The phonetics and phonology of Uspanteko (Mayan)*

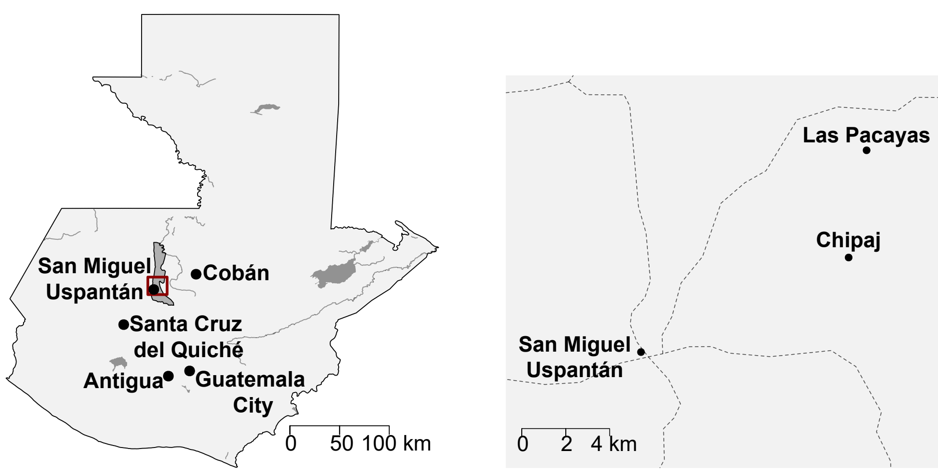
Ryan Bennett, Meg Harvey, Robert Henderson, Tomás Alberto Méndez López

Uspanteko is an endangered Mayan language spoken by up to 6000 people in the Guatemalan highlands. We provide an overview of the phonetics and phonology of Uspanteko, focusing on phenomena which are common in Mayan languages and/or typologically interesting. These include glottalized consonants (ejectives, implosives, and glottal stop), uvular consonants, vowel length contrasts, syllable structure, stress, and lexical tone. Tone is unusual among Mayan languages, especially in Guatemala, and the phonetic description here complements the small handful of existing descriptions of tone in Uspanteko and within the Mayan family.

1 The Uspanteko language

Uspanteko (ISO 639-3: usp) is a K'ichean-branch Mayan language spoken in the municipality of San Miguel Uspantán in the department of El Quiché, Guatemala (Fig. 1).

Figure 1: To the left: map of Guatemala, with the municipality of Uspantán shaded. Boxed region indicates inset area to the right. To the right: Inset showing communities with >200 native speakers of Uspanteko, according to Us Maldonado (no date(b)), with major roads shown dashed.



*We thank the Uspanteko speakers whose recordings we describe here, and all the speakers who have helped us better understand their language – k'omo chawe chaq! We also thank the Comunidad Lingüística Uspanteka for their generous support of our work, and for making this research possible. We are particularly grateful to Salvador Pinula Ical, Rosa Lidia Ajpoop, Alejandro Pedro Vázquez Tay, Devora Ixcoy Patzan, and Juana Bernadina Ajpop Tiquiram for their help over the years. Two reviewers provided thoughtful feedback which helped improve the content and presentation of this paper. This research was supported by NSF grants BCS/DEL-1757473 (to Bennett) and BCS/DEL-1551666 (to Henderson). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Autonyms for the Uspanteko language include *Tz'unun Tziij* ('Hummingbird Word'), *Tz'unun Yolooj* ('Hummingbird Speech'), and *Tz'unun Tziijb'al* ('Hummingbird Language') (Us Maldonado 2010, no date(b)). These names accord with *Tz'unun Kaab'* ('Sweet Hummingbird'), a post-classic fortified city that the Uspanteko people inhabited until the colonial period, which began for the Uspantekos in 1529 (Us Maldonado no date(b)). The toponym *Uspantán*, and thus the language name *Uspanteko*, comes from Nahuatl *Uzpantlan* ('Walled City of Hummingbirds'), which owes to the Nahuatl-speaking guides, advisors, and troops that accompanied the colonial Spanish as they moved into Guatemala.

