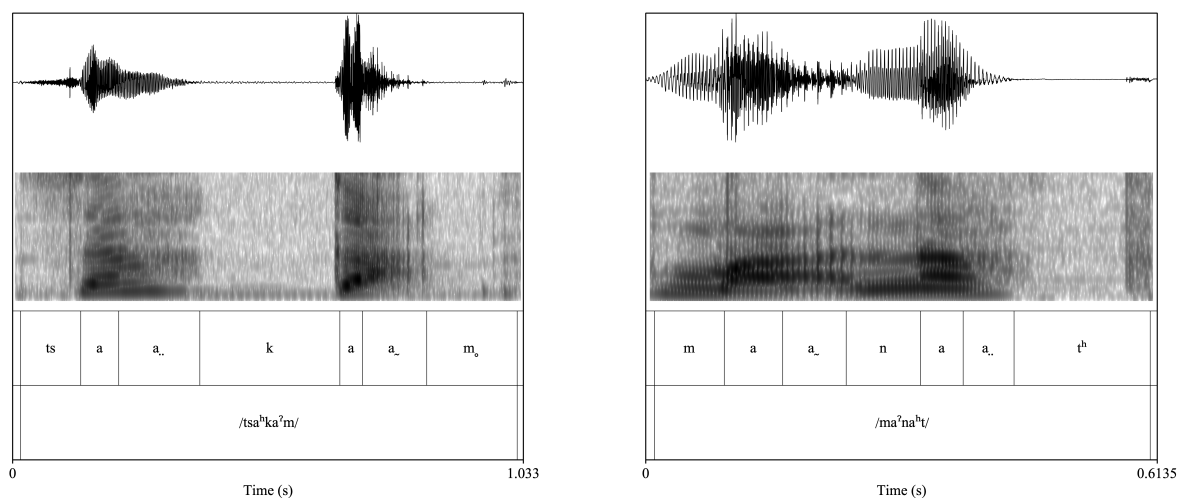
This section describes the phonetic properties of laryngeals that will help determine their appropriate phonological categorization. To begin with, Section 4.1 confirms the phonetic status of laryngeals as phonationally distinct phases, outlining the visual characteristics of modal, breathy, and creaky voicing. Section 4.2 presents the phonotactic behavior of laryngeals, which, while not strictly phonetic in nature, serves to contextualize subsequent findings from the data. The subsequent sections examine duration (Section 4.3), formants (Section 4.4), and intensity (Section 4.5), followed by a description of primary stress manifestation and its implications (Section 4.6).

4.1 Phonation

Yánesha’ exhibits modal, breathy, and creaky phonations, in accordance with Gordon and Ladefoged’s (2001) definitions. In Yánesha’, when breathy or creaky phonations arise, they

follow a modal phase of comparable vowel quality and roughly equal duration. Figure 4 displays waveforms and spectrograms of word-medial laryngeals in the words /tsa^hka[?]m/ ‘firefly’ and /ma[?]na^ht/ ‘s/he disappeared’. Whereas these and following phonological representations presume the vocalic affiliation of laryngeals (per the first hypothesis), the laryngeals are represented in isolation in the phonational tier, enabling evaluation of all hypotheses. Here, as the speaker transitions from modal [a] to breathy [a_h], a sudden drop in intensity is visible in the waveform, and an increase in aperiodic noise is visible in the spectrogram, aligning with the typological characterization of breathy voicing (Gordon & Ladefoged, 2001). In both cases, voicing is maintained until the closure of the following stop and the frication sounds distinctly glottal, characteristics that are consistent across all examples of fricated laryngeals – or breathy phases – in the dataset.

Figure 4: Waveform (top) and spectrogram (middle) of laryngealized vowels with manual segmentations (bottom) in /tsa^hka[?]m/ (left) and /ma[?]na^ht/ (right)



The creaky phases, [a_h], in Figure 4 exhibit low intensity and irregularly spaced impulses, as predicted by Gordon and Ladefoged (2001).⁵ Creaky voice in /ma[?]na^ht/ indicates necessary revision of Wise’s “vowel + glottal stop” description of glottalized vowels (Wise, 1958). Whereas one could argue that creakiness in /tsa^hka[?]m/ is a coarticulatory effect of a glottal stop between /a/ and /m/, in the many cases like /ma[?]na^ht/, where there is no visible or auditory evidence of a glottal stop, inherent creakiness is a more plausible explanation than glottal stop deletion with necessary creaky residue.

Word-final laryngeals are more varied than word-medial laryngeals, as seen in Figure 5. As compared to non-final phases, word-final breathy voicing may not show the same degree of jaggedness, creaky impulses may not be as spread as wide, and intensity may not exhibit

⁵Per the dataset, creaky phonation may also occur in sonorants adjacent to creaky vowel segments, but it does not do so with any regularity.

the sharp decrease for either laryngeal category. However, laryngeal phases remain audibly perceptible and visually distinct from word-final modal vowels. By comparing word-final [o] in /onta^hpo/ ‘at the river’ (5e) to word-final [ə] in /pona^h/ ‘scorpion’ (5a) and [a] in /tsa^htʃma^ʔ/ ‘forest, group of trees/sticks’ (5c), we get a sense of the differences in intensity, regularity, and periodic noise between modal and laryngeal voicing.

On occasion, creaky phases are followed by one or more voiceless glottal stop [ʔ], most commonly when occurring word-finally. Likewise, breathy portions may be followed by a voiceless glottal fricative [h]. In Figure 5, /pona^h/ (5b) and /tsa^htʃma^ʔ/ (5d) are seen again, this time with voiceless glottal segments following vocalic laryngeal phases; /pona^h/ features a voiceless fricative phase distinct from the preceding voiced phase, while /tsa^htʃma^ʔ/ exhibits a complete stop closure followed by a single pulse release. Glottal segments in this context are analyzed as allophonic continuations of the glottal gesture beyond the vowel, given their lexically inconsistent and infrequent nature, as well as the fact that they never occur if not preceded by a laryngeal. For reasons of clarity and phonational consistency, occurrences of [ʔ] and [h] are not included in the analysis of laryngeal phases.

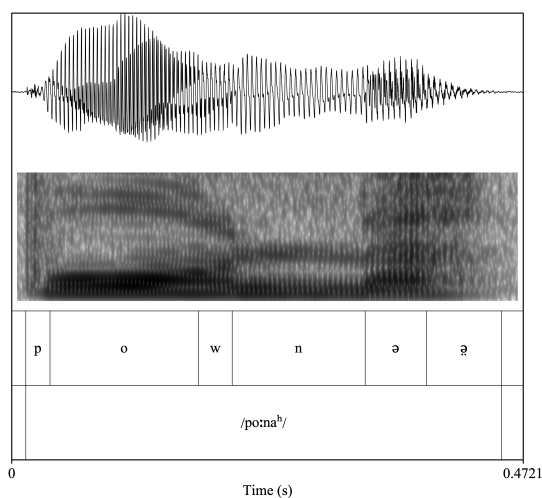
While many vowels surface as fully modal, vowels rarely surface as fully breathy or fully creaky (i.e., laryngeals rarely occur without a preceding modal phase). Only 4 of 200 potentially aspirated vowels are fully breathy, while 21 of 84 potentially glottalized vowels are fully creaky; in all these cases, purely laryngeal segments alternate with modal + laryngeal combinations. This trend suggests sensitivity to modal retention, as suggested by Gordon (1998). Fully laryngeal segments occur word-medially or -finally, and are more often unstressed than stressed. (One fully breathy vowel receives primary stress in a muttered utterance, and no fully creaky vowels receive primary stress.) In /korne^hʃa^ʔ/ ‘chief’ in Figure 5f, the final vowel /a^ʔ/ surfaces as the entirely creaky vowel [æ], without a preceding modal phase. It is possible that fully creaky segments are more common than fully breathy segments due to the decreased identifiability of vowel quality in breathy voice, as compared to creaky voice (Gordon & Ladefoged, 2001). Additionally, breathy voice may be more easily construed as quiet or whispered modal voice, and given its contrastive role, such perceptual ambiguity or construal would be undesirable.

Phonemically modal vowels occasionally exhibit vowel-initial laryngeal portions, typically at the onset of an utterance as speakers ramp up their vocalization. Instances of such vowel-initial laryngealization are not lexically consistent and show lower rates of intensity ($\bar{x}$ = 60.1 dB, SD = 4.5 dB for phonemically modal creaky phases; $\bar{x}$ = 52.6 dB, SD = 5.0 dB for breathy phases) and shorter durations ($\bar{x}$ = 84 ms, SD = 34 ms for creaky phases; $\bar{x}$ = 61 ms, SD = 27 ms for breathy phases), as compared to breathy and creaky voice in phonemic laryngealized vowels (intensity: creaky $\bar{x}$ = 62.8 dB, SD = 6.0 dB; breathy $\bar{x}$ = 64.4 dB, SD = 4.5 dB; duration: creaky $\bar{x}$ = 93 ms, SD = 36 ms; breathy $\bar{x}$ = 89 ms, SD = 38 ms).⁶

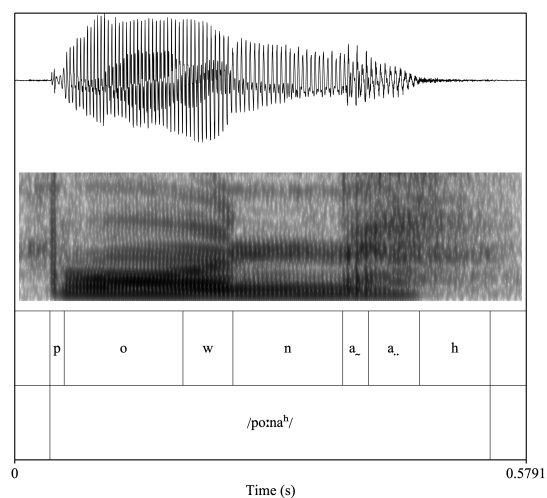
⁶Throughout the paper, ‘ $\bar{x}$ ’ denotes the mean and ‘SD’, the standard deviation.

