Glottalization at the margins: phonology and phonetics of Zongozotla Totonac glottal stops and glottalized vowels

Marc Garellek[1*], Osbel López-Francisco[2], and Jonathan D. Amith[3]

[1]Department of Linguistics, University of California San Diego, La Jolla CA, USA
[2]Facultad de Estudios Superiores, Universidad Nacional Autónoma de México-Iztacala, Tlalnepantla MX, Mexico
[3]Department of Anthropology, Gettysburg College, Gettysburg PA, USA
[*]Address correspondence to: mgarellek@ucsd.edu

Word count: 7,800

Abstract

Glottal stops and glottalized ('laryngealized') vowels in Totonac and Tepehua languages are crucial for historical reconstructions (MacKay and Trechsel, 2018; Beck, 2023), but their phonological and phonetic properties usually pose analytic problems for synchronic descriptions (McFarland, 2009). In this paper, we provide an in-depth phonological and phonetic analyses of glottal stops and glottalized vowels in the variety of Totonac spoken in Zongozotla, Puebla State, Mexico. We argue that glottal stops and glottalized vowels are marginal in the language: glottal stops only appear phrase-finally, and the vocalic phonation contrast has a low functional load in addition to being phonetically weak. And though glottal stops and glottalized vowels are in complementary distribution, we argue that they should be treated as distinctive sounds in the language. We provide a diachronic explanation for many of the attested patterns, and argue that a constraint against phrase-final voicing has played, and continues to play, an important phonological role in Zongozotla Totonac and across other varieties. Overall, our paper provides a detailed, unified, analysis of glottal stops and glottalized vowels in Totonac, as well as evidence for the role of postlexical structure in creating 'intermediate phonological relationships' (Hall, 2013) at the lexical level.

Keywords: Laryngealization, Glottalization, Phonation, Sound change, Marginal phonemes, Totonac

1 Introduction

Contrast and allophony are at the core of phonological analysis, yet the relationship between pairs of sounds can sometimes be difficult to ascertain. Hall (2013) provides an overview of 'intermediate relationships' that lead to many types of contrasts being described as 'marginal.' She highlights how contrasts may be marginal and ambiguously contrastive in a language for a variety of reasons. For example, the mid-vowel /e∼ɛ/ and /o∼ɔ/ contrasts of Standard Italian can be considered marginal because there are few minimal pairs, and because they are lexically variable and may to some degree be phonologically conditioned to some degree (Renwick and Ladd, 2016). And in Zongozotla Totonac, the language we analyze here, [e] and [o] generally only occur predictably, as allophones of /i/ and /u/ adjacent to uvular /q/ or (more variably) glottal /h/ and /ʔ/. But [e] and [o] can also appear unpredictably, for example in loanwords like the frequent /peɾo/ 'but' (< Spanish *pero*). We therefore need to posit /e/ and /o/ as contrastive sounds in the language, even if their phonemic status is marginal.

Why are some phonological relationships more difficult to characterize than others? As Hall (2013) and others mention, this can result from different criteria being used by different researchers, because a given criterion often does not provide straightforward evidence for or against contrast vs. allophony, and/or because different criteria can be in conflict with one another. A classic case is the English contrast between /h/ and /ŋ/: they are in complementary distribution (suggesting they are in an allophonic relationship), but are so phonetically dissimilar so as to make their inclusion in the same phonemic category very unlikely. But there are other reasons why a phonological relationship can be difficult to determine. A common reason is the presence of foreign or specialized strata in the phonology, such as the aforementioned case of Totonac mid vowels that we mentioned earlier. High variability in how a category is realized, as reported earlier for Italian mid vowels (Renwick and Ladd, 2016), and a sound's low frequency, are other such reasons.

Prosodic structure also plays an important role in intermediate relationships. Sounds can have limited phonotactic distributions within the word, as is the case for /h/ and /ŋ/ in English. But higher phrasal structure can also matter. In Dagbani (as well as other West African languages), final glottal stops appear only pre-pausally, as long as certain phonological, morphological, syntactic, and pragmatic conditions are met (Hyman, 1988). In this paper, we also focus on glottalization—glottal stops and glottalized vowels—in Zongozotla Totonac (henceforth ZoT). To foreground our analysis, we will argue that glottalization displays three kinds of marginality. First, glottal stops are marginal in terms of their prosodic distribution: they are almost always word-final, but word-final glottal stops only surface when the word is also phrase-final. Second, the contrast between glottalized and modal vowels is marginal because there are few minimal pairs, and because the glottalized vowels are phonetically only weakly glottalized. Finally, glottal stops and glottalized vowels, which we argue form distinct categories, are nonetheless in complementary distribution. And by comparing to neighboring varieties of Totonac, we will also provide a diachronic explanation for the synchronic state of ZoT, which highlights the role that phrasal phonology can play in intermediate phonological relationships.

1.1 Zongozotla Totonac

The Totonac languages belong to the Totonac-Tepehua ('Totonacan') group of languages that are spoken by about 250,000 people in the Eastern Sierra Madre range of Mexico, centered in the state of Puebla (see map in Figure 1). The language family is fairly small, but there exist proposals that link it to the Mixe-Zoquean languages (Brown et al., 2011) and even to Chitimacha in Louisiana (Brown et al., 2014). The family is generally divided into Totonac and Tepehua branches, but internal divisions are still poorly understood (Beck, 2023).

Effectively, Zongozotla, with a population of approximately 10–12,000 individuals, is the only community in the municipality that bears its name. The vast majority of its population speak Totonac with a significant number bilingual in Spanish to differing degrees of fluency. The younger generation is beginning to lose their linguistic skills in Totonac although this is still the language that dominates communication inside and outside the family. Some inhabitants only speak Spanish while a small minority is bilingual in Totonac and Nahuatl. In a wider context Zongozotla is one of many communities, with a total population of about 120,000, that speak what has been classified as Highland Totonac (Glottocode: high1243; ISO 639-3: tos).

To our knowledge, previous to our work, the only existing literature on ZoT is a short wordlist by McQuown (1976). But the variety is geographically close and linguistically similar to that variety spoken in Zapotitlán de Méndez, described in considerable detail by Herman Aschmann (Aschmann, 1946; Aschmann and Wonderly, 1952; Aschmann, 1983). Still, there are considerable differences between our analysis of glottalization and that of neighboring varieties of Highland Totonac, as we describe in more detail in Section 5.

1.2 The corpus

In what follows, we describe our analysis of the sounds of ZoT, based on our fieldwork. The corpus is part of a broader NSF-funded project (led by third author Jonathan D. Amith) whose goals are to document the sounds and ethnobotanical terms across Totonac and other indigenous languages of Mexico. We formulated a wordlist that was designed to

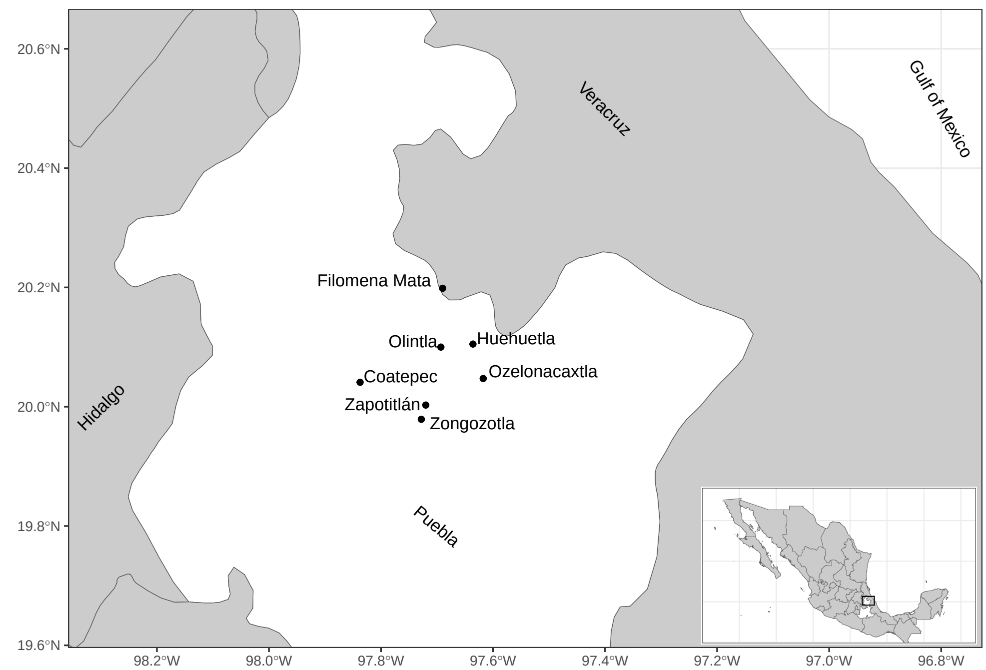


Figure 1: Map showing Zongozotla and neighboring varieties of Highland Totonac mentioned throughout the paper.

illustrate the sounds of the language, and in particular to highlight contrasts between modal vs. glottalized vowels. The first author, Marc Garellek, drafted a Totonac wordlist with Spanish glosses based on lexical items from Zapotitlán Totonac (Aschmann, 1946), given the two municipalities' geographic proximity and phonological similarities between the two varieties. The second author, Osbel López-Francisco, who is a Totonac speaker from Zongozotla, checked and revised the wordlist, the final version of which comprised 229 lexical items. The latter two authors recorded the data from eight speakers (four women and four men, including from the second author) in Zongozotla in May 2022. Demographic information for the speakers can be found in Table 1. Recordings took place over 4 days for about 4 hours each day. Two speakers per day would alternate pronouncing about half the list (about 1 hour of recording for each half list). Speakers were compensated for their participation.

Audio recordings were made starting at about 10 pm each day (to avoid outside sounds) in a quiet room with acoustic foam to mitigate echo. The recorder was a Sound Devices 722 set at 48kHz and 16 bits, with each speaker recorded with a Countryman e6 ear-worn omnidirectional microphone. Speakers were instructed to read the words from the 229-word list in randomized order. The words appeared in Totonac and Spanish. When the

Code	**Gender**	**Age**
APG 426	Female	49
CLC 503	Female	31
ESP 427	Female	43
IPN 389	Male	51
OLF 385 (second author)	Male	31
PLC 504	Female	31
RLC 505	Male	59
SLC 388	Male	54

Table 1: Demographic information about the speakers in the corpus

speaker had difficulty, second author López-Francisco would intervene and try to prompt the speaker to utter the targeted word. It was rarely necessary from him to pronounce the solicited word himself.