Uspanteko is endangered, with an estimated number of speakers ranging from 1200 (Richards 2003) to 5850. The latter figure comes from a 2018-2019 survey by the Comunidad Lingüística Uspanteka (CLU), the organization tasked by the Guatemalan government with supporting and promoting Uspanteko language and culture (see also Us Maldonado no date(b), who reports about 4000 speakers). The count of 1200 speakers reported by Richards (2003) comes from the official 1994 Guatemalan Census, which systematically undercounts speakers of Indigenous languages and members of Indigenous communities (Fischer & Brown 1996). The most recent 2018 census counted 4909 Uspanteko speakers (`https://www.censopoblacion.gt/`).

In some communities children are still acquiring Uspanteko as their first language, particularly in the town of Las Pacayas (Fig. 1). However, many children in the traditional Uspanteko area are now learning Spanish or K'iche' as their primary language(s). (K'iche', a closely related Mayan language with over 1 million speakers, sometimes serves as a lingua franca in the Guatemalan highlands.) This pattern of language shift is reinforced in the local school system, which prioritizes Spanish and K'iche' (Can Pixabaj 2007, Us Maldonado no date(b):Ch. 3). Essentially all Uspanteko speakers are bilingual in K'iche' and/or Spanish. Uspanteko-speaking households also sometimes include speakers of Q'eqchi' and Poqomchi', two related K'ichean languages spoken mostly to the east. Lastly, speakers of Ixil, a more distantly related Mamean language, are also found in the Uspanteko region. Henderson et al. (to appear) speculate that historical contact with Ixil may be responsible for some of the unique grammatical properties which clearly distinguish Uspanteko from other K'ichean languages.

Documentation of Uspanteko is limited relative to better-studied Mayan languages, including other languages of the K'ichean branch. Still, grammars, dictionaries, and other descriptive materials do exist for Uspanteko, most of which were written with the participation of native speakers (e.g. Comunidad Lingüística Uspanteka 2001, Can Pixabaj 2007, Vicente Méndez 2007, Us Maldonado 2010, no date(a), and other publications by the Comunidad Lingüística Uspanteka). These materials, along with Stoll (1884, 1887, 1888, 1896), Huff & Huff (1971), Grimes (1971, 1972), Kaufman (1976), Campbell (1977), Bennett & Henderson (2013), Bennett et al. (2019, 2022, ms.), and Henderson et al. (to appear), constitute the bulk of the primary descriptive literature on Uspanteko. (For additional sources, see England & Zavala Maldonado 2013, Us Maldonado no date(b), and `http://www.language-archives.org/language/usp`.)

The phonetics and phonology of Uspanteko are particularly interesting because Uspanteko has innovated a system of contrastive, grammatically-controlled lexical tone. No other Guatemalan Mayan language has a comparable tone system, though lexical tone does occur in a few Mayan languages in Mexico which are only distantly related to Uspanteko (Bennett 2016, DiCanio & Bennett 2021, Bennett et al. 2022). As discussed in Bennett & Henderson (2013) and Bennett et al. (ms.), the tone system of Uspanteko exhibits complex interactions with word-level prosodic phenomena like stress, weight, and syncope. Additionally, the tone system shows complex interactions with sentence-level prosodic factors related to focus / giveness and intonational boundary tones (Bennett et al. 2019, 2022). The phonetics and phonology of Uspanteko are thus critically important for understanding the prosody of Mayan languages more broadly.