Figure 5: Word-final vowels of various phonation types and phonetic realizations

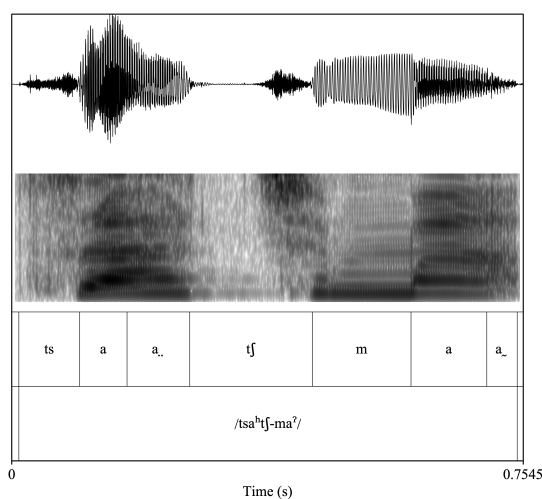
(a) Word-final breathy phase



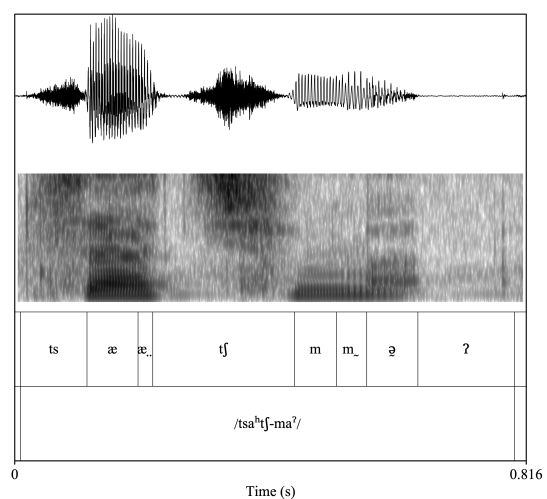
(b) Breathly phase + [h]



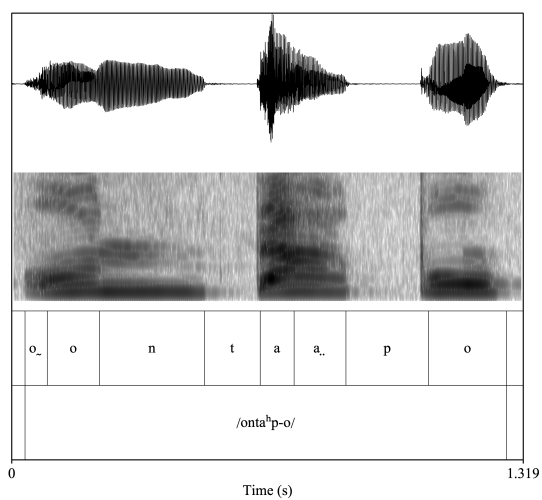
(c) Word-final creaky phase



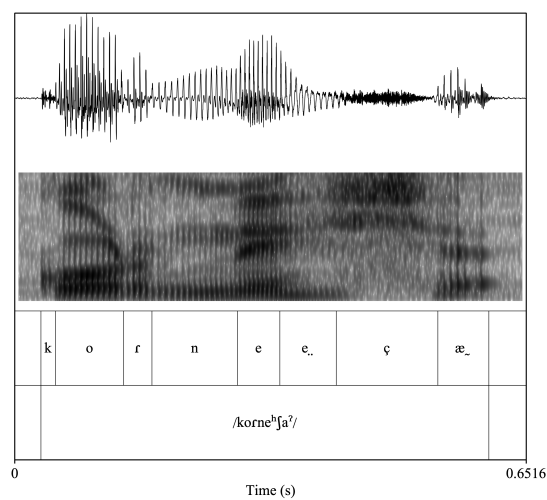
(d) Creaky phase + [ʔ]



(e) Word-final modal vowel



(f) Fully creaky vowel



4.2 Phonotactics

All phonemic vowel qualities /a, e, o/ and their respective allophones can precede breathy and creaky phases of equivalent quality (including [ə] in unstressed vowels). Laryngeals may occur word-medially or -finally following a modal phase and preceding a consonant, while hypothetical laryngealized vowels may occur word-initially, -medially, or -finally, after any consonant. Creaky phases can occur before any consonant (with the exception of retroflex affricates, which are unattested). The dataset reflects 38 occurrences of creaky phases before plosives, 14 before nasals, 8 preceding affricates, 4 before fricatives, 4 before approximants, 1 preceding a tap, and 19 word-finally. On the other hand, breathy phases do not precede approximants, and are less frequent preceding sonorants (in the dataset, there are only four pre-lateral occurrences based on one root *ta^hɬem* ‘finger’ with varied possessive prefixes, and no pre-nasal or pre-tap occurrences). The dataset reflects 64 occurrences of breathy phases before fricatives, 53 preceding plosives, 48 before affricates, and 31 word-finally. It is worth noting, however, that Duff-Tripp’s dictionary includes examples of aspirated vowels preceding nasals and taps. Table 5 exemplifies the possible post-laryngeal consonants by natural class. Examples attested in Duff-Tripp (1998) but not in the current dataset are indicated with an asterisk (*).

Table 5: Laryngeals by following phonological environment

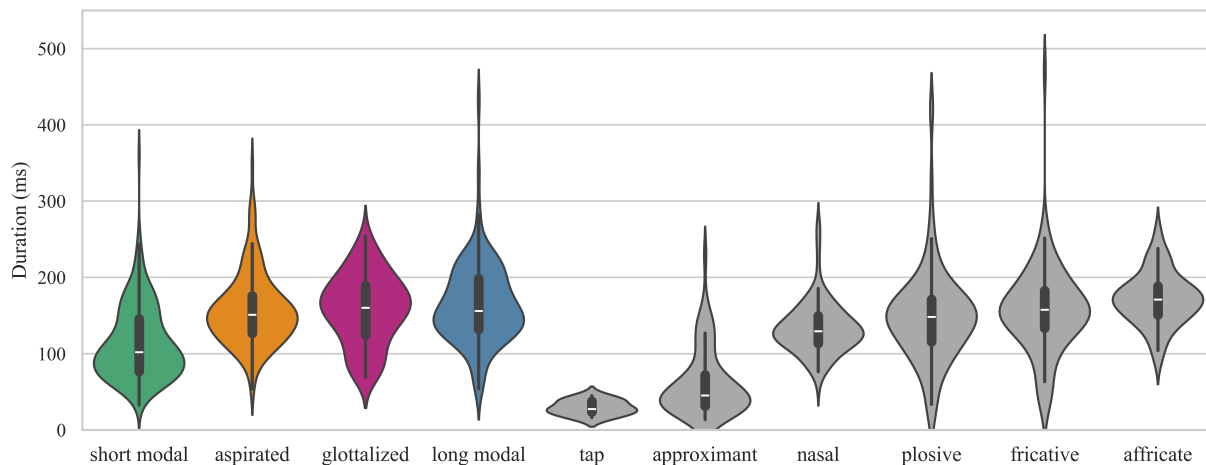
	Breathy phases	Creaky phases
Pre-plosive	/ma ^h poz/ ‘fly (insect)’	/ne-tsa [?] p/ ‘my face’
	/j-a ^h to [?] jo:s/ ‘our grandfather god’	/eso [?] t/ ‘what’
	/tsa ^h ka [?] m/ ‘firefly’	/tʃa [?] k/ ‘ant species’
Pre-affricate	/a ^h ts-erts/ ‘mud’	/po [?] -tsom/ ‘his/her light’
	/tsa ^h tʃ/ ‘wood, tree, stick’	/o [?] tʃ/ ‘irrealis auxiliary’
	/koja:nef-a ^h tʃno ^h / ‘different women’	<i>unattested</i>
Pre-fricative	/n-a ^h s/ ‘my tooth/molar’	/po [?] -sep/ ‘his daughter’
	/enka:ne ^h ʃa [?] / ‘man’	/pa [?] -ʃet:ʃep/ ‘his/her fingernail’
	/a ^h zo:z/ ‘moon’	* /a [?] zo:tʃe [?] t/ ‘slide/move’
Pre-nasal	* /tsa ^h m-a ^h t/ ‘wash clothes (causative)’	/tsa ^h ka [?] m/ ‘firefly’
	* /a ^h n/ ‘fly (verb)’	/ko [?] nes/ ‘manioc beer’
	<i>unattested</i>	/p ^w e [?] -nar/ ‘his/her grandson’
Pre-approximant	<i>unattested</i> ⁷	/ma [?] ja:r/ ‘tiger’
Pre-tap	* /apa ^h re [?] t/ ‘feel ones way in the dark’	/ʃa [?] rep/ ‘lizard’
Pre-lateral	/ta ^h ɬem/ ‘finger’	/wara [?] ɬ/ ‘big butterfly’
Word-final	/mare ^h / ‘mosquito’	/enka:ne ^h ʃa [?] / ‘man’

⁷I have no conclusive explanation for the lack of pre-approximant aspirated vowels, other than to note that in general, aspirated vowels are less common before sonorants, and might be sensitive to the high sonority of glides /j/ and /w/.