Each word was said in isolation three times, and then included in the carrier sentence *X iyma-n ta'chiwí:'n* 'X is a word (in Totonac).' Thus the ZoT corpus on which subsequent analyses are based includes 229 lexical items, each recorded four times (three times in isolation, once in the carrier), for a total of about 916 tokens per speaker and over 7300 tokens in total (some tokens were excluded due to background noise or mispronunciations).

1.3 Basics of the sound inventory of Zongozotla Totonac

Our analysis of the overall sound inventory of ZoT reveals a system that is quite similar to those described for other Totonac languages (Beck, 2023), particularly those belonging to the Highland group (Aschmann, 1946; Troiani, 2007; Román Lobato, 2008): consonants contrast six places of articulation, voicing is not contrastive in obstruents (but stops are usually phonetically voiced word-internally after nasals), and affricates and fricatives contrast in terms of central vs. lateral airflow (see also Table 2). As in many Totonac-Tepehua languages (Román Lobato, 2008; McFarland, 2009; Herrera Zendejas, 2021), /q/ can variably be realized as a stop, affricate [q^{χ}], fricative [χ], or as a pre-fricated affricative [$^{\chi}q^{\chi}$]; to our current knowledge, this variation is not predictable. Glottal stops occur phonetically on word-initial vowels (a point which we return to when describing vowels), but otherwise are found almost exclusively word-finally. This is a crucial point for our analysis in Section 4. In contrast to the cross-linguistic tendency for glottal 'stops' to be mostly (creaky-)voiced, even utterance-finally (Garellek et al., 2023), in ZoT they are almost categorically realized as "prototypical" glottal stops, i.e. with a period of sustained voiceless closure followed by a release.

Glottal /h/ is realized as [x∼ç] in onsets ([ç] before front vowels), but we nonetheless

	Labial	Dental/ Alveolar	Postalveolar/ Palatal	Velar	Uvular	Glottal
Stop	p	t		k	q	ʔ
Affricate		ts	tʃ			
Lateral affricate		tɬ				
Fricative		s	ʃ			h
Lateral fricative		ɬ				
Nasal	m	n				
Approximant	w	l	j			

Table 2: Phonemic consonant inventory of ZoT for Totonac lexicon. Rhotic /ɾ/ occurs only in Spanish loanwords, but is also contrastive.

consider it to be underlying glottal due to its phonological behavior, which we will describe in Section 2. All sonorants tend to be breathy-voiced and/or devoiced phrase-finally but this tendency is gradient. For example, /aw, aj, an/ can each surface as [aw̤∼aw̥, aj̤∼aç, an̤∼an̥] at ends of utterances and utterance-medial phrases. This tendency for phrase-final devoicing is an important fact to which we will return throughout this paper.

There are three contrastive vowel qualities, each of which contrasts further in terms of length and phonation type (see also Table 3). Vowels /i, u/, irrespective of their length or phonation type, lower to [e, o] categorically adjacent to /q/, even when a nasal intervenes, and are orthographically marked with *e, o*, as in (1); before /h, ʔ/, high-vowel lowering is common but more variable in occurrence (and rarely marked orthographically), and is often gradiently realized (e.g. /ih/ can surface as [ih], [eh], or [iᵉh]). In Spanish loans like /peɾo/ 'but,' mid vowels occur non-adjacent to any uvular/glottal and thus could be considered phonemic as well (but they do not contrast in terms of length or phonation). Vowel /a/ also tends to be produced further back as [ɑ] adjacent to uvulars, as found across the Totonac-Tepehua family (e.g., in Mecapalapa Tepehua; Herrera Zendejas 2021). In all contexts, short /a/ is often realized as [ə].

(1) *Categorical high-vowel lowering adjacent to /q/ vs. gradient lowering before /h, ʔ/:*

/tʃaqiːj/	[tʃaˈqeːj]	*chaqé:y*	'*lo lava*[1], s/he washes it'
/pṵːqu/	[ˈpo̰ːqo]	*po:'qo*[2]	'*sucio*, dirty'
/lunqnan/	[loɴqˈnan]	*lonqnán*	'*hace frío*, it's cold'
/kukuh/	[ˈkukuh, ˈkukoh]	*kukuh*	'*arena*, sand'
/pa̰ʃniʔ/	[ˈpa̰ʃniʔ, ˈpa̰ʃneʔ]	*pa'xni'*	'*cochino*, pig'

We refer to phonation contrast as one between modal vs. *glottalized* vowels, departing from the research tradition on Totonac which refers to the latter as 'laryngealized' (in Spanish, *laringealizado/laringizado/rechinado*). This is for two reasons, one language-internal and the other language-general. First, we wish to highlight the intermediate phonological relationship that exists between glottal stops and glottalized vowels. Second, when discussing the phonological category of non-modal vowels, we wish to abstract away from details of the glottalized vowels' phonetic realization, focusing instead on the fact that they are produced with glottalization, i.e. with some degree of glottal constriction (Garellek et al., 2023). (In that sense, the term 'laryngealization' is even more general, in that any sound produced with some amount of (epi-)laryngeal constriction could be considered 'laryngealized.') And as we will show in Section 3, phonetically the glottalized vowels are best described as being produced with 'tense voice' (Dawson et al., 2022), which has also been reported (in Spanish as *voz tensa*) in Olintla Totonac, another Highland variety (Tino Antonio, 2020). However, a detailed acoustic analysis of the tense voice in Totonac is still lacking.

Of particular relevance for this paper is the limited distribution of certain vowels. In ZoT long vowels do not appear word-finally. This is in contrast to neighboring varieties from Zapotitlán and Ozelonacaxtla, where word-final long vowels are attested. Cognates with word-final long vowels in neighboring varieties appear in ZoT with a final consonant, especially /j, h/. For example, /tʃaqiːj/ *chaqé:y* '*lo lava*, s/he washes it' from the example in (1) is /tʃiqiː/ in Ozelonacaxtla Totonac (Román Lobato, 2008, p. 34).

Our analysis of ZoT reveals that modal and glottalized vowels are subject to other phonological processes and have restricted distributions that differ from the patterns reported for related varieties. As in other varieties of Totonac, there is no phonation contrast on immediately word-initial vowels (that is, on word-initial vowels not preceded by an onset); for closely-related Zapotitlán Totonac, Aschmann (1946, 1983) analyzes immediately word-initial vowels as underlyingly glottalized ('laryngealized'). This is largely due to phonetic reasons, namely that word-initial vowels are irregular in voicing and often preceded by a glottal stop. We will return to this point in Section 2.2. And unlike in neighboring varieties, in ZoT glottalized vowels also do not occur underlyingly in word-final position, and modal vowels devoice phrase-finally (e.g. see final /a/ in Figure 3). These facts will be crucial for our analysis of the relationship between glottal stops and glottalized vowels in Section 4, for our diachronic explanation in Section 5, and for our proposal in Section 6 that Totonac languages show a constraint against phrase-final voicing.

As with other varieties of Totonac, ZoT has contrastive placement of lexical stress (which is also dependent to some degree on the morphology; McFarland, 2009), but length and phonation contrasts are found on both unstressed and stressed syllables. In our broad phonemic transcriptions then, we will avoid marking stress unless its placement is non-default (e.g. always appear on a given morpheme of a polymorphemic word), but narrow allophonic transcriptions will always be marked for lexical stress.[3]

	Front	Central	Back
Short (long) modal	i(ː)	a(ː)	u(ː)
Short (long) glottalized	ḭ(ː)	a̰(ː)	ṵ(ː)

Table 3: Phonemic vowel inventory of ZoT for Totonac lexicon. Mid-vowels [e, o] (short and long, modal and glottalized) are allophonic in words of Totonac origin but occur contrastively (only for short, modal vowels) in Spanish loanwords.

2 The distribution of glottal stops

In this section, we argue that glottal stops should be considered marginally contrastive sounds in Zongozotla Totonac, based on their limited word-internal and phrasal distributions.

2.1 Word-final glottal stops

Evidence for the phonemic status of glottal stop comes from word-final position, where /ʔ/, /h/, and ∅ contrast, as in (2).

(2) *Word-final glottal contrasts:*

/ja̰ːstaʔ/	[ˈja̰ːstaʔ]	*ya:'sta'*	'*cuñado de mujer*, woman's brother-in-law'
/taːtah/	[ˈtaːtah]	*ta:tah*	'*abuelo*, grandfather'
/ʃkṵta/	[ˈʃkṵtḁ]	*xku'ta*	'*agrio*, bitter'

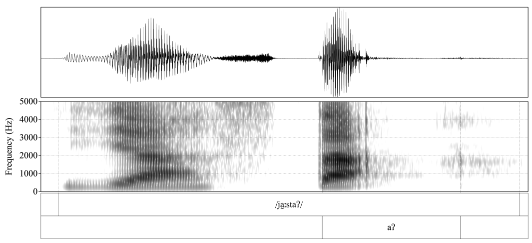
Although words ending in an underlying glottal consonant appear to be common in the lexicon, the glottal consonants only surface as shown in (2) when they occur phrase-finally. Elsewhere, word-final /ʔ, h/ delete and word-final vowels retain their voicing, as shown in Figure 2. This is presumably due to a constraint, common across Totonac varieties, against C#V sequences across phrase-medial word boundaries (McFarland, 2009). When a word ends in a consonant, the constraint is satisfied via deletion (of the glottal consonant) or /-i/ epenthesis (if the first word ends in a non-glottal consonant, as in /paskaːt/ *paská:t* '*mujer*, woman'). Examples of these alternations are seen in (3).