2 Data collection

We have carried out regular fieldwork with Uspanteko speakers in Guatemala since 2010. Data for the quantitative analyses presented here were collected from 9 native speakers of Uspanteko in 2018 (3 male, 6 female; 23-50 years old, mean 35, median 30, SD = 9.6). Eight speakers were from the town of San Miguel Uspantán, and one from the nearby village of La Lagunita. The speakers each produced a list of 182 target words (or short phrases), presented on index cards in Spanish with suggested Uspanteko translations on the back. Most speakers were familiar with most of the words on these cards, though they occasionally volunteered variant translations. The speakers also produced different numbers of items due to disfluencies and repetitions during the task. The words were produced in the frame sentence *Yaj Tek'* _____ *tijb'ij* [ˈjaχ ˈtekˀ _____ tiχ.ˈɓiχ] 'Diego says _____'. The analysis is based on 1612 total target words, and 2420 total vowels (see Appendix for further details).

Recordings were made in a quiet room with a headset microphone (Audio-Technica ATM73a) and solid-state portable recorder (Zoom H5), at a 48 kHz sampling rate with 24 bit quantization. The recordings were transcribed in the Uspanteko orthography, then converted to phonetic transcriptions using custom Python scripts. The recordings were segmented into word- and phoneme-level annotations using forced alignment (McAuliffe et al. 2017). These semi-automatic, time-aligned segmentations were then hand-corrected by trained undergraduate coders.[1] The recordings in question may be downloaded in their entirety at `https://github.com/rbennett24/articles/tree/master/Uspanteko_phonetic_description`; see Garellek et al. 2020 for related recommendations. For purposes of illustration, these recordings were occasionally supplemented by additional recordings made by co-author Méndez López, as well as selected recordings taken from our previous fieldwork on the language.

All plots in this article were drawn with the `ggplot2` package in `R` (Wickham 2016, R Development Core Team 2020), and phonetic diagrams were drawn with `Praat` (Boersma & Weenink 2020). Spectrograms were generated with a window length of 7.5 ms, a timestep of 1 ms, and a frequency step of 20 Hz.

3 Consonants

There are 22 consonant phonemes in Uspanteko, across 6 places of articulation (Table 1):

[1]We thank Ivona Borissova, Zarya Mejia, Edward Martínez, Michael Ward, and Sonia Domínguez for their excellent work on these corrections.

Table 1: Uspanteko phonemic consonant inventory, including common inter-speaker and/or context-free phonetic variation.

	Bilabial	**Alveolar**	**Post-alveolar**	**Velar**	**Uvular**	**Glottal**
Stop	p ɓ̥/pˀ	t tˀ		k kˀ	q qˀ/ʛ̥	ʔ
Affricate		t͡s t͡sˀ	t͡ʃ t͡ʃˀ			
Fricative		s	ʃ	x/χ		
Nasal	m	n				
Glide	w		j			
Lateral		l				
Rhotic		ɾ/r/ɾ̥				

Voicing is not contrastive in Uspanteko. Instead, voiceless oral stops and affricates /T/ contrast with glottalized counterparts /Tˀ/ at the same place of articulation. Glottalized stops and affricates are typically realized as ejectives, though the glottalized labial stop is normally a voiceless implosive /ɓ̥/, and the glottalized uvular stop /qˀ/ often has voiceless implosive realizations [ʛ̥] alongside frequent ejective productions [qˀ].

We transcribe the 'basic' form of the glottalized labial as implosive /ɓ̥/ because that is its most characteristic realization. Additionally, the phonotactic patterning of /ɓ̥/ distinguishes it from other glottalized stops in Uspanteko and other Mayan languages (Bennett 2016), which may further justify treating it as fundamentally implosive rather than ejective (see section 5.1.8 below). For similar reasons, we transcribe the basic form of the glottalized uvular as an ejective /qˀ/ rather than an implosive, though both phonetic variants of this sound do occur.

The alveolar ejective /tˀ/ is a somewhat marginal phoneme, occurring in relatively few words, many of which have expressive content (England 2001:26, Bennett 2016). That said, there are minimal and near-minimal pairs establishing contrast between /t/ and /tˀ/, such as *tooj* /toːχ/ 'payment' and *t'ooj* [tˀoːχ] 'throw it!' (Vicente Méndez 2007:257,264).