4.3 Duration

By and large, breathy and creaky phases pattern similarly in terms of their durational relationships to surrounding segments and phonation types. In this section, I first examine the durational relationships under the assumption that laryngeal phases are part of the vowel segment (aspirated and glottalized vowels, respectively) and then as their own entities (breathy and creaky phases, respectively). To begin with, Figure 6 summarizes the durations of all segments in the dataset. The consonants are grouped by natural class, while the vowels, by contrastive vowel type. This figure shows data from word-medial items only, with the understanding that word-medial examples are least affected by word-initial and word-final effects on duration. We see that aspirated vowels ($\bar{x} = 157$ ms; $SD = 47$ ms) and glottalized vowels ($\bar{x} = 158$ ms; $SD = 46$ ms) are similar in length to long vowels ($\bar{x} = 165$ ms; $SD = 53$ ms), as well as the obstruent categories: plosives ($\bar{x} = 148$ ms; $SD = 61$ ms), fricatives ($\bar{x} = 156$ ms; $SD = 58$ ms), and affricates ($\bar{x} = 172$ ms; $SD = 35$ ms). The large upper range of short modal vowels ($\bar{x} = 114$ ms; $SD = 48$ ms) is attributable to inconclusive contrastive length marking, due to the fact that not all utterances are attested in previous materials depicting contrastive length.

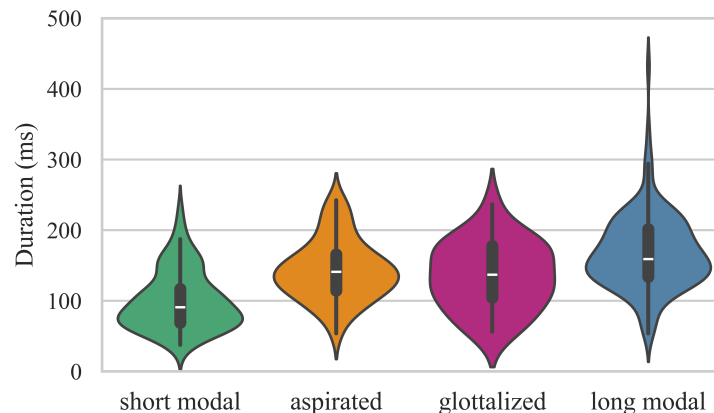
Figure 6: Segment duration by natural class (word-medial only)



Because contrastive vowel length could not be assessed in all words, a subset of 127 instances of 45 different words, for which phonemic vowel length has been previously established (Fast, 1953; Wise, 1958; Duff-Tripp, 1997, 1998), were analyzed to determine contrastive length ratios. Per this subset, 86 short vowels ($\bar{x} = 100$ ms, $SD = 42$ ms) and 133 long vowels ($\bar{x} = 168$ ms, $SD = 54$ ms) result in a short:long vowel ratio of 1:1.68. Modal vowel durations were also compared to laryngealized vowel durations, revealing durational similarities between long modal and laryngealized vowels. The durations of glottalized ($\bar{x} = 158$ ms; $SD = 46$ ms) and aspirated vowels ($\bar{x} = 157$ ms; $SD = 47$ ms) are not significantly different from one another ($t(35) = 0.2$, $p = 0.863$), nor do glottalized and long vowel durations show a significant difference ($t(32) = 1.5$, $p = 0.13$) (Kuznetsova et al., 2017).

Aspirated vowels are significantly shorter than long vowels, though the difference is quite small ($t(145) = 2.4$, $p = 0.019$). All three vowel types differ significantly in duration when compared to short modal vowels ($p < 0.001$ in all three cases). Figure 7 summarizes the relative durations of the contrastive vowel types. As depicted here, long vowels alone feature few but notable instances of extreme length, where the vowel exceeds 300 ms. The combination of phonological length and articulatory uniformity (i.e., no need for a durational balance across multiple phonations) may mean that the upper durational limit for long vowels is not as strict as, for example, its lower durational limit.

Figure 7: Vowel duration by contrastive vowel type (established length subset only)



When considered separately from modal vowel phases, laryngeal phases are also durationally comparable to one another. Both creaky and breathy phases are, on average, slightly longer than the preceding modal phase of a given vowel. When phonemic aspirated and glottalized vowels are entirely non-modal (i.e., creaky and breathy phases account for the entire vowel segment), the laryngeal phases are closer in length to short modal vowels than long modal vowels. Fully creaky and breathy phases only occur in unstressed vowels in word-medial or -final positions and are far less frequent than biphonational vowels. In every case, biphonational vowels are evidenced in other instances of the word and are thus considered the canonical forms of laryngealized vowels.

Crucially, pre-laryngeal modal phases are significantly shorter than short modal vowels. In particular, the difference between pre-breathy modal phases and fully modal vowels is significant ($t(139) = 3.6$, $p < 0.001$), as is the difference between pre-creaky modal phases and fully modal vowels ($t(36) = 2.8$, $p = 0.008$) (Kuznetsova et al., 2017). These modal phases are compared in Figure 8, along with a summary of phonation-specific durations in Table 6.

Under an analysis in which laryngeal phases are considered their own separate segments, they exert a clear shortening effect on preceding modal vowels. To test the plausibility of such an effect, short modal vowel duration was further examined to see if any class of following consonants had a similar effect. Interestingly, short modal vowels preceding approximants

Figure 8: Comparison of modal phase durations in laryngealized and short modal vowels

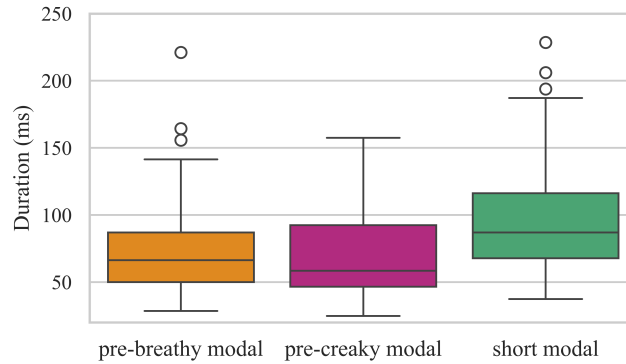


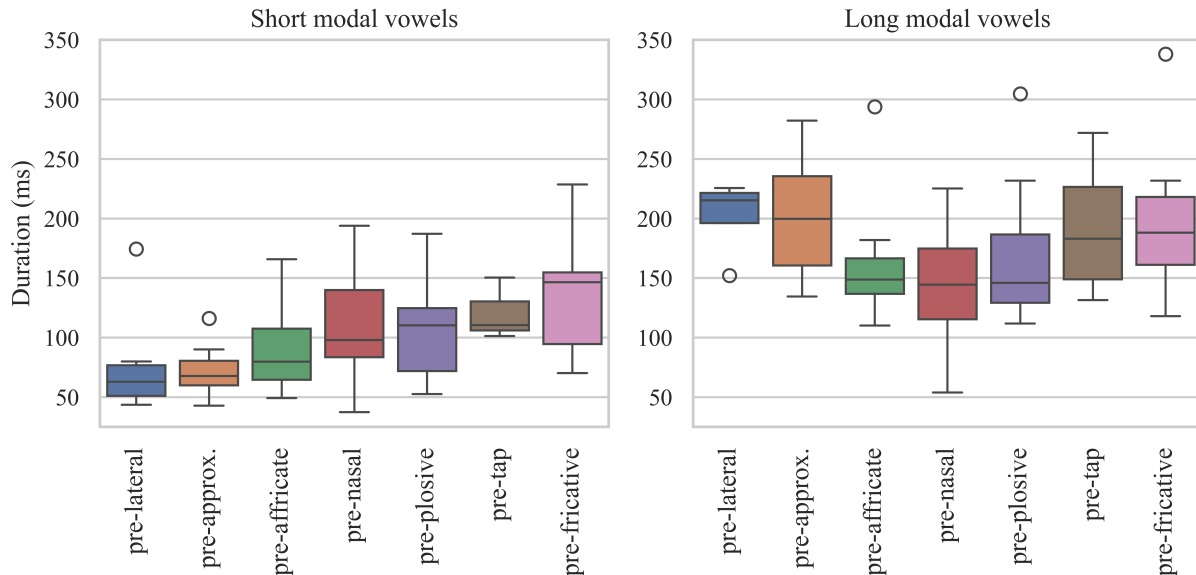
Table 6: Duration by phonation portion

Phonation portion	Mean	SD	Count
pre-creaky modal portions	75 ms	34 ms	64
pre-breathy modal portions	77 ms	29 ms	183
breathy portions	89 ms	38 ms	183
creaky portions	91 ms	33 ms	64
short modal vowels	100 ms	42 ms	86
fully creaky phases	103 ms	41 ms	21
fully breathy phases	116 ms	72 ms	4
long modal vowels	168 ms	54 ms	133