(3) *Constraint against C#V sequences across phrase-medial word boundaries:*

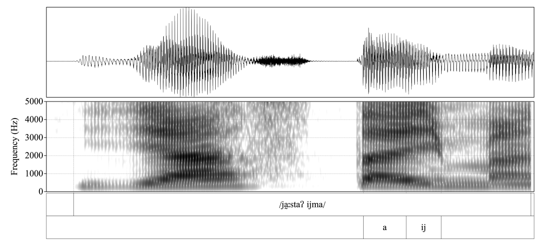
		Phrase-final	*Phrase-medial*
/-ʔ/	/ja̰ːstaʔ/	[ˈja̰ːstaʔ]	[ˈja̰ːsta]
/-h/	/taːtah/	[ˈtaːtah]	[ˈtaːta]
/-V/	/ʃkṵta/	[ˈʃkṵtḁ]	[ˈʃkṵta]
/-C/	/paskaːt/	[paˈskaːt]	[paˈskaːt-i]

Thus glottal stops, though underlyingly contrastive word-finally, rarely surface in a phrase. This is common across Totonac varieties, and has led some researchers to posit

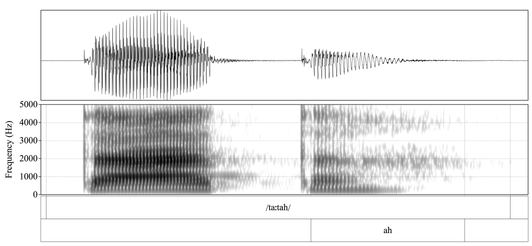
(a) /ja̰ːstaʔ/ (Final)



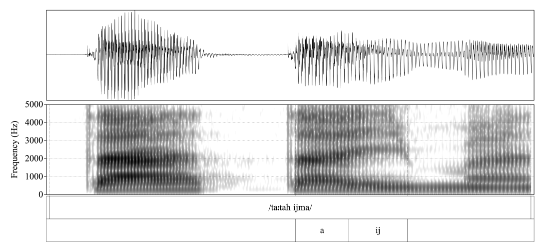
(b) /ja̰ːstaʔ ijma/ (Medial)



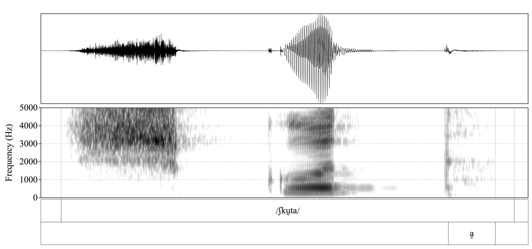
(c) /taːtah/ (Final)



(d) /taːtah ijma/ (Medial)



(e) /ʃku̯ta/ (Final)



(f) /ʃku̯ta ijma/ (Medial)

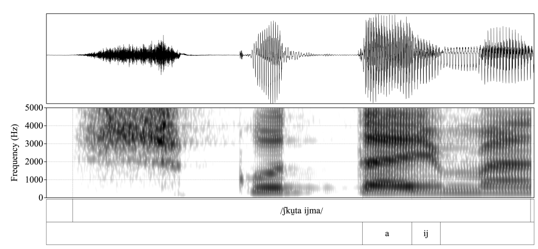


Figure 2: Comparisons between /ʔ, h, a/ in phrase-final (left) vs. phrase-medial (right) positions. Note the absence of glottal consonants phrase-medially.

that phrase-final glottal stops are either inserted phrasal markers (Ozelonacaxtla Totonac; Román Lobato, 2008), similar to what Hyman (1988) reports for Dagbani, or that lexical glottal stops are changing to become postlexical, i.e. phrasal, markers (Filomena Mata Totonac; McFarland, 2009). We will return to this point in Section 6.

In contrast to /h/, glottal stops cannot appear in coda position in the middle of the word. Indeed, morphological derivation that should in theory lead to a word-medial coda /ʔ/ instead results in deletion of the glottal stop. For instance, ZoT has a first-person plural possessive nominal circumfix *ki(n)-X-kán* 'our X.' When the nominal root ends in an /h/, the fricative is retained even though it occurs word-medially; in contrast, a root ending in /ʔ/ loses its glottal in derived forms, as in (4).

(4) *Loss of coda /ʔ/ but retention of /h/ with suffixation:*

/kin-tʃitʃiʔ-ˈkan/	[kintʃitʃiˈkan]	*kinchichikán*	'*nuestro perro*, our dog'
/kin-taːtah-ˈkan/	[kintaːtahˈkan]	*kinta:tahkán*	'*nuestro abuelo*, our grandfather'

In sum, underlying word-final glottal consonants do not surface except when the word is phrase-final. Glottal fricatives /h/ have a less restricted distribution, as they can appear in word-medial codas (as well as in onset position).

2.2 Glottal stops in other positions

As we mentioned earlier, in Zongozotla Totonac vowel-initial words are often preglottalized; that is, they begin with a glottal stop. Figure 3 shows a token of [ʔuˈkʃiɬḁ] *ukxilha* '*lo ve*, s/he sees it/him,' where the word-initial vowel is preceded by a glottal stop.

Immediately word-initial vowels (those not preceded by an onset consonant) also do not contrast in terms of phonation. These facts have led some researchers (e.g. Aschmann (1946) for Zapotitlán Totonac) to treat word-initial vowels in Totonac as underlyingly glottalized rather than modal. In that case, the glottal stop would be part of the phonetic implementation of a glottalized vowel in word-initial position. Thus if true for ZoT, the word illustrated in Figure 3 could be transcribed phonemically as /ṵkʃiɬa/ instead of as /ukʃiɬa/. But contemporary understanding of the sources of irregular voicing (Garellek, 2022) suggest that irregular voicing on the initial vowel shouldn't be used to motivate its underlying status as glottalized. Glottal stops usually lead to creaky voice on an adjacent vowel (Garellek, 2014; Garellek et al., 2023), so word-initial vowels in ZoT (as well as in Zapotitlán) can 'look glottalized' by virtue of an inserted glottal stop that is motivated by postlexical phrasal position rather than by lexically-specified phonation.

We also note that a third alternative exists, namely that all syllables must have an onset, such that so-called "word-initial" vowels are in fact preceded by a phonemic glot-

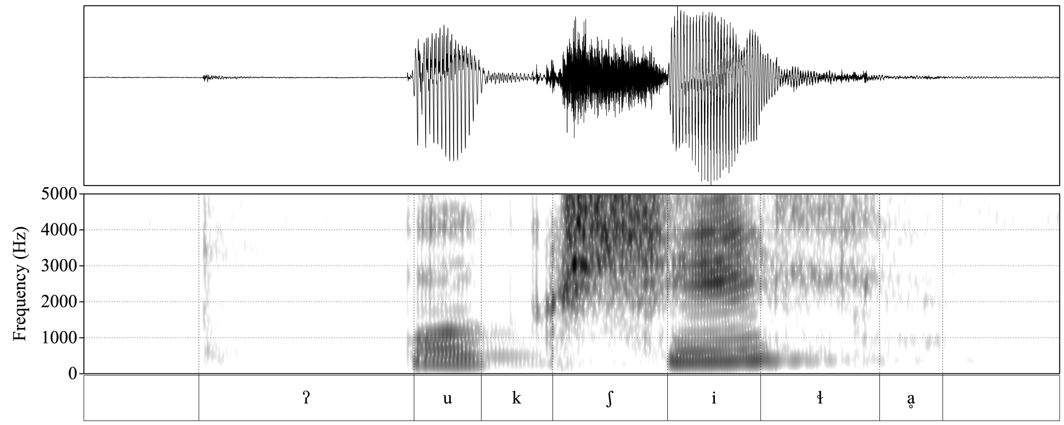


Figure 3: Vowel-initial [ʔuˈkʃiɬḁ] *ukxilha* '*lo ve,* s/he sees it/him,' with a preceding glottal stop.

tal stop (e.g. /ʔukʃiɬa/). But we believe such word-initial glottal stops are best analyzed as postlexical glottalization of initial vowels, rather than as phonemic /ʔ/, because they occur phrase-initially, where domain-initial strengthening in many languages leads to glottalization (Cho, 2016; Garellek, 2022). If the glottal stop were underlying, then we would need some explanation for why almost invariably it does not surface. For example, when a vowel-final word like /ʃkṵta/ occurs in our carrier sentence before vowel-initial [ijma] (which could also be analyzed as, hiatus is never repaired: [ˈʃkṵt**a** ˈ**i**jma-n ta̰tʃiˈwḭːn]; see also the lack of glottalization in hiatus for the phrase-medial tokens in Figure 2. If word-initial glottal stops were underlying then, we would need to explain why intervocalic glottal stops are so rare, especially given that word-*final* /ʔ/ is always realized strongly as a phonetic glottal stop. But if instead we assume that the glottal stop is a result of prosodic strengthening of a word-initial vowel, that would make ZoT similar to the many languages with variable word-initial glottalization.

The lack of a phonation contrast in immediate word-initial position leaves unresolved the question of whether word-initial vowels should be analyzed as underlyingly modal vs. glottalized. For instance, even if the glottal stop in [ʔuˈkʃiɬḁ] is due to prosodic strengthening, is the underlying representation of the word /ṵkʃiɬa/ (with a glottalized vowel) or /ukʃiɬa/ (with a modal one)? For Zapotitlán Totonac, Aschmann (1946, 1983) considers these to be glottalized, but it is unclear if that's based solely on phonetic evidence, which would be confounded with prosodic strengthening effects.

In word-medial position, glottal stops are extremely rare and variable across speakers.

To our knowledge, these can occur only in hiatus between two glottalized vowels, as in (5). The comitative prefix is /ta̰ː-/, which we know contains a glottalized vowel because the glottalization predictably surfaces with this prefix, as in [ta̰ːtɬaˈwaj] *ta:'tlawáy* '*lo hace con él*, s/he does it with him.' The verb root for 'go' is /a̰n/, with a glottalized vowel that is predictably glottalized, as in [ka̰n] *ka'n* '*voy*, I go.' When /a̰n/ is preceded by the comitative prefix, the verb can surface as [ta̰ːˈʔa̰n] *ta:'an* '*se va con él*, s/he leaves with him,' with a glottal stop between the two glottalized vowels, or as [ta̰ːˈa̰n], without the glottal stop. In our data set, instances of phonetic glottal stop [ʔ] in this word are speakers-specific: half of the eight speakers consistently say [ta̰ːˈʔa̰n], whereas the other half consistently say [ta̰ːˈa̰n], and these groups do not appear to be structured according to age or gender. Therefore, we analyze word-medials glottal stops as a speaker-dependent form of prosodic strengthening of glottalized vowels under hiatus.

(5) *Variable word-medial glottal stops at hiatus between glottalized vowels*

	With comitative /ta̰ː-/	*With 1SG. /(h)k-/*
/tɬawaj/ '*hacer*, do'	[ta̰ːtɬaˈwaj] *ta:'tlawáy*	[ktɬaˈwaj] *ktlawáy*
	'*lo hace con él*, s/he does it with him'	'*hago*, I do'
/a̰n/ '*ir*, go'	[ta̰ːˈʔa̰n, ta̰ːˈa̰n] *ta:'an*	[ˈhka̰n] *jka'n*
	'*se va con él*, s/he leaves with him'	'*voy*, I go'

2.3 Summary of the distribution of glottal stops

In this section we showed that, while glottal stops can be considered contrastive in Zongozotla Totonac, their distribution is limited. They contrast only in coda position; onset glottal stops, which are found before word-initial vowels and between glottalized vowels at a morphological juncture, are analyzed as derived from prosodic strengthening of a word-initial vowel or from hiatus involving two glottalized vowels. In terms of their lexical phonotactics then, glottal stops appear to have a limited distribution similar to that found in other unrelated languages, including Chinese varieties with coda /ʔ/ (Chai, 2022) as well as Western Muskogean (Ulrich, 1993).