($\bar{x} = 72$ ms, $SD = 23$ ms) and laterals ($\bar{x} = 77$ ms, $SD = 45$ ms) are comparable in length to the modal phases preceding breathy and creaky phases, as shown in the left panel of Figure 9. It is worth noting, however, that short modal vowels preceding plosives ($\bar{x} = 106$ ms, $SD = 39$ ms) and fricatives ($\bar{x} = 136$ ms, $SD = 56$ ms) are substantially longer than pre-laryngeal modal phases; were breathy and creaky phases considered consonants (fricatives and plosives, respectively), they would greatly skew the vowel durations preceding their respective natural classes. Additionally, consonant natural classes have a starkly different effect on the duration of preceding long modal vowels, as shown in the right panel of Figure 9. The fact that pre-approximant and pre-lateral long vowels show the greatest durations, as compared to long vowels in other environments, implies that approximants and laterals do not demonstrate the uniform durational effect on modal phases seen with laryngeals. In the case of approximants, it is worth noting the possibility of inconsistent measurements, given that approximant–vowel transitions lack the distinct boundaries seen in vocalic transitions with other consonant classes.

The vowel shortening behavior of laryngeal phases could alternatively be considered coda-driven compression, a common crosslinguistic phenomenon in which the presence of a coda (potentially including laryngeals) shortens the preceding nucleus. To test the plausibility of

Figure 9: Comparison of modal vowel duration by length and following natural class



this argument, short modal vowels in closed syllables (specifically, in C_CC contexts) were compared durationally to pre-laryngeal modal phases. The nine relevant instances from the dataset measured 93 ms on average ($SD = 25$ ms), comparable to the 100 ms average duration of short modal vowels overall, and substantially longer than pre-laryngeal modal phases, as shown in Table 6. While a larger sample is required to confirm this trend, laryngeal-triggered vowel shortening appears to be unrelated to the trivial shortening of closed vowels in the language.

4.4 Formants

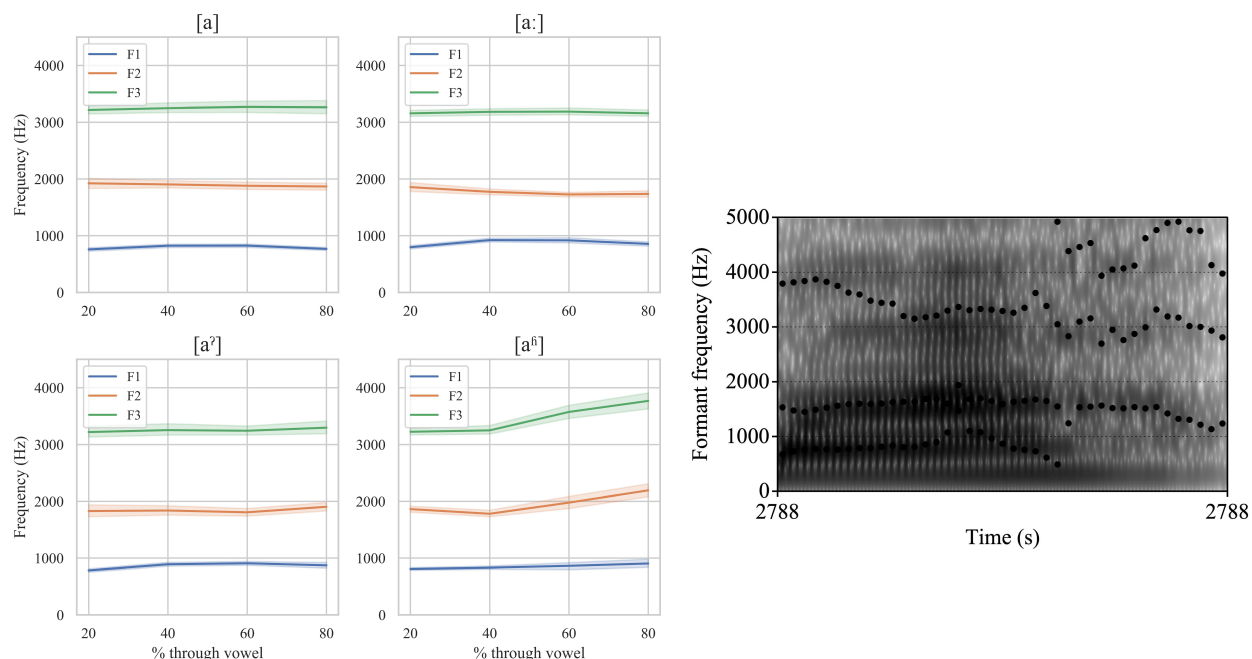
Per the current dataset, laryngeal phases largely maintain the formants of the immediately preceding modal phase. Given this finding, formants are here analyzed by contrastive vowel type, such that laryngeals are part of the vowel.⁸ Notably, formants behave similarly across all contrastive vowel types.⁹ For all vowel qualities, formants 1, 2, and 3 are primarily stable over the course of the vowel, reflecting occasional minor frequency shifts in long, glottalized, and aspirated vowels. Sustained formants across all vowel types are demonstrated in the spectrograms in Section 4.1. However, Praat’s formant tracker is significantly skewed by aperiodic noise, such that it predicts rising formants over the course of aspirated vowels.

⁸Laryngealized vowels were measured from the onset of the modal portion to the offset of the laryngeal portion.

⁹Fundamental frequency (as a proxy for pitch) was also considered in the frequency analysis, but did not play a meaningful role in discerning the status of laryngeals. For all contrastive vowel types, f_0 trends slightly upward from vowel onset to offset.

Aspirated vowels have been visually examined to ensure that formants do not, in fact, reveal significant change. Instead, Praat’s formant tracker registers a false increase in formant measures 40-60% of the way through aspirated vowels, due to the addition of aspiration (i.e., aperiodic noise) which regularly exhibits higher frequency than purely modal voice (Harrison, 2013). As such, Praat does not output the most accurate formants for breathy voice but lends support to its accurate categorization as breathy. Figure 10 shows aggregate formant measures of the vowel quality /a/ across all four contrastive vowel types and exemplifies the formant tracker’s reaction to aspirated vowels. The vowel quality /a/ was chosen for its largest sample size, but is representative of trends across all vowel qualities.

Figure 10: Formant change by vowel type (left) and Praat formant reading of /a^h/ in /ma^hp^we/ ‘stone’ (right)

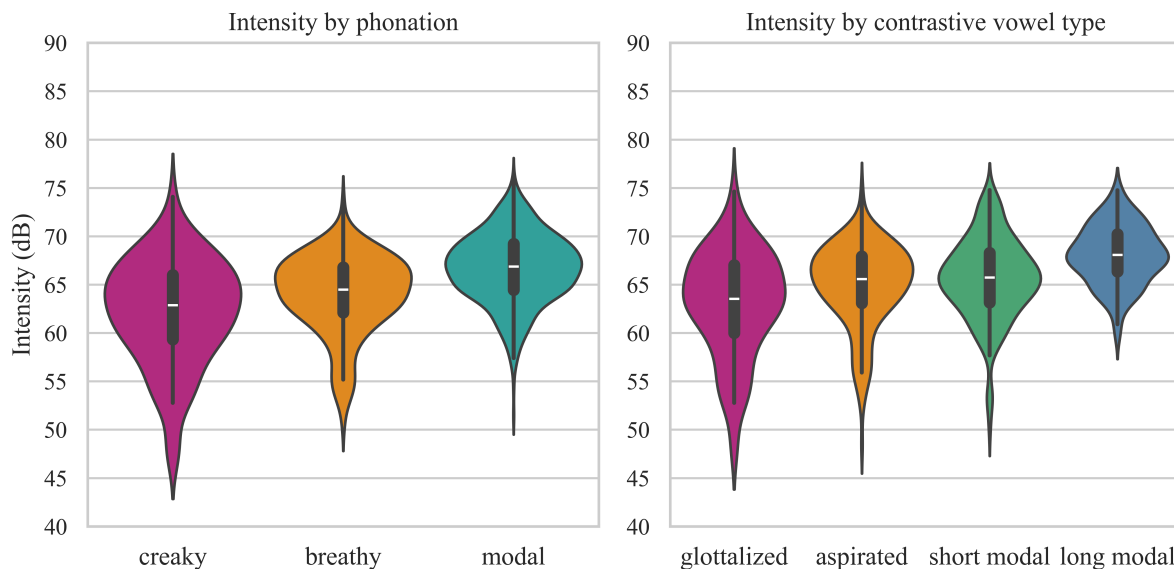


4.5 Intensity

In keeping with Gordon and Ladefoged’s (2001) predictions, both types of laryngeals demonstrate reduced intensity, as compared to modal vowels. Creaky phases average an intensity of 62.2 dB (SD = 5.4 dB), while breathy phases average 64.0 dB (SD = 4.1 dB). By comparison, modal phases are 66.7 dB on average (SD = 3.6 dB). All three phonations differ significantly in intensity from one another.¹⁰ Likewise, at the contrastive vowel level, glottalized vowels

¹⁰Creaky intensity compared to modal intensity: $t(93) = 7.5$, $p < 0.001$. Breathy versus modal intensity: $t(293) = 8.4$, $p < 0.001$. Breathy versus creaky intensity: $t(125) = 2.8$, $p = 0.006$.

Figure 11: Intensity by phonation and contrastive vowel type



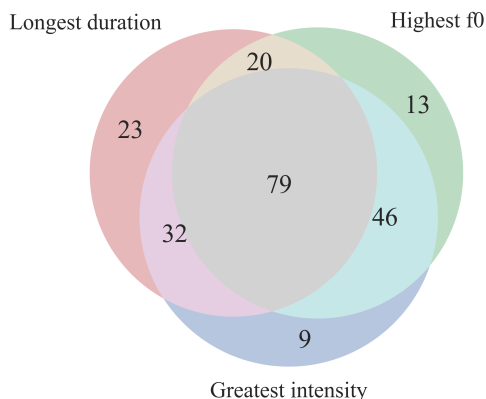
are less intense than aspirated vowels, which are less intense than short and long modal vowels. Such trends are captured in Figure 11. Notably, creaky phases and glottalized vowels show the greatest range and standard deviation in intensity.

4.6 Primary stress effects

Duff-Tripp asserts that prosodic accent in Yánesha' corresponds with greatest intensity and highest pitch (1997:152). To confirm the phonetic expression of primary stress, three common indices (Fry, 1955, 1958) were considered: intensity (as a proxy for amplitude), fundamental frequency (as a proxy for pitch), and duration. 231 stressed vowels were then compared to unstressed vowels in the same utterance to see whether the former exhibited consistently higher measures of intensity, f_0 , or duration.

This comparison showed that in Yánesha', primary stress mainly manifests as the vowel segment with the greatest average intensity. In the control dataset (in which all words feature a CVCVC structure), 76% of stressed vowels exhibit the greatest average intensity of all vowels in the word, while 72% exhibit the highest intensity spike (72% and 71% respectively in the full dataset). Primary stress corresponds to highest average f_0 in 67% of the words considered (68% in the full dataset), but to longest duration in only 55% of these cases (66% in the full dataset). The Venn diagram in Figure 12 shows that, in many cases, stressed vowels are superlative in more than one phonetic category. Only 7 of 231 stressed vowels are not superlative in at least one category. It should be noted that the high count of longest vowels is impacted by the fact that contrastively long vowels are common recipients of primary stress, as discussed further below.

Figure 12: Phonetic expression of primary stressed vowels



With the phonetic manifestation of stress determined, an important pattern is confirmed: the loudest, highest, and/or longest vowel in a given word is also the heaviest contrastive vowel type. This finding offers phonetic confirmation that primary stress is assigned based on vowel weight, in keeping with the weight scale in Figure 1; however, the data suggest a crucial amendment to Duff-Tripp's (1997) stress assessment: primary stress is morphologically sensitive. For example, when possessive prefixes [ne^h] 'my' or [pa^ʔ] 'his/her' attach to noun roots with short modal vowels, as in [ne^h-sér] 'my bracelet' or [pa^ʔ-ták] 'his/her paw', the short modal vowel consistently receives primary stress, despite its lower position in the vowel weight hierarchy. By contrast, verbs appear to host primary stress on the overall heaviest vowel, whether root-internal or affixal; verbs marked by imperfective [e:n], such as [n-e^htʃ-é:n] 'I have', exhibit primary stress on the long vowel, despite its suffixal status.

In Table 7, sample words show that primary stress (indicated in bold) occurs on the heaviest available vowel.¹¹ As shown in words like /'pa^h.tʃer/ and /'tsa^h.ka^ʔm/, primary stress does not favor closed syllables, nor does it favor a particular position (e.g., /'pa^h.tʃer/ versus /ma.'re^h/). If all vowels have the same weight, stress is ultimate by default. This stress hierarchy was found to be systematic and robust, both in Duff-Tripp (1997) and the current data.

As we saw in Section 4.5, average intensity differs significantly by phonation, with modal phases showing greater intensity than breathy phases, which are more intense than creaky phases. However, because high intensity is correlated with primary stress and laryngeal phases have lower amplitude than modal phases, glottalized and aspirated vowels have the greatest potential change in intensity when stressed versus unstressed. Indeed, the data reflect this pattern, as seen in Figure 13. In particular, we see the biggest shift in intensity

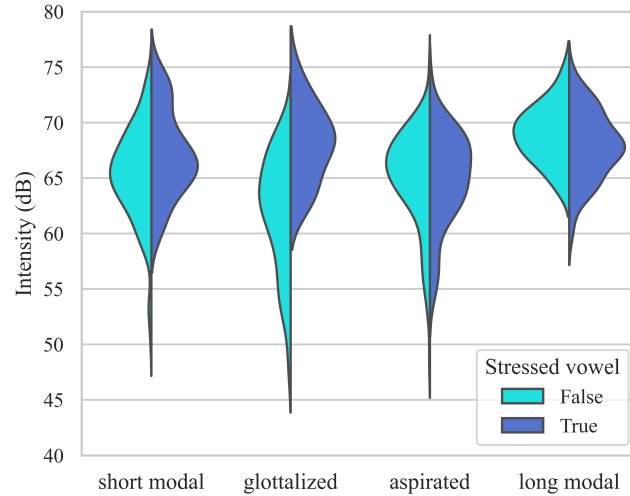
¹¹Potential distinctions by syntactic class require further research, as the current word pool is heavily nominal.

Table 7: Primary stress hierarchies by vowel weight

	DISYLLABIC ROOTS	TRISYLLABIC ROOTS	ROOT-INTERNAL STRESS
$V < V^?$	/ko.tʃa [?] m/	<i>unattested</i>	/po [?] -.tsom/
$V < V^h$	/pa ^h .tʃer/ /ma.re ^h /	/kor.ne ^h .ʃa [?] /	/ne ^h -.tak/
$V < V:$	/o:.tʃek/	/ʃe.ma:.ʃer/	<i>unattested</i>
$V^? < V^h$	/tsa ^h .ka [?] m/	/kor.ne ^h .ʃa [?] /	/ne ^h -.tsa [?] p/
$V^? < V:$	/ma [?] .ja:r/	/je-.na:.ne ^h .ʃa [?] /	<i>unattested</i>
$V^h < V:$	/tsa:.pa ^h tʃ/	/je-.na:.ne ^h .ʃa [?] /	/a ^h .ts-e:ts/
ultimate stress	/a.jon/	/a.ran.kom/	<i>unattested</i>

between unstressed and stressed glottalized vowels. Interestingly, stressed modal vowels are somewhat less intense than their unstressed counterparts, although the average intensity of long modal vowels is, unsurprisingly, greater than other contrastive vowel types.

Figure 13: Intensity of stressed and unstressed vowels by contrastive type



Because laryngealized vowels are biphonational, one possible explanation for the intensity differences seen in Figure 13 is that the modal portion of laryngealized vowels compensate (i.e., increase in intensity to surpass short modal vowel intensity) in stressed environments. If we look within laryngeal phases by stress context, however, we see that creaky and breathy voices react differently to stress. As shown in Table 8, creaky phases – the least intense phonation overall – shift notably in intensity depending on primary stress; the upper range of these intensity scores correlates with stressed contexts, while the lower range correlates with unstressed contexts. Breathy phases, on the other hand, maintain or decrease in intensity in stressed contexts. Meanwhile, pre-laryngeal modal phases show greater intensity in stressed vowels, as compared to unstressed vowels.

Table 8: Intensity in stressed and unstressed vowels by phonation type

Phonation	Environment	Mean	SD
Pre-creaky modal phases	In stressed vowels	69.0 dB	3.4 dB
	In unstressed vowels	65.6 dB	3.2 dB
Pre-breathy modal phases	In stressed vowels	66.6 dB	3.5 dB
	In unstressed vowels	65.8 dB	3.6 dB
Creaky phases	In stressed vowels	67.4 dB	3.6 dB
	In unstressed vowels	64.2 dB	4.1 dB
Breathy phases	In stressed vowels	63.7 dB	4.0 dB
	In unstressed vowels	63.8 dB	4.0 dB

4.7 Phonetic summary

In this section, we have seen that Yánesha' exhibits three distinct phonations: modal, breathy, and creaky voicing. Phonotactically speaking, we saw that these phonations occur in a lexically predictable fashion; modal phases consistently precede laryngeal phases, which can precede most or all consonants (creaky phases are more common before sonorants than are breathy phases) across multiple iterations of certain words. We also saw that, as compared to preceding modal phases, laryngeal phases show decreased intensity (especially creaky phases), sustained formants, and slightly greater duration. When laryngeal phases are considered in conjunction with preceding modal phases as aspirated and glottalized vowels, phonetic trends are upheld, with the crucial difference that aspirated vowels receive primary stress over glottalized vowels, in almost all cases.