But the distribution of glottal stops is especially limited, because they cannot appear in word-medial coda position; they are only found word-finally, and morphophonological alternations that involve suffixation to a root ending in a glottal stop results in the loss of this sound. Therefore, there must be an active constraint in the language against word-*non*final glottal stops. And ZoT further restricts surface glottal stops to phrase-final position.

3 The intermediate phonological relationship between modal and glottalized vowels

For a language with a vocalic phonation contrast, Zongozotla Totonac stands out for two reasons. First, the contrast has a very low functional load and second, the contrast is phonetically very weak, with phonologically glottalized vowels almost never showing strong glottalization.

Although many words have glottalized vowels, we were able to find only a few minimal or even near-minimal pairs between modal and glottalized vowels in ZoT. Our phonetic analysis will involve only nine (near-)minimal pairs, because those are the only pairs we have managed to find so far. In all then, the phonological relationship between modal vs. glottalized vowels can be considered what Hall (2013) calls 'intermediate.' And as we'll show in the next section, the contrast is also weakly realized phonetically.

In this section, we provide an acoustic analysis of the contrast between modal and glottalized vowels. Our impressions listening to the recordings suggest that the contrast is more strongly realized on long vowels than on short vowels, but in general the contrast is quite subtle. This is illustrated in Figure 4, which shows two representative (near-)minimal pairs differing in terms of vowel phonation. For both pairs the glottalized vowel looks remarkably similar to the modal one, with regular voicing throughout. But the glottalized vowels in both words have more energy in the higher frequencies than their modal counterparts, and the long glottalized vowel shows a more pronounced drop in amplitude towards its end than does its modal counterpart.

Based on our informal audiovisual investigation, we expected that glottalized vowels will be differentiated from modal ones primarily in terms of their spectral tilt and voicing intensity, though we also expected there to be an interaction with vowel quality. To control as much as possible for other sources of acoustic variation, we restrict this analysis to minimal or near-minimal pairs, controlling for placement of lexical stress and the manner of articulation of surrounding consonants, as both factors may influence voice quality (Garellek, 2022). Our list of nine word pairs is shown in Table 4.

Words were read three times in isolation (= the phrase-final condition), followed by once in the carrier (= the phrase-medial condition). Across all speakers, a total of 557 tokens were analyzed. The target vowels were segmented based on the onset and offset of F1 and F2 excited by voicing. The acoustic measures were calculated using VoiceSauce (Shue et al., 2011), which outputs a value of each measure every millisecond. We targeted the acoustic measures shown in Table 5: four spectral tilt measures of different spectral bands; two noise measures, CPP (a measure of broadband noise), HNR$<$ 500 Hz (a measure of low-frequency noise); overall root-mean-squared (RMS) energy, Strength of Excitation

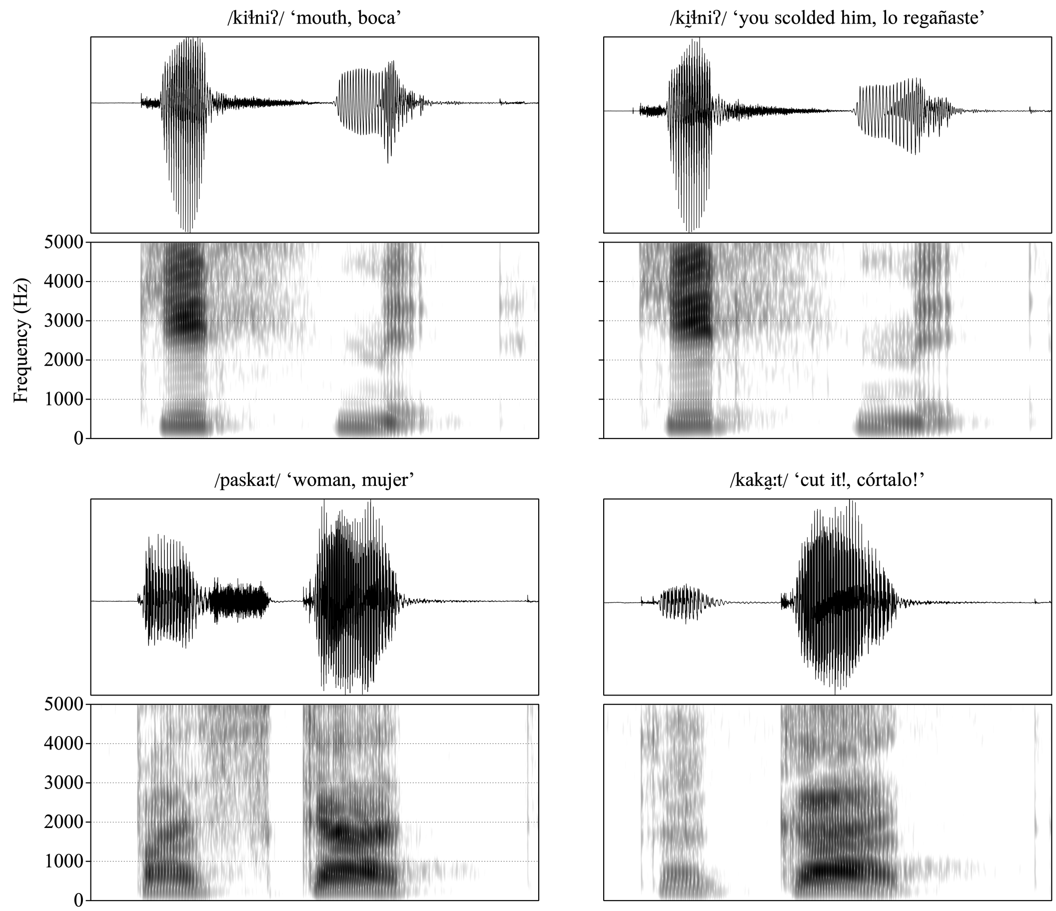


Figure 4: Minimal and near-minimal pair in terms of phonation. Words with glottalized vowels appear on right. The first pair (top row) was uttered by female speaker APG 426; the second pair (bottom row) by male speaker IPN 389.

(amplitude of voicing), and Residual H1*. Except for Residual H1*, these are relatively well-known measures of voice quality (see Garellek, 2022 for an overview). Chai and Garellek (2022) proposed Residual H1* as a new measure that assesses the amplitude of H1 (corrected for formant frequencies and bandwidths) but controlled for RMS energy. VoiceSauce’s default settings were used to calculate these parameters; the F0 was calculated using STRAIGHT (Kawahara et al., 1998) and the formants via Snack (Sjölander, 2004).

F0 values greater than 3 standard deviations from each speaker’s mean were considered outliers and removed. Within each vowel category, we calculated the Mahalanobis distance on the F1–F2 space between each individual token relative to the mean of the

Modal		**Glottalized**	
/ˈʃanat/	*xanat*	/ˈʃa̰nat/	*xa'nat*
'flower'	'*flor*'	'sweat'	'*sudor*'
/paˈskaːt/	*paská:t*	/kaˈka̰ːt/	*kaká:'t!*
'woman'	'*mujer*'	'cut it!'	'*córtalo!*'
/ˈʃkut/	*xkut*	ˈ/ʃkṵta/	*xku'ta*
'coati'	'*tejón*'	'bitter'	'*agrio*'
/ˈpaqɬ/	*paqlh*	/ˈpa̰qɬ/	*pa'qlh*
'it blossomed'	'*floreció*'	's/he broke it'	'*lo quebró*'
/ˈtʃaːn/	*cha:n*	/ˈtʃa̰ːn/	*cha:'n*
'cooked'	'*cocido*'	'ant'	'*hormiga*'
/ˈpuːqu/	*po:qo*	/ˈpṵːqu/	*po:'qo*
'thick'	'*espeso*'	'dirty'	'*sucio*'
/aːmaːˈtʃaʔ /	*a:ma:chá'*	/ama̰ːˈtʃaʔ/	*ama:'chá'*
's/he's lying there'	'*allá está acostado*'	's/he's going there'	'*va por allá*'
/ˈkiɬniʔ/	*kilhni'*	/ˈkḭɬniʔ/	*ki'lhni'*
'mouth'	'*boca*'	'you scolded him'	'*lo regañaste*'
/ˈpaqʃa/	*paqxa*	/ˈpa̰qʃa/	*pa'qxa*
'hit (onomat.)'	'*ruido de un golpe*'	's/he shells it'	'*lo desvaina*'

Table 4: Wordlist used for the phonation analysis

Spectral tilt	**Noise**	**Other**
H1*–H2*	CPP	Root-mean-squared (RMS) energy
H2*–H4*	HNR$<$ 500 Hz	Strength of Excitation
H4*–H2kHz*	Subharmonics-to-harmonics ratio	F0
H2kHz*–H5kHz		Residual H1*

Table 5: The acoustic measures of voice quality used in the analysis of phonation.

category; the larger the Mahalanobis distance is, the more deviant the token is from the center of the category and the more likely there is a tracking error for that vowel. We also considered tokens with a Mahalanobis distance larger than 6 as outliers. We then removed all timepoints with f0 and formant outliers, and averaged each measure over the entire vowel. Duration was first log-transformed due to its being log-normally distributed.

To determine which acoustic measures, when taken together, predict glottalized vs. modal vowels, we fitted a Bayesian logistic regression model using *brms* (Bürkner, 2018) in R. We predicted vowel phonation (dummy coded with 'modal' as baseline) by the scaled mean acoustic measures and their interaction with vowel length and with random intercepts by speaker and word pair. The model was specified with weakly informative priors as Normal(0,1.5) in log-odds space for both the intercept and the fixed effects, and was fitted to draw 5000 samples in each of four Markov chains, with a burn-in period of 1000 iterations per chain.

We find compelling evidence for an effect of the following parameters as predictors of the phonation contrast: CPP ($\beta = 0.79$, 95% CrI = $[0.36, 1.23]$), HNR< 500 Hz ($\beta = -1.01$, 95% CrI = $[-1.63, -0.42]$), SoE ($\beta = -1.08$, 95% CrI = $[-1.48, -0.71]$), energy ($\beta = 0.39$, 95% CrI = $[0.02, 0.77]$), duration ($\beta = 1.17$, 95% CrI = $[0.72, 1.63]$), and the interaction between energy and vowel length ($\beta = -0.45$, 95% CrI = $[-0.82, -0.08]$). Compared to modal vowels, glottalized vowels are less noisy in terms of their broadband noise (Figure 5a), but are noisier in the lowest frequencies below 500 Hz (Figure 5b); this suggests a moderate amount of voicing irregularity for glottalized vowels. Glottalized vowels also have lower SoE, suggesting weaker voicing due to greater glottal constriction (Figure 5c), and are slightly longer (Figure 5d). Glottalized vowels also have more energy overall, but this effect is driven by long vowels (Figure 5e).