5 Phonological analysis

Having established the phonetic characteristics of Yánesha' laryngeals, we now turn to an analysis of their phonological features and associations. Section 5.1 establishes the association of laryngeal phases to preceding vowels, as opposed to following consonants or free-standing segments. Subsequently, Section 5.2 provides a subsegmental account of laryngealized vowels, following Q-theory (e.g. Inkelas & Shih, 2014).

5.1 Support for the vocalic association of laryngeals

In this section, I evaluate the evidence for and against each of the hypotheses stated in Section 1 and synthesized as follows:

- (1) Laryngeals are features associated with the following consonant segment.
- (2) Laryngeals are free-standing glottal segments, /h/ and /ʔ/.

- (3) Laryngeals are features associated with the preceding vowel segments.

The hypotheses are addressed in order of least to greatest plausibility. Ultimately, I show that laryngeal phases are associated with the preceding vowel, ruling out their association to the following consonant or their potential status as free-standing segments. Furthermore, I argue that glottalization and aspiration are phonologically meaningful components of the vowels in which they occur. This analysis is supported by phonotactic behavior, durational patterns, and interactions between syllable weight and primary stress.

5.1.1 Evidence against consonantal association (pre-laryngealized consonants)

The association of laryngeals to pre-aspirated and pre-glottalized consonants predicts that laryngeals should never occur word-finally, in the absence of a subsequent consonant. However, as demonstrated in Sections 4.1 and 4.2, both breathy and creaky phases occur word-finally. Moreover, word-final laryngeals can form minimal pairs, (e.g., *t̚soh* ‘species of edible tuber’ versus *t̚so* ‘consecutively’), indicating that they are not merely a phonetic biproduct of tapering off speech at the end of a word or utterance.

Despite the persuasive evidence of word-final laryngeals, the possibility remains that word-medial laryngeals are associated to consonants in Yánesha’, as a phonologically distinct category of laryngeals. The fact that word-initial and -medial laryngeals are always pre-consonantal (as described in Section 4.2) renders this possibility worth exploring. In the case of creaky phases, the crosslinguistic rarity of pre-glottalized consonants, paired with the distributional facts, offers no substantive support for pre-glottalized consonants in Yánesha’. On the other hand, pre-aspirated consonants are more commonly reported crosslinguistically than are post-aspirated vowels. For this reason, I here consider the similarities and differences between pre-consonantal frication in Yánesha’ and other languages to determine whether Yánesha’ diverges from or is consistent with typological trends in pre-aspiration.

The term *aspiration* has historically encompassed a range of varied definitions whose essential component is the wide opening of the vocal folds in relation to a constriction (Ladefoged & Maddieson, 1996). Timing and voicelessness are also crucial features; post-aspiration is characterized by “a period of voicelessness after the release of an articulation, and before the vocal folds start vibrating” (p. 69) whereas pre-aspiration is “a period of voicelessness at the end of the vowel, nasal, or liquid preceding the onset of the stop closure” (p. 70). Provided its relation to constrictions, aspiration is, strictly speaking, a property of consonants, most commonly obstruents. Indeed, apart from Yánesha’ (as far as I know) vocalic phenomena have only been termed ‘aspirated vowels’ in Ch’ol (Mayan) (Attinasi, 1973; Coon, 2016).¹² Silverman (2003) defines *pre-aspiration* as a period of voicelessness or a burst of turbulent air preceding the closure of a stop. Other accounts cast a broader net of possible pre-aspirated consonants, including all fricatives, affricates, and nasals (Ladefoged &

¹²For such vowels to truly qualify as ‘aspirated’, the definition would need to be revised to a wide opening of the vocal folds in relation to comparatively narrower opening of the vowel folds. That said, I will leave this terminological can of worms for another paper.

Maddieson, 1996). Voicelessness is due to a lack of a downstream noise source, though some voicing may survive due to the resonant properties of the vocal tract. He also notes that pre-aspiration does not mirror post-aspiration, the former being less perceptually salient and (perhaps consequently) less stable diachronically; pre-aspiration often shifts to pre-spirantization (i.e., strengthening) or vowel lengthening (weakening), surviving primarily in stressed syllables, thanks to the boost in acoustic prominence. As such, pre-aspiration is uncommon cross-linguistically and not shown to be phonemic in any language. Velar, palatal, or even labio-dental frication are often termed pre-aspiration (Czarnecki, 2013; Silverman, 2003; Stevens & Hajek, 2004c), although Silverman's definition excludes all but glottal frication. With concern to these characterizations, it is worth noting that Yánesha' aspiration regularly precedes obstruents, making it a good candidate for pre-aspiration. However, pre-obstruent aspiration in Yánesha' is distinct from reported cases of pre-aspiration in that it is consistently voiced. Furthermore, past and current analyses of Yánesha' aspiration support its contrastive contribution, which contradicts standard characterizations of pre-aspiration.

Among the best-known examples of pre-aspiration are Icelandic, Scottish Gaelic, and Faroese (Ladefoged & Maddieson, 1996). Tarascan, Eastern Ojibwa, Cree, Hopi, Southern Paiute, and Mazatec pattern similarly, as well as two Arawakan languages: Guajiro (also called Wayuu) and Chamicuro (according to Ladefoged & Maddieson, 1996; Silverman, 2003). Notably pre-aspiration does not occur word-initially in any of these languages, with the exception of Mazatec, so the fact that aspiration is never word-initial in Yánesha' does not alone exempt it from pre-aspiration status. Evidence from Guajiro (Arawakan) implies diachronic shift away from pre-aspiration; Holmer (1949) states that, at the time of his investigations, many speakers no longer pre-aspirated, and Maddieson and Disner (1984) note only sporadic occurrences of a "breathy voiced offset to a vowel that was followed by a long stop" in the one speaker examined, further concluding that pre-aspiration does not (at least currently) contribute to phonological contrasts (p. 406). The description, however, is not thorough enough to classify the frication's association to consonants versus vowels. Interestingly, Silverman (2003) includes Chamicuro (Arawakan) as a textbook case of pre-aspiration, and nods to a similar phenomenon in Yánesha'; however, his categorization is based on Parker's (1994) phonological analysis (discussed in Section 6.2) and Payne's (1991) proto-Arawakan reconstruction, both of which categorize /h/ as segmental, not pre-aspirational. Silverman notes that, in Chamicuro, "plain stops" pre-aspirate when the proceeding syllable is stressed (p. 588). Not only does pre-aspiration seem irrelevant to stress in a different syllable, but this pattern suggests a similar correlation between laryngealized vowels and stress assignment to that seen Yánesha'.

In summary, Yánesha' word-medial aspiration fits the phonotactic norms of pre-aspiration (i.e., it precedes obstruents) but differs in its voicing and contrastive nature. Furthermore, a categorization of breathy phases as pre-aspiration would ignore significant symmetries between the two laryngeal features, provided that pre-glottalization is not a widely attested phenomenon crosslinguistically.

5.1.2 Evidence against free-standing segments

If breathy and creaky phases differed notably from one another in their phonetic and phonotactic behavior, such differences might imply their association to distinct segment groups, provided that distinct segments are liable to pattern together and differ in a variety of ways. In such a case, segmental /h/ and /ʔ/ would be worth considering. However, Yánesha' breathy and creaky phases both appear consistently after modal phases (word-medially and -finally), both maintain the formants of those modal phases, are both similar in length and less intense than preceding modal phases, and both occur before (almost) any consonant – to name just a few of their parallel characteristics. In sum, no positive evidence from notably different behavior between breathy and creaky phases was found in support of the segmental hypothesis.

Conversely, significant negative evidence was found from phonotactic behavior. Yánesha' laryngeals pattern differently from phonemic consonants in ways that render their status as independent segments implausible. Were they considered autonomous glottal segments /h/ and /ʔ/, numerous exceptions would need to be made for their phonotactic behavior. The following patterns are observable in both the current data and Duff-Tripp's (1997) and (1998) accounts. Firstly, unlike all other consonants, neither glottal phone occurs word-initially (excluding irregular, non-phonemic occurrences due to natural speech variation). Secondly, *h* and *ʔ* can only appear before another consonant word-medially, a restriction which does not apply to the rest of the consonant inventory. Thirdly, *h* and *ʔ* cannot intervene between two vowels – or adjacent to long vowels at all – on a phonological level, unlike all other consonants. Fourthly, glottal segments would constitute an exception to monosegmental codas, provided that syllables with the structure CVhC and CVʔC regularly occur in roots, thus making it unlikely that syncope has occurred in all cases. Finally, glottal segments would violate a constraint, implied by Duff-Tripp (1997), against three-part consonant clusters (permitted only if the first and third consonants are nasal, while the second consonant is non-nasal). Words like /asoʔtʃnehtʰ/ 'possessing a name' and /ahsmeʔʰahtʰ/ 'possessing a tail' would necessitate flexibility in the nasal status of the first consonant, and words like /ahtpaʔʰ/ 'parrot species' and /aʔtpets/ 'crush, smash' would call for total revision of the consonant cluster constraint. If, on the other hand, laryngeals are considered as non-segmental features, no exceptional phonotactic behavior need be posited, as they simply function as part of preceding monosegmental vowels or following monosegmental consonants.