Therefore, glottalized vowels differ from their modal counterparts in ways that are expected for creaky vs. modal contrasts. While the higher CPP for glottalized vowels is unexpected, this effect could be driven in part by the greater energy associated with long glottalized vowels. It is especially surprising (from a cross-linguistic standpoint) how so few measures, including none of the four spectral tilt measures or Residual H1*, emerged as credible predictors of the contrast. This implies that the glottalization is weaker than expected given our understanding of how glottalized/creaky vowels in other languages are realized (Gordon and Ladefoged, 2001; Esposito and Khan, 2020; Garellek, 2022). Indeed, as the figures show, the average difference between phonation type is numerically very small. Therefore, we can conclude that the phonation contrast in ZoT is not only marginal (in terms of the rarity of minimal pairs), but also that it is only weakly realized phonetically.

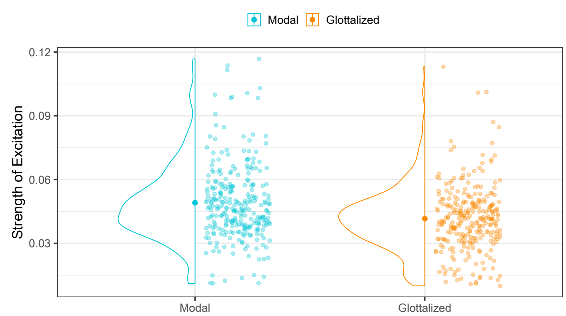
To explore further the phonation contrast and its phonetic realization, in Figure 6 we plot time course data for the four acoustic measures (aside from duration) that emerged as credible predictors. (The bottom-right facet showing RMS energy is further subdivided by vowel length, given the interaction that emerged in the regression model.) For CPP, SoE, and energy, the distinction between modal vs. glottalized vowels is realized throughout the vowel. But the lower HNR $<$ 500 Hz for glottalized vowels occurs mostly in the latter half of the vowel. This suggests that f0 becomes more irregular, if only slightly, over the course of a glottalized vowel.

Next we explore the variation across word pairs. Figure 7 shows, for each acoustic measure, the difference between the modal vs. glottalized vowel in each word pair. We can see that some measures are more robust across word pairs: strength of excitation is higher for modal vowels across all pairs except for *xkut-xku'ta* and *paqxa-pa'qxa*, which show no difference along this measure; duration is lower for modal vowels across all pairs

(a) CPP

(b) HNR < 500 Hz

(c) SoE



(d) Duration

(e) Energy

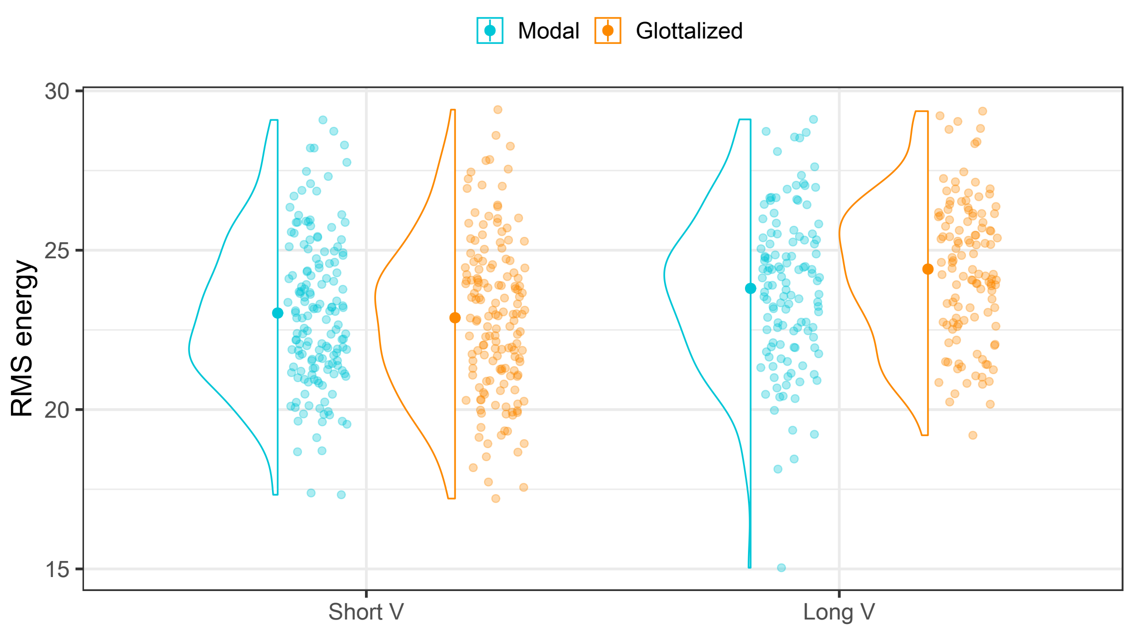


Figure 5: Credible acoustic predictors of the phonation contrast. Violin plots show the distribution and points show each observation. The larger point indicates the mean value.

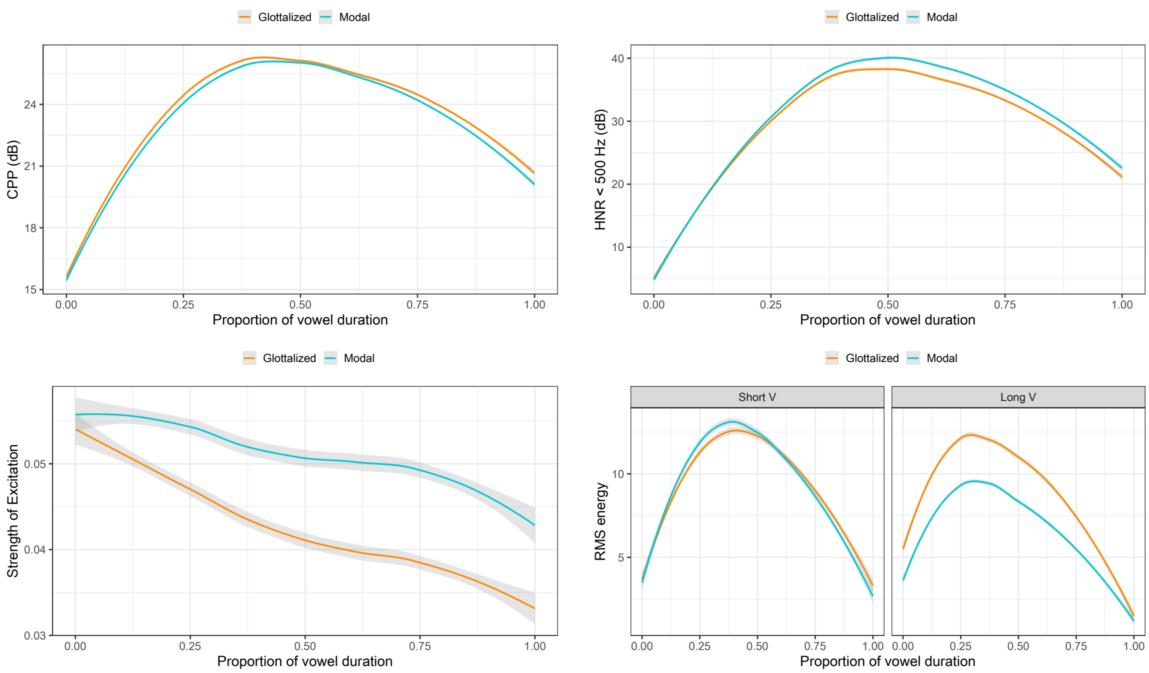


Figure 6: Time course plots for the four acoustic measures that emerged as predictors of the contrast. Shaded areas indicate Loess smoothing about the mean value.

of words except for *xkut-xku'ta* (no difference) and *paqlh-pa'qlh* (effect in the opposite direction). The other acoustic measures show either more pairs that overlap with 0, or more pairs whose differences are in the opposite direction from the main effect for that measure. Crucially, there is no single pair of words for which a main effect (in the expected direction) is not found for any acoustic measure.

Finally, we explore the cross-speaker variation. Figure 8 shows the difference between the modal vs. glottalized vowels, here averaged across all word pairs, for each acoustic measure. We see that some speakers more reliably produce a difference in phonation than others: SLC388 only has a slightly higher SoE for modal vs. glottalized vowels, which are also shorter in duration (contra the main effect of longer glottalized vowels). RLC 505 produces the contrast mainly in terms of CPP and HNR $<$ 500 Hz, and both noise measures are higher for modal vs. glottalized vowels. This is expected based on cross-linguistic generalization, but the HNR $<$ 500 Hz pattern goes against the main effect found in the data set. And as with the pattern across word pairs, SoE shows the more robust pattern across speakers.

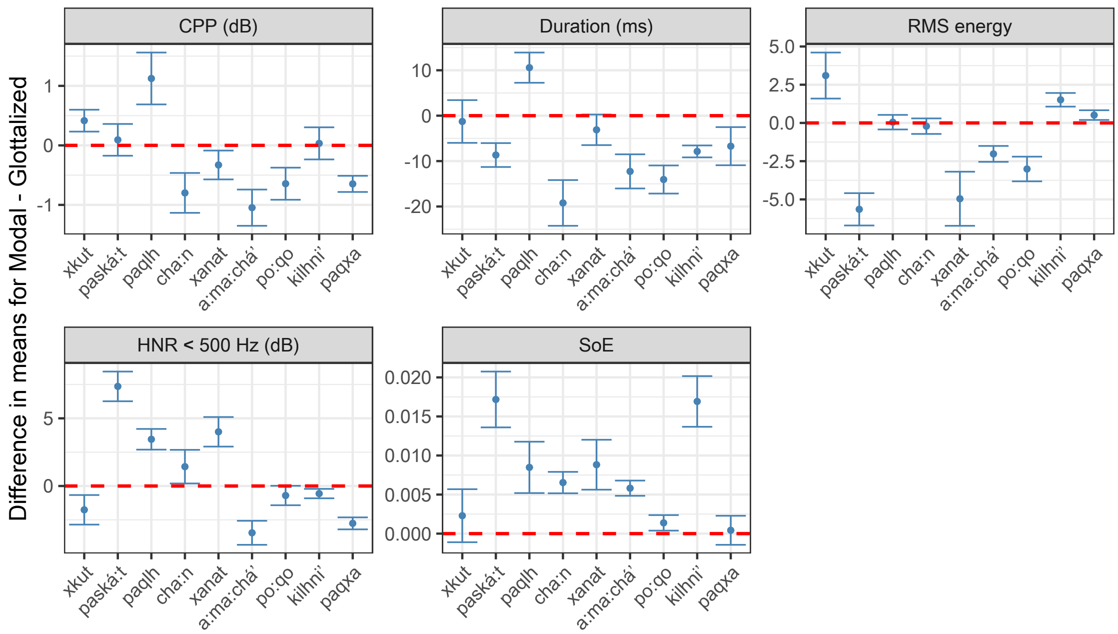


Figure 7: Differences between modal vs. glottalized vowels for the acoustic measures that emerged as predictors, separated according to word pair. The x-axis label shows only the modal word in its orthographic representation. The dot shows the mean difference, and error bars indicate standard error about the mean. No difference between modal vs. glottalized is inferred by error bars that overlap with 0.

4 The intermediate phonological relationship between glottalized vowels and glottal stops

The main question we will address in this section is, what is the relationship between glottalized vowels and glottal stops in Zongozotla Totonac? While we have been treating them as distinctive sounds in the language, in fact [V̰] and [Vʔ] sequences are in complementary distribution: glottalized vowels generally do not occur word-finally, whereas [Vʔ] sequences *only* occur word-finally (and recall that the [ʔ] only surfaces at the end of a phrase). Instances of derived word-final glottalized vowels provide the sole exception to this distribution: if a word ends in /V̰h/ and appears phrase-medially, the /h/ is not realized (recall (3)). Thus /skuhma̰h/ *skujma'h* '*está trabajando*, s/he is working' is realized as [skuhma̰] in phrase-medial position— without the word-final /h/ but retaining a glottalized vowel that appears word-finally in the derived form. In the same environment, a word ending in a glottal stop would be realized with a word-final modal vowel. A summary of these distributions by phrasal position is shown in (6). Note that glottalized vowels are

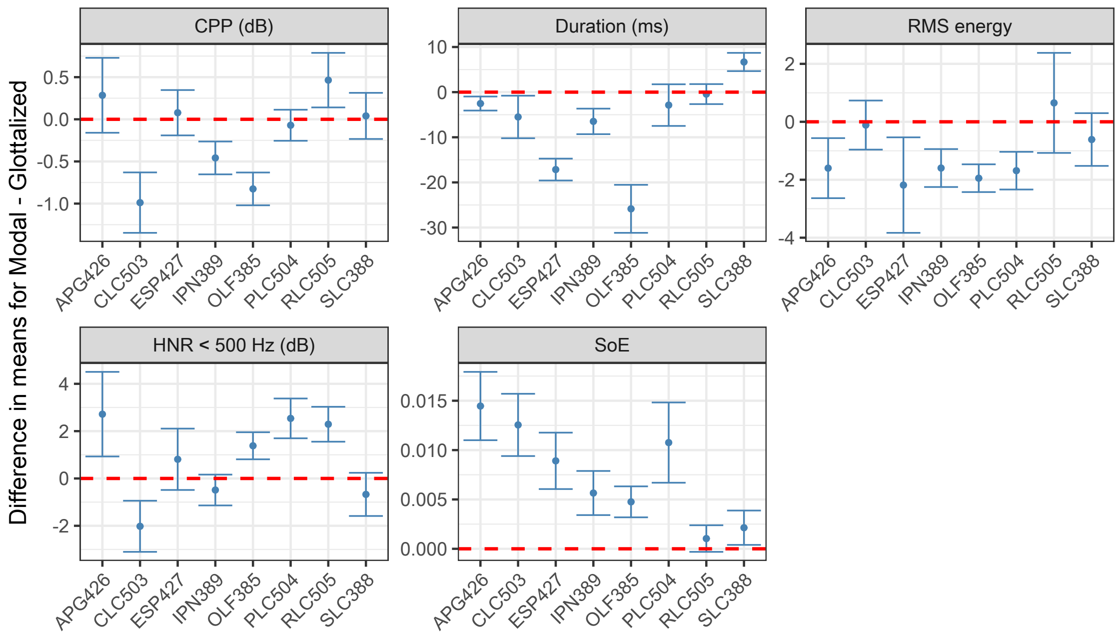


Figure 8: Differences between modal vs. glottalized vowels for the acoustic measures that emerged as predictors, according to each speaker. The dot is the mean difference, and error bars indicate standard error about the mean. No difference between modal vs. glottalized is inferred by error bars that overlap with 0.

never followed by a coda glottal stop, and in word-final position long vowels are not found in open syllables or in those closed by a glottal consonant.

(6) *Distributions of relevant word-final rhymes:*

	Phrase-final	*Phrase-medial*
/-V/	[-V̥]	[-V]
/-Vh, -V̰h, -Vʔ/	[-Vh, -V̰h, -Vʔ]	[-V, -V̰, -V]
/-V̰ʔ, -Vː, -V̰ː, -Vːʔ, -Vːh/	(unattested)	(unattested)

The complementary distribution of [V̰] vs. [Vʔ] sequences does at the very least suggest that [Vʔ] sequences are allophonic realizations of underlying word-final /V̰/. Nonetheless, we argue that they should be treated as contrastive sounds. One reason is that speakers consider glottalized vowels and glottal stops to be “different” sounds, i.e. the sounds are perceptually distinctive in a way that would render them, at the very least, ‘quasi-phonemes’ (Kiparsky, 2014). Another reason is that, as we have argued in Section 3, the contrast between modal vs. glottalized vowels is marginal, with the latter being only weakly differentiated from the former. Yet the realization of glottal stops is phonetically robust, so much so that they are almost always realized as canonical voiceless glottal stops.

But morphophonological alternations provide probably the strongest evidence that [V̰] vs. [ʔ] represent distinctive sounds in synchronic ZoT. Recall in (4) that, in the first-person possessive plural circumfix *ki(n)-X-kán* construction, if the nominal root ends in an /h/, the fricative is retained; in contrast, root-final /ʔ/ disappears (7). If [Vʔ] were the word-final allophone of underlying /V̰/, then we would expect it to surface as [V̰] when it appears in this construction. Instead, the stem-final /ʔ/ disappears and the preceding vowel remains modal: /kin-tʃitʃiʔ-ˈkan/ 'our dog' surfaces as [kintʃitʃiˈkan], not as *[kintʃitʃḭˈkan, kintʃitʃiʔˈkan]. This cannot be explained by a constraint against glottalized vowels in this construction: with /liːwa̰j/ *li:wa'y* '*carne*, meat,' the glottalized vowel remains.

(7) *Loss of coda /ʔ/ but retention of glottalized vowels with suffixation:*

/kin-tʃitʃiʔ-ˈkan/	[kintʃitʃiˈkan]	*kinchichikán*	'*nuestro perro*, our dog'
/kin-taːtah-ˈkan/	[kintaːtahˈkan]	*kinta:tahkán*	'*nuestro abuelo*, our grandfather'
/kin-liːwa̰j-ˈkan/	[kiliːwa̰jˈkan]	*kili:wa'ykán*	'*nuestra carne*, our meat'

Therefore, the phonological relationship between glottalized vowels and glottal stops can also be considered what Hall (2013) calls 'intermediate.' On the one hand, they are in complementary distribution, suggesting an allophonic relationship. On the other hand, speakers consider the two sounds to be distinctive, and the sounds' divergent behavior in alternations provides evidence that /ʔ/ should be considered synchronically contrastive.

5 Diachronic considerations

In this section, we highlight the diachronic changes that help clarify the current marginal status of glottal stops and glottalized vowels, as well as their relationship to one another. Glottalization plays an outsize role in both diachronic and synchronic analyses of the phonology across the Totonac-Tepehua (Totonacan) family. In terms of historical analyses, MacKay and Trechsel (2018) state (p. 55): "The key question that must be addressed in any reconstruction of [Proto-Totonac-Tepehua] concerns the status of laryngealized vowels and glottalized consonants in the protolanguage." That is because scholars disagree on whether the protolanguage should be hypothesized as having glottalized vowels (Arana Osnaya, 1953; Levy, 1987; Brown et al., 2011; Davletshin, 2019) or glottalized consonants (MacKay and Trechsel, 2018). We take no position on the matter: both theories would reconstruct glottalized vowels (rather than glottalized consonants) in pre-Highland Totonac, the branch to which Zongozotla belongs, and so it suffices to assume that glottalized vowels in ZoT are inherited (minimally from pre-Highland Totonac, and possibly as far back as proto-Totonacan) rather than innovative.

But the analysis of glottalization in present-day Totonac and Tepehua languages is also contentious. As McFarland (2009) writes in her dissertation on Filomena Mata Totonac (p. 13): “The writers of published grammars of all varieties [of Totonac-Tepehua languages] have struggled with the analysis of glottal features, which are variously accounted for as the phoneme /ʔ/, ejection on stops, laryngealization of vowels, and/or part of the vocalic nuclei, (either Vʔ, ʔV or ʔVʔ).”

Part of the reason for the analytic struggles is that, across Highland Totonac varieties in particular (as well as beyond within the family), the historical contrast between modal vs. glottalized vowels shows a continuum between full maintenance and complete loss, with many varieties having lost the contrast (in favor of modal vowels) in all, or nearly all, contexts. On the most conservative end of the continuum, Zapotitlán Totonac is characterized by Aschmann (1946) and McQuown (1976) as having the contrast in all word positions excepts word-initially, and on both long and short vowels. On the less conservative and more innovative end of the continuum, Coatepec (McQuown, 1976) and Huehuetla Totonac (Troiani, 2007) have only modal vowels, with Vʔ as the reflex of *V̰#.

ZoT falls in the middle of the continuum. Unlike in Coatepec and Huehuetla Totonac, word-medial glottalized vowels are retained. But as in those varieties, word-final glottal stops correspond to word-final glottalized vowels in the more conservative Zapotitlán Totonac, as shown for the word ‘*ceniza* ash(es)’ in (8). No matter where one stands with respect to the reconstruction of Proto-Totonac-Tepehua (or Proto-Totonacan), pre-Highland-Totonac would have *ɬka̰ka̰ for this lexical item, implying that Zapotitlán is fully conservative with regard to the vocalic phonation contrast.

(8) *Glottalized vowels and glottal stops across Highland Totonac varieties:*

Zapotitlán	Zongozotla	Coatepec/Huehuetla	Gloss
ɬka̰ka̰	ɬka̰kaʔ	ɬkakaʔ	‘*ceniza*, ash(es)’

Other varieties behave like ZoT, at least for short glottalized vowels. In Olintla Totonac the phonetic reflex of historical word-final *V̰ is [Vʔ] (proto long glottalized vowels have become modal). But whereas we analyze ZoT as having innovated a *contrastive* glottal stop in that position, Tino Antonio (2020, p. 14) still treats word-final glottal stops as allophones of /V̰/. Thus, on the surface Olintla resembles ZoT (also in terms of its implementation of glottalized vowels with tense voice; see Section 3), but the two varieties are analyzed as having different phonological interpretations of the word-final [ʔ].