In addition to the phonotactic arguments outlined above, four phonetic patterns also render the segmental status of laryngeals implausible. Firstly, short modal vowel phases are consistently shorter before laryngeal phases than they are before any established phonemic consonant, even when those consonants are in coda position. This vowel-shortening effect would constitute an unusual exception for two phonemic consonants (i.e., glottal segments), further suggesting the non-segmental status of Yánesha' laryngeals. Secondly, consistent formant readings and voicing bars in breathy phases imply that a segmental glottal fricative would be more accurately analyzed as voiced /h/, a segment which is unattested throughout the vast Arawakan language family, making its occurrence in Yánesha' anomalous (Payne,

1991; Michael, 2020). Thirdly, creaky phases, in and of themselves, are not consonants, unless they can be assessed as messy surface realizations of underlying /ʔ/. In this case, creakiness surfaces regularly in careful, stressed syllables, implying that creakiness, and not a single glottal impulse, is part of the phonemic target. Finally, in reduced or compressed syllables, laryngealized vowels can become fully laryngealized, such that no part of the vowel segment is modal. While this is expected with shifts in phonation at the surface level, it would be unexpected for a consonant to entirely overtake the preceding vowel nucleus.

5.1.3 Evidence in support of vocalic association

In addition to the implausibility of the pre-laryngealized consonant and segmental hypotheses, the vowel-like behavior and phonotactic patterns of laryngeals lend support to the laryngealized vowel hypothesis. For one, when laryngeal phases occur, they adopt the formants of the preceding vowel without significant alteration. By contrast, all consonants result in a significant change in formants. Additionally, laryngeals never occur word-initially (i.e., in the absence of a preceding vowel), which is in keeping with the predictions of vocalic association.

The most substantive support for this hypothesis, however, comes from the interaction between vowel type and stress. As reviewed in Section 2.3 and confirmed by phonetic data in Section 4.6, phonation type plays an important role in primary stress assignment. Table 7 shows that primary stress occurs on the heaviest available vowel, with sensitivity to morphology. The interaction between vowel phonation and stress assignment indicates that, in addition to their vocalic association, laryngeals are a phonologically significant component of such vowels; primary stress reacts to vowel length and phonation alike.

In sum, combined evidence from phonotactics, durational interactions between phones, and primary stress assignment support the association of Yánesha' laryngeals to vowels, as opposed to following consonants or free-standing segments. A subsegmental analysis of Yánesha' laryngeals enables a parsimonious account of these facts; if laryngeals are not considered in association with the vowel segment, then phonotactic exceptions must be made for /h/ and /ʔ/, an explanation for their shortening effect on preceding vowels provided, and a less straightforward theory of primary stress assignment must be adopted to account for what appears to be irregular stress placement. I therefore propose that laryngeal phases contribute to two contrastive vowel types, aspirated and glottalized, which join the phonemic ranks alongside short and long modal vowels. The next section explores the formal composition of these contrastive vowel types.

5.2 A Q-theoretic analysis of laryngealized vowels

Having established the affiliation of Yánesha' laryngeals with vowel segments, we now look inside laryngealized vowel segments to account for their biphonational composition. As seen in Section 4, laryngeal phases maintain the preceding vowel quality in terms of both formants and voicedness, but differ markedly in terms of phonation type. Provided this

congruity, I propose that breathy and creaky phases in Yánesha' possess the feature bundles of the preceding modal vowel phase, with a crucial addition: [+spread glottis] for breathy phases, and [+constricted glottis] for creaky phases. Phonation-specific feature bundles are exemplified in Figure 14.

Figure 14: Abbreviated feature compositions of [a] by phonation

[a]	[+voice, -back, -front, +low, -round...]
[a̤]	[+voice, -back, -front, +low, -round, +spread glottis...]
[a̰]	[+voice, -back, -front, +low, -round, +constricted glottis...]

The featural connection between modal and laryngeal phases leads logically to a subsegmental analysis of laryngealized vowels, in which modal and laryngeal phases are temporally ordered subsegments of a unified vowel segment. The following analysis is informed by Q-theory (Inkelas & Shih, 2014, 2016, 2017; Garvin et al., 2018; Schwarz et al., 2019), which builds on the bipartite segmental framework proposed by Aperture Theory (Steriade, 1993, 1994), instead putting forth tripartite segmental representations.

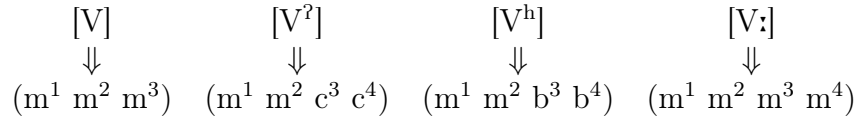
While Aperture Theory accounts well for some complex stops and affricates, numerous studies on contour segments, excrescent segments, geminate consonants, and other linguistic phenomena entailing partiality or relative timing suggest the necessity of increased granularity (e.g. Akinlabi & Liberman, 2001; Kim, 2008; Hyman, 2009; Garvin et al., 2018; Schwarz et al., 2019). Q-theory enables a flexible degree of granularity within a segment [Q], for which three temporally ordered subsegments of comparable duration, q^1 , q^2 , q^3 , are the default composition, roughly corresponding to the onset, target, and offset components of the gestural phase, per Articulatory Phonology (Browman & Goldstein, 1989, 1990, 1992; Gafos, 2002; Garvin et al., 2018) (Browman & Goldstein 1989, 1990, 1992; Gafos 2002).¹³ However, within Q-theory, the nature of the phenomenon dictates the number of subsegments, resulting in fewer (e.g. Inkelas & Shih, 2016) or more than (e.g. Garvin et al., 2018) three subsegments, as appropriate.

In Yánesha', laryngealized vowels are composed of modal subsegments (m) followed by either breathy or creaky subsegments, (b) or (c). These subsegments possess the feature bundles outlined in Figure 14, according to phonation. Laryngealized vowels could minimally be captured by two subsegments, provided their biphonational composition; however, such an analysis would fail to capture patterns in duration (e.g., short modal vowels are markedly shorter than the other three contrastive vowel types). Alternatively, laryngealized and long vowels could be portioned into three subsegments, while short modal vowels would have two subsegments. Although such an analysis captures patterns in duration, including an approximation of the 1:1.6 vowel length ratio (if rounded to 1:1.5), it predicts that short modal vowels lack either an onset, target, or offset, without a phonetic or phonological motivation for doing so. I therefore propose that laryngealized and long modal vowels have four

¹³[Q] stands for 'quantized'.

subsegments (whose targets are q^2 and q^3), and short modal vowels have three subsegments, as shown in Figure 15. Superscript numbers indicate temporal positions.

Figure 15: Q-theoretic representation of contrastive vowel types in Yánesha'



A subsegmental representation of Yánesha' laryngealized vowels accounts easily for their temporal composition; the modal phase always precedes the laryngeal phase, in representation and realization alike. Moreover, provided that subsegments are comparable in duration, the differing subsegment counts of the contrastive vowel types captures numerous durational phenomena in Yánesha', seen in Section 4.3. Firstly, the quadripartite compositions of $[V:]$, $[V^?]$, and $[V^h]$, in contrast to the tripartite $[V]$, capture the durational similarity between laryngealized and long modal vowels, to the exclusion of short modal vowels. Secondly, the fact that $[V^?]$ and $[V^h]$ are two parts modal and two parts laryngeal accounts for the proportional duration of laryngealization as roughly half (40-60%) of the total vowel segment. Thirdly, the three modal subsegments in $[V]$ represent the longer duration of short modal vowels than pre-laryngeal modal phases, represented by only two modal subsegments in $[V^?]$ and $[V^h]$. Although the 3:4 subsegment ratio of $[V]$ compared to $[V:]$ does not numerically align with the 1:1.6 contrastive vowel length ratio, difference in length is broadly captured, and subsegment counts are consistent with other analyses of short and long vowels (e.g., Garvin et al., 2020). The model in Figure 15 can also withstand phonetic differences between the edges and target of a vowel; even if onsets and offsets are less perceptually salient as transitional elements of a segment, laryngealized vowels have two phonations in their target, such that both are salient.

6 Cross-linguistic comparison and extension of the Yánesha' laryngeal analysis

In this section, laryngealized vowels in Yánesha' are considered in light of broader areal trends and related laryngeal analyses. Subsequently, the current analysis is extended to laryngeals in closely related Chamicuro.