Thus the sound change that led to the loss of glottalized vowels in ZoT, as well as other varieties like Coatepec, Huehuetla (Troiani, 2007), and Olintla (Tino Antonio, 2020), can be formulated as follows: *V̰# > Vʔ#. Thus, glottalized vowels and glottal stops in ZoT are in complementary distribution because, at some earlier stage of the language, word-final glottalized vowels ended in a glottal stop. Language users then reinterpreted these final glottal stops as consonants following modal vowels, instead of as the phonetic implementation of word-final glottalized vowels.

Why would some varieties show diachronic loss of the phonation contrast? We argue that the relatively small number of contrasts (Davletshin, 2019) contributed to the partial or full loss of the phonation contrast. As we discussed in Section 3, the functional load of the phonation contrast is low, both in ZoT and across the family.When there is competition in the lexicon, such as when a word has at least one minimal pair competitor, we can expect hyperarticulation of the phonetic attributes that help differentiate competitors (Nelson and Wedel, 2017; Wedel et al., 2018). Conversely, a relative dearth of competition is associated with phonetic hypoarticulation. Moreover, a higher functional load of a contrast can inhibit diachronic loss of that contrast (Wedel et al., 2013). Therefore, diachronic phonation weakening and loss across Highland Totonac varieties can have its origins in functional considerations of the contrast, namely the lack of competition between lexical items differing in terms of phonation type. It may also help explain why glottalized vowels are phonetically so weakly differentiated from modal ones. Are glottalized vowels realized as only weakly non-modal because of the lack of competition in the lexicon, because the contrast is undergoing diachronic loss, for both these interrelated reasons, or for independent reasons? We don't know the answer, but we suspect both functional load and an ongoing change towards phonation loss are at play.

6 Discussion and conclusion

Throughout this paper we have argued that contrasts involving glottalization—both glottal stops and glottalized vowels—are marginal in Zongozotla Totonac. Glottal stops have a limited phonotactic distribution within the word, and only surface when that word occurs phrase-finally. Glottalized vowels are phonetically weak, produced with only slight increased constriction that is variably realized phonetically both across pairs and speakers; the contrast between glottalized and modal vowels also has a low functional load. And then the contrast between glottalized vowels and glottal stops is only marginally contrastive, with the two categories occurring in complementary distribution due to their historical state of allophony.

In the previous section, we appealed to synchronic factors as well as to diachronic considerations to account for most of the relevant facts. In this section, we go a step further by hypothesizing as to why a sound change rule like *V̰# > Vʔ# would exist in the first place, and why glottal stops are so strongly realized in ZoT, in contrast to the typological tendency for glottal stops to be mostly voiced (Garellek et al., 2023). We propose that both facts are accounted for by what we call the *constraint against phrase-final voicing*. Across Totonac languages, researchers report that phrase-final vowels devoice, and that sonorants devoice or are weakly voiced (Aschmann, 1946; Troiani, 2007; Román Lobato, 2008; McFarland, 2009; Puderbaugh, 2019; Tino Antonio, 2020; Garcia-Vega, 2022). Interestingly, in Totonac the constraint against phrase-final voicing contrasts with another constraint against voiceless sounds appearing before a phrase-medial word boundary. The constraint against word-final voiceless sounds (within a phrase) sometimes leads to epenthesis (Román Lobato, 2008; McFarland, 2009), but presumably is also the reason for the loss of word-final glottal consonants in phrase-medial position, as we showed in (3) and Figure 2.

The constraint against phrase-final voicing, however, leads to both the retention and strengthening of the glottal consonants, which remain voiceless. Vowels also devoice in this position, as do sonorant consonants (albeit more variably). Although we described the constraint as active in Totonac, it is worth noting that it may in fact be an areal, i.e. Mesoamerican (DiCanio and Bennett, 2020), constraint. Similar patterns are found across Mayan languages (Bennett, 2016), in Chicontepec Nahuatl (Aguilar, 2020), and in Mexico City Spanish (Avelino, 2018; Dabkowski, 2018). The constraint is also phonetically motivated in utterance-final position, because ends of utterances are associated with low subglottal pressure, more vocal fold spreading and higher transglottal flow (Slifka, 2006), which together favor breathiness and devoicing, as well as irregular voicing, in the form of unconstricted spread-glottis creak (Keating et al., 2015; Garellek, 2019).

The constraint against phrase-final voicing is clearly active in ZoT and other varieties of Totonac. Assuming that it has long been present in the language, it may also account for the posited sound change whereby *V̰# > Vʔ#. That rule was posited for word-final position, but its source may in fact be specifically utterance-final: the pressure to devoice utterance-finally led modal vowels to devoice, but also led to glottalized vowels' ending in a glottal stop. And since glottal stops represent more strongly produced glottalization than voiced glottalization (Garellek et al., 2023), this change can be considered a form of prosodic strengthening of glottalization. Thus, glottal stops emerged from strengthening of /V̰/ in utterance-final position due to the constraint against utterance-final voicing. Glottal stops were subsequently reanalyzed by language users as lexically-contrastive sounds. But since in ZoT and other varieties [ʔ] is only found phrase-finally, some researchers have understandably argued that the glottal stop is an inserted phrasal marker (e.g. in Ozelonacaxtla; Román Lobato, 2008) or might be becoming one (e.g. in Filomena Mata; McFarland, 2009). While that might be true in those varieties of Totonac, in ZoT we favor the lexical analysis. If [ʔ] were a phrasal marker, why would it only be found after vowels that are historically derived from *V̰?

While it is generally the case that prosodic strengthening is more common in domain-initial rather than domain-final positions, which typically is manifested by lengthening

(Fougeron and Keating, 1997; Keating et al., 2003; Cho, 2016). Phrase-final strengthening is attested across languages of the world (Tabain, 2003; Cho, 2005). In Mesoamerica specifically, it has been documented for Itunyoso Trique (DiCanio, 2010) and Yoloxóchitl Mixtec (DiCanio et al., 2015), though in the latter case it is unclear whether the prosodic strengthening is due to prominence or domain-finality, or both.

If glottal stops developed from historical glottalized vowels in utterance-final position, what happened to word-final glottalized vowels in utterance-medial positions? Our assumption is that the glottal stop realization must have spread from utterance-final to word-final position, such that all glottalized vowels would have been realized as [Vʔ] word-finally at some intermediate stage of the language. (This would indicate generalization from utterance-final position to other domain-final positions, as posited for obstruent devoicing (Westbury and Keating, 1986; Myers and Padgett, 2015).) If that is indeed what occurred, then we also have to account for the absence in phrase-medial position of glottal stops on the surface: recall that word-final /ʔ/ do not surface unless they are also utterance-final. But because word-final /h/ is also prohibited from surfacing in phrase-medial position (3), then we can assume that the absence of both /h/ and /ʔ/ reflects the constraint against voiceless sounds appearing before a phrase-medial word boundary. The upshot is that the constraint against phrase-final *voicing* likely led to the development of glottal stops from historically glottalized vowels, but the constraint against *voiceless* sounds before a phrase-medial word boundary is what lead to their frequent alternations with zero in the current state of the language, as shown in (9).

(9) *Diachronic and synchronic processes involving glottalization:*

Proposed sound changes	*Phrase-final*	*Phrase-medial*
Phrase-final devoicing	*V̰ > [Vʔ]	
Generalization to word-final position		*V̰ > /Vʔ/
Synchronic rule	*Phrase-final*	*Phrase-medial*
/h, ʔ/ → ∅ / ___#[		/Vʔ/ → [V]

Our account of ZoT glottalization makes certain predictions that can be tested across the Totonac family. Our first prediction is that the constraint against phrase-final voicing should lead to instances of glottal stops even in varieties that retain word-final glottalized vowels. That is, there may well be varieties of Totonac that retain word-final /V̰ V̰ː/, but in which these sounds are realized as [V̰ʔ V̰ːʔ] in phrase-final position. Because we hypothesize that phrase-final glottal stops emerged due to the constraint against phrase-final voicing, we also predict that, if there exist varieties without that constraint, they will *not* show correspondences between historical *V̰ and any glottal stops that might occur. Finally, because the weaker phonetic realization of glottalized vowels in ZoT is tied to the gradual loss of the phonation contrast, and because ZoT doesn't show evidence for word-final long vowels (of any phonation type), we suspect that Totonac languages with strongly phonetic realizations of glottalized vowels should retain the phonation contrast even in long vowels that occur word-finally. We leave these predictions for future work.

In conclusion, we have analyzed different aspects of glottalization in the phonology of Zongozotla Totonac, and claim that glottal stops likely developed from word-final glottalized vowels in order to satisfy a broad-acting constraint against phrase-final voicing in Totonac. But overall, glottalization in ZoT is marginal across the board: glottal stops only appear at ends of phrases, and are in complementary distribution with glottalized vowels. For their part, glottalized vowels are only weakly distinct phonetically from modal vowels, perhaps because the contrast itself has a low functional load and thus could be considered marginal. An important message to be gleaned from ZoT is that the intermediate phonological relationships that lead to marginal contrasts (Hall, 2013) can arise from high up the prosodic hierarchy. Only by comparing patterns of sounds at different prosodic levels can we arrive at a complete picture of their behavior.

Notes

[1]Glosses will appear throughout in both Spanish (in italics) and in English to ensure that examples are accessible to Totonac speakers and Spanish-speaking Totonac-language researchers.

[2]In the working orthography for ZoT, certain allophonic processes are indicated. For example, vowel lowering adjacent to uvulars is always marked, and word-final vowels that devoice phrase-finally are not marked when the word appears in isolation, but are marked when the vowel is retained. Thus depending on its position, /pṵ:qu/ can be written as either *p'o:qo* or *p'o:q*. But throughout the paper, we will include the orthographic variant of a word that most closely aligns with its phonemic transcription, unless otherwise indicated.

[3]The working orthography for the language marks stress using acute accents: stress goes unmarked if it occurs on the penult, otherwise it is marked.

References

Aguilar, A.E., 2020. Phonology and phonetics of laryngeal sounds in Chicontepec Nahuatl. Ph.D. thesis. University of California, San Diego.

Arana Osnaya, E., 1953. Reconstrucción del protototonaco. Revista Mexicana de Estudios Antropológicos 23, 123–130.

Aschmann, H., 1946. Totonaco phonemes. International Journal of American Linguistics 12, 34–43. doi:10.1086/463885.

Aschmann, H., Wonderly, W.L., 1952. Affixes and implicit categories in Totonac verb inflection. International Journal of American Linguistics 18, 130–145. doi:https://doi.org/10.1086/464163.

Aschmann, H.P., 1983. Vocabulario totonaco de la Sierra. 2 ed., SIL International, Mexico City.

Avelino, H., 2018. Mexico City Spanish. Journal of the International Phonetic Association 48, 223–230. doi:https://doi.org/10.1017/S0025100316000232.

Beck, D., 2023. Totonacan languages, in: Wichmann, S. (Ed.), The Languages and Linguistics of Middle and Central America: A Comprehensive Guide. Mouton de Gruyter, Berlin.

Bennett, R., 2016. Mayan phonology. Language and Linguistics Compass 10, 469–514. doi:https://doi.org/10.1111/lnc3.12148.

Brown, C.H., Beck, D., Kondrak, G., Watters, J.K., Wichmann, S., 2011. Totozoquean. International Journal of American Linguistics 77, 323–372. doi:https://doi.org/10.1086/660972.

Brown, C.H., Wichmann, S., Beck, D., 2014. Chitimacha: a Mesoamerican language in the Lower Mississippi Valley. International Journal of American Linguistics 80, 425–474. doi:https://doi.org/10.1086/677911.

Bürkner, P.C., 2018. Advanced bayesian multilevel modeling with the R package brms. The R journal 10, 395–411. doi:https://doi.org/10.32614/RJ-2018-017.

Chai, Y., 2022. Phonetics and phonology of checked phonation, syllables, and tones. Ph.D. thesis. University of California San Diego.

Chai, Y., Garellek, M., 2022. On H1–H2 as an acoustic measure of linguistic phonation type. Journal of the Acoustical Society of America 152, 1856–1870. doi:https://doi.org/10.1121/10.0014175.

Cho, T., 2005. Prosodic strengthening and featural enhancement: Evidence from acoustic and articulatory realizations of /ɑ,i/ in English. Journal of the Acoustical Society of America 117, 3867–3878. doi:https://doi.org/10.1121/1.1861893.

Cho, T., 2016. Prosodic boundary strengthening in the phonetics–prosody interface. Language and Linguistics Compass 10, 120–141.

Dabkowski, M.F., 2018. Variable vowel reduction in Mexico City Spanish. Ph.D. thesis. The Ohio State University.

Davletshin, A., 2019. Laryngealized vowels and laryngealized consonants in the history of the Totonacan languages of Mexico. Journal of Language Relationship 17, 177–196. doi:10.31826/jlr-2019-173-404.

Dawson, H., Garellek, M., López-Francisco, O., Amith, J.D., 2022. Tense voice without the high f0: the case of glottalized vowels in Zongozotla Totonac. doi:https://doi.org/10.1121/10.0016292. Poster presented at the Fall 2022 meeting of the Acoustical Society of America.

DiCanio, C., Bennett, R., 2020. Mesoamerica, in: Gussenhoven, C., Chen, A. (Eds.), The Oxford Handbook of Language Prosody. Oxford University Press, Oxford, pp. 408–427. doi:10.1093/oxfordhb/9780198832232.013.25.

DiCanio, C., Nam, H., Amith, J.D., García, R.C., Whalen, D.H., 2015. Vowel variability in elicited versus spontaneous speech: Evidence from Mixtec. Journal of Phonetics 48, 45–59. doi:dx.doi.org/10.1016/j.wocn.2014.10.003.

DiCanio, C.T., 2010. Itunyoso Trique. Journal of the International Phonetic Association 40, 227–238. doi:10.1017/s0025100310000034.

Eberhard, D.M., Simons, G.F., Fennig, C.D., 2023. Ethnologue: Languages of the World, Twenty-sixth edition. http://www.ethnologue.com. (Last checked July 16, 2023). URL: `http://www.ethnologue.com`.

Esposito, C.M., Khan, S., 2020. The cross-linguistic patterns of phonation types. Language and Linguistics Compass 14, e12392. doi:https://doi.org/10.1111/lnc3.12392.

Fougeron, C., Keating, P.A., 1997. Articulatory strengthening at edges of prosodic domains. Journal of the Acoustical Society of America 101, 3728–3740.

Garcia-Vega, M., 2022. Morphology of Zihuateutla Totonac. Ph.D. thesis. University of Alberta.

Garellek, M., 2014. Voice quality strengthening and glottalization. Journal of Phonetics 45, 106–113. doi:dx.doi.org/10.1016/j.wocn.2014.04.001.

Garellek, M., 2019. The phonetics of voice, in: Katz, W., Assmann, P. (Eds.), Routledge Handbook of Phonetics. Routledge, Oxford, pp. 75–106. doi:https://doi.org/10.4324/9780429056253-5.

Garellek, M., 2022. Theoretical achievements of phonetics in the 21st century: Phonetics of voice quality. Journal of Phonetics 94, 1–22. doi:https://doi.org/10.1016/j.wocn.2022.101155.

Garellek, M., Chai, Y., Huang, Y., Van Doren, M., 2023. Voicing of glottal consonants and non-modal vowels. Journal of the International Phonetic Association 53, 305–332. doi:10.1017/s0025100321000116.

Gordon, M., Ladefoged, P., 2001. Phonation types: a cross-linguistic overview. Journal of Phonetics 29, 383–406. doi:https://doi.org/10.1006/jpho.2001.0147.

Hall, K.C., 2013. A typology of intermediate phonological relationships. The Linguistic Review 30, 215–275. doi:https://dx.doi.org/10.1515/tlr-2013-0008.

Herrera Zendejas, E., 2021. Mecapalapa Tepehua. Journal of the International Phonetic Association doi:https://doi.org/10.1017/S0025100321000098.

Hyman, L.M., 1988. The phonology of final glottal stops, in: Proceedings of the 1st Western Conference on Linguistics (WECOL1). California State University, Fresno, pp. 113–130.

Kawahara, H., de Cheveigné, A., Patterson, R.D., 1998. An instantaneous-frequency-based pitch extraction method for high-quality speech transformation: revised TEMPO in the STRAIGHT-suite, in: ICSLP-1998, p. 0659.

Keating, P., Cho, T., Fougeron, C., Hsu, C.S., 2003. Domain-initial articulatory strengthening in four languages, in: Local, J., Ogden, R., Temple, R. (Eds.), Phonetic Interpretation (Papers in Laboratory Phonology 6). Cambridge University Press, Cambridge, pp. 143–161.

Keating, P., Garellek, M., Kreiman, J., 2015. Acoustic properties of different kinds of creaky voice, in: Proceedings of the 18th International Congress of Phonetic Sciences, Glasgow.

Kiparsky, P., 2014. New perspectives in historical linguistics, in: Bowern, C., Evans, B. (Eds.), The Routledge Handbook of Historical Linguistics. Routledge, London and New York, pp. 64–102.

Levy, P., 1987. Fonología del totonaco de Papantla, Veracruz. Universidad Nacional Autónoma de México, Mexico City.

MacKay, C.J., Trechsel, F.R., 2018. An alternative reconstruction of Proto-Totonac-Tepehua. International Journal of American Linguistics 84, 51–92. doi:10.1086/694609.

McFarland, T.A., 2009. The phonology and morphology of Filomeno Mata Totonac. Ph.D. thesis. University of California, Berkeley. Berkeley, CA.

McQuown, N.A., 1976. Vocabularios totonacos: Hueytlalpan, Olintla, Ozomatlán, Papantla, Tajín, Tepanco, Zapotitlán, Zongozotla (recopilados en el invierno de 1940 por Norman A. McQuown), in: Microfilm collection of manuscripts on cultural anthropology. University of Chicago. number 188 in XXXV.

Myers, S., Padgett, J., 2015. Domain generalisation in artificial language learning. Phonology 31, 399–433.

Nelson, N.R., Wedel, A., 2017. The phonetic specificity of competition: Contrastive hyperarticulation of voice onset time in conversational English. Journal of Phonetics 64, 51–70. doi:https://doi.org/10.1016/j.wocn.2017.01.008.

Puderbaugh, R., 2019. Phonetics and phonotactics of vowel laryngealization in Upper Necaxa Totonac, in: Calhoun, S., Escudero, P., Tabain, M., Warren, P. (Eds.), Proceedings of the 19th International Congress of Phonetic Sciences, Melbourne, Australia. pp. 2085–2089.

Renwick, M.E.L., Ladd, D.R., 2016. Phonetic distinctiveness vs. lexical contrastiveness in non-robust phonemic contrasts. Laboratory Phonology 7, 1–29. doi:http://dx.doi.org/10.5334/labphon.17.

Román Lobato, G., 2008. La juntura fonológica en el totonaco de Ozelonacaxtla, Huehuetla, Puebla. Master's thesis. CIESAS.

Shue, Y.L., Keating, P.A., Vicenik, C., Yu, K., 2011. VoiceSauce: A program for voice analysis, in: Proceedings of the International Congress of Phonetic Sciences, Hong Kong. pp. 1846–1849.

Sjölander, K., 2004. Snack sound toolkit. Stockholm KTH. URL: `http://www.speech.kth.se/snack`.

Slifka, J., 2006. Some physiological correlates to regular and irregular phonation at the end of an utterance. Journal of Voice 20, 171–186. doi:https://doi.org/10.1016/j.jvoice.2005.04.002.

Tabain, M., 2003. Effects of prosodic boundary on/aC/sequences: articulatory results. Journal of the Acoustical Society of America 113, 2834–2849. doi:https://doi.org/10.1121/1.1564013.

Tino Antonio, J., 2020. Las vocales laringizadas y su manifestación fonética en el totonaco de Olintla. Lingüística Mexicana. Nueva Época 2, 7–30.

Troiani, D., 2007. Fonología y morfosintaxis de la lengua totonaca. Municipio de Huehuetla, Sierra Norte de Puebla. Instituto Nacional de Antropología e Historia. Colección científica 515. Mexico City.

Ulrich, C.H., 1993. The glottal stop in Western Muskogean. International Journal of American Linguistics 59, 430–441. doi:https://doi.org/10.1086/466212.

Wedel, A., Kaplan, A., Jackson, S., 2013. High functional load inhibits phonological contrast loss: A corpus study. Cognition 128, 179–186. doi:https://doi.org/10.1016/j.cognition.2013.03.002.

Wedel, A., Nelson, N., Sharp, R., 2018. The phonetic specificity of contrastive hyperarticulation in natural speech. Journal of Memory and Language 100, 61–88. doi:http://dx.doi.org/10.1016/j.jml.2018.01.001.

Westbury, J.R., Keating, P.A., 1986. On the naturalness of stop consonant voicing. Journal of Linguistics 22, 145–166. doi:https://doi.org/10.1017/S0022226700010598.