6.1 Yánesha' laryngeal features in light of relevant analyses

This subsegmental analysis of Yánesha' laryngeal features is informed by previous analyses concerning geographically- and typologically-related languages, in particular, Silva's (2016)

account of laryngeals in Desano, an Eastern Tukanoan language spoken in northwest Amazonia (including Peru). Like Yánesha', Desano is a polysynthetic and agglutinating language whose laryngeal features show a very similar distribution to one another. Silva investigates the phonetic and phonological status of *h* and *ʔ*, previously assessed as glottal segments, and suggests a counter-analysis, in which suprasegmental laryngeal features are assigned to root morphemes. This argument is supported by the phonetic realization and distribution of Desano laryngeals, both of which show striking similarities to Yánesha' phenomena. In terms of phonetic realization, waveforms and spectrograms reveal similar trends for breathy and creaky phonations (e.g., jagged waveforms, increased periodic noise, irregular impulses) and comparable durational relationships to surrounding phones, including the shortening of preceding modal vowels. As for their distribution, Desano laryngeals are the only (potential) consonants to not occur word-initially, as seen in Yánesha'. Additional patterns arise, which, though unlike Yánesha' in substance, reveal similar distributional parallels: Desano laryngeals occur only after the first root-internal vowel, never occur in affixes, and break the tendency for codaless syllables. Further similarities abound: glottal stops can occur before any segment, post-aspiration is non-contrastive, and both laryngeal features are right-edge aligned. Silva also notes that aspiration does not occur across morpheme boundaries, and glottal fricatives do not occur before voiceless segments, which shed light on potential equivalent patterns in Yánesha', not currently attested by the available data.

Certain differences between Desano and Yánesha' laryngeal features are also noteworthy. For one, Desano prohibits first-syllable codas, unlike Yánesha' but in keeping with Chamicuro. As Yánesha' likely inherited complex codas from Quechua, it seems plausible that subsegmental laryngeal features are more prominent in languages with CV syllable structures, like much of the Arawakan family.

The vocalic association of laryngeals is also posited in the Oto-Manguean and Yucatec Mayan families. Macaulay and Salmons (1995) take a similar prosodic approach to that of Silva in their assessment of *ʔ* in Chalcatongo Mixtec and other dialects (Oto-Manguean). Macaulay and Salmons critique previous categorizations of *ʔ* as a consonant, provided a numerous (now familiar) distributional exceptions: glottal stops alone can close syllables and shorten preceding vowels, and they are absent from affixes and clitics. Instead, they propose a “floating glottalic feature as a (facultative) characteristic of the root (or “couplet” in traditional Mixtecanist terms)”, thus sidestepping any correlation between stress and glottalization. Within this framework, glottalization, which occurs consistently on the penult, is viewed as a feature of syllables rather than of vowels.

On the other hand, accounts of Yucatec Mayan laryngeals are contrastive rather than prosodic in nature. Coon (2010) asserts that in Ch'ol (Yucatec Mayan), “aspiration is a feature of the vowel”, following Attinasi (1973). Represented orthographically as *Vj*, so-called “aspirated vowels” are shown in minimal pairs like *sak* ‘stinging’ and *sajk* ‘grasshopper’, and are a productive means of forming unaccusative stems (Coon, 2010). Furthermore, aspirated vowels cause devoicing of root-final consonants (e.g., [tam] ‘long’ versus [tahm] ‘mecapal, a leather strap used for carrying’). Though Coon does not speak in subsegmental terms, the contrastive nature of aspiration and its association to the vowel are strongly reminiscent of

Yánesha' aspirated vowels.

More broadly across the Yucatec Mayan language family, phonation is shown to productively affect syntactic voice (Hofling, 2000; Lois et al., 2011; Coon, 2016). As Coon (2016) notes, "Contrasts in tone, vowel length, and height, as well as plain versus glottalized vowels affect verbal valence", such that CVC verb roots characterize active transitive constructions (e.g., *k-u-juch'-ik* 'she grinds it'), while CV'VC roots (in which V'V is a glottalized vowel) characterize passive voice (e.g., *k-u-ju'uch'-ul* 'it is ground') (Lois et al., 2011). Once again, glottalized vowels are not discussed in subsegmental terms, but they reveal a contrastive nature like that in Yánesha'.

Further investigation of laryngeal behavior and vowel qualities more broadly across the Arawakan family and geographically-related languages might reveal residue of patterns found in Yánesha', shedding light on both diachronic change and so-thought exceptional consonant behavior. In the meantime, we turn to Yánesha's closest relative, Chamicuro.

6.2 Subsegmental laryngeal features in Chamicuro

Chamicuro exhibits the laryngeals *h* and *ʔ*, whose behavior is remarkably similar to those in Yánesha'. Before delving into the details, however, a few relevant differences between the two languages are worth noting. Unlike Yánesha', Chamicuro has a five-vowel system (also featuring contrastive length), highly regular penultimate primary stress, and a low tolerance for codas, which, when present, are non-complex.

Like Yánesha', Chamicuro laryngeals contrast with one another and with open syllables (i.e., with modal vowels), as demonstrated in minimal pairs (Parker 1994: 264-265). Glottal stops are shown to occur before obstruents and sonorants, whereas the provided data do not show glottal fricatives preceding sonorants.

The two languages exhibit corresponding laryngeal features in many lexical items as well. In an initial reconstruction of Proto-Western Maipuran (PWM), Parker (1991) showcased a series of 168 Chamicuro–Yánesha' cognate sets, 56 of which show correspondence in vowel type (i.e., Chamicuro short vowels correspond to Yánesha' short vowels, Chamicuro glottalized vowels correspond to Chamicuro glottalized vowels, and so on), although many of these sets only exhibit short modal vowels. Such correspondences are exemplified in Table 9.¹⁴ Chamicuro is shown to be much more conservative, closely or entirely resembling the proto-forms. While reconstruction is beyond the scope of this paper, it is worth noting that both laryngeal features are hypothesized in the proto-language.

Parker (1994) analyzed Chamicuro laryngeals as contrastive consonants /*h*/ and /*ʔ*/, which together comprise a special class of segments due to a number of exceptional behaviors: (1) glottal segments are the only consonants that cannot appear in syllable onset position, (2) they account for over 90% of all codas in the language, and (3) glottal stops allow optional vowel rearticulation in emphatic speech, resulting in the only circumstance in which stress

¹⁴These cognate sets reflect prevalent vowel lowering and elision in Yánesha', as well as loss of initial /**k*/ /*ot*/ 'hand' also shows metathesis, another common diachronic process in Yánesha'.

Table 9: Corresponding vowel types and their proposed proto-forms (Parker, 1991)

PWM	Chamicuro	Yánesha'	Gloss
*tʃo:ma	tʃo:ma	o:m	<i>pumpkin/squash</i>
*gihse	kihse	behs	<i>cotton</i>
*keʔm	keʔm	eʔm	<i>hear</i>
*ti	fi	ot (<i>from to</i>)	<i>hand</i>

is antepenultimate (e.g., [túʔlu] ‘chest’ versus [túʔlu] ‘chest’). To explain the first exception, Parker proposes the Onset Filter, which prohibits syllable-initial laryngeals, leaving them to necessarily occur syllable-finally and resulting in the second exception (Parker 1994: 264). Parker suggests that primary stress assignment proceeds optional rearticulation, by way of explaining the third exception. Nonetheless, /h/ and /ʔ/ remain conspicuous members of Chamicuro’s consonant class.

The parallel nature of laryngeals in Yánesha’ and Chamicuro, combined with the languages’ genealogical ties and shared lexical items, set the stage for a unified analysis of laryngeal features. Moreover, the subsegmental analysis proposed above easily extends to the Chamicuro facts laid out by Parker (1994), going a step further in simplifying certain phenomena which must be framed as exceptions within Parker’s segmental framework. If Chamicuro possesses subsegmental laryngeal features that associate to vowels, then the unusual phonotactic behavior and irregular stress discussed by Parker are predictable rather than exceptional. The occurrence of rearticulated vowels simply illustrates the increased flexibility in the placement of [+constricted glottis] in emphatic speech. Parker’s findings therefore bolster the current argument, implying that subsegmental laryngeal features can be hypothesized at the proto-level as well.

7 Conclusions

This study examined laryngeals in Yánesha’ to gain insight into their phonetic characteristics and phonological status, arriving at their categorization as contrastive subsegmental features associated with vowels. In terms of their phonetic traits, laryngealized vowels are segments consisting of a modal voiced portion followed by a breathy or creaky voiced portion of similar or slightly longer duration. As a speaker transitions from the first phonation portion to the second, formants and f0 are primarily sustained, intensity decreases, and periodic noise or impulse irregularity (depending on the laryngeal in question) increase. Pre-laryngeal modal portions are generally shorter than phonemic modal short vowels, whereas the entire laryngealized segment (combined modal and laryngeal portions) is roughly equal in length to phonemic long vowels. Laryngealized vowels occur word-initially, -medially, and -finally, following any consonant though differing slightly in which consonants they commonly precede.

In terms of their phonological classification, we have seen support from the laryngeals' unique distribution, durational patterns, and interaction with primary stress assignment. Together, these properties favor the subsegmental status of laryngeals, which share the feature bundle of the preceding vowel with the addition of [+spread glottis] or [+constricted glottis]. Following Q-theory, laryngealized vowels have four subsegments comprised of modal (m), breathy (b), and/or creaky (c) subsegments. This representation lends itself to a gradient conceptualization of mora activity, following Gradient Symbolic Representations, and forming a topic of future inquiry. Finally, Yánesha's laryngeal behavior shows similarities to languages like Desano and Ch'ol, and the proposed analysis may account for laryngeal patterns in closely related Chamicuro.

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