Additionally, palatalized velar /kʲkˀʲ/ occur in Uspanteko, as in (1) and Fig. 2.[2]

(1) Plain [k] vs. palatalized [kʲ kˀʲ]

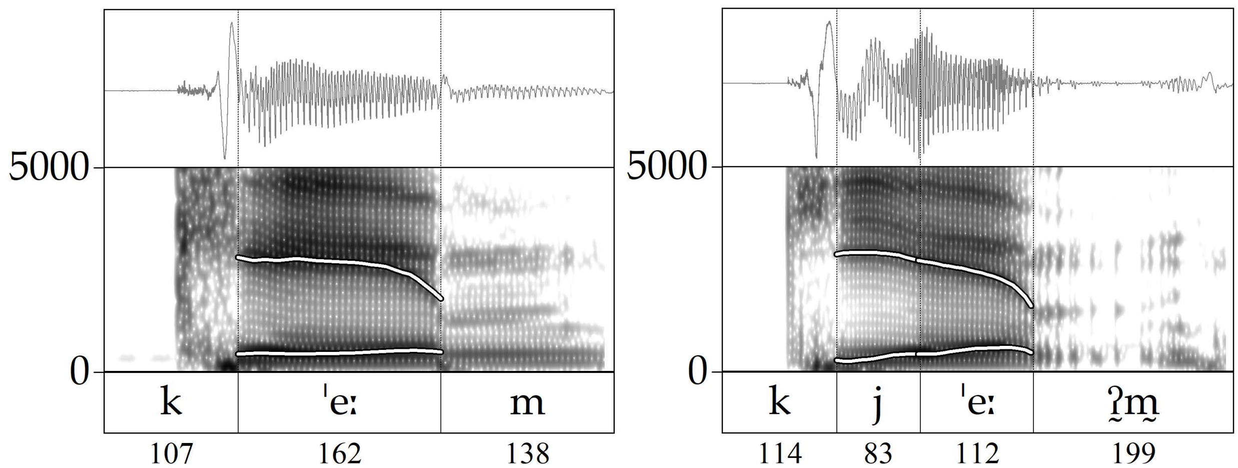
a. *keem* [keːm] 'a weaving'
b. *kee'm* [kʲeːʔm] ∼ [keːʔm] 'ground (ADJ)'
c. *íxk'eq* [ʔíxkˀʲeq] 'fingernails'

[2]Recordings corresponding to the figures and examples in this paper are available at `https://github.com/rbennett24/articles/tree/master/Uspanteko_phonetic_description`.

In segmenting waveforms and spectrograms, we follow the recommendations of Turk et al. (2006): segmental boundaries are marked at points of significant amplitude change (particularly in the F2 region and above), which often coincide with sudden changes in the overall quality of the acoustic spectrum (e.g. the appearance of aperiodic noise for fricatives). These segmental boundaries are necessarily approximate, and segmentation of this sort is an idealization which abstracts away from coarticulatory overlap between segments. In cases of extreme coarticulatory overlap, particularly between glottal stop /ʔ/ and neighboring segments, we opt to include the overlapped segments in a single interval, as in Fig. 2 and section 3.4.

We describe these sounds as ‘palatalized’ in deference to past literature on Mayan languages (Campbell 1977, Ohala 1981, 1993, Bennett 2016, England & Baird 2017 and references there). It may be that they are better analyzed phonologically as stop+glide sequences (section 5.1 below). While the distribution of palatalized velar stops is mostly predictable and allophonic in K’ichean languages, it is possible that they are becoming contrastive in Uspanteko, given doublets like Fig. 2 for some speakers (Campbell 1977, England 2001, Can Pixabaj 2007:Ch. 2.1, England & Baird 2017). This remains a topic for further investigation.

Figure 2: Apparent contrast between plain [k] and ‘palatalized’ [kʲ]: *keem* /keːm/ ‘a weaving’ vs. *kee’m* /kʲeːʔm/ ‘ground (ADJ)’ (speaker 8 LLVM 2018), with approximate F1/F2 values highlighted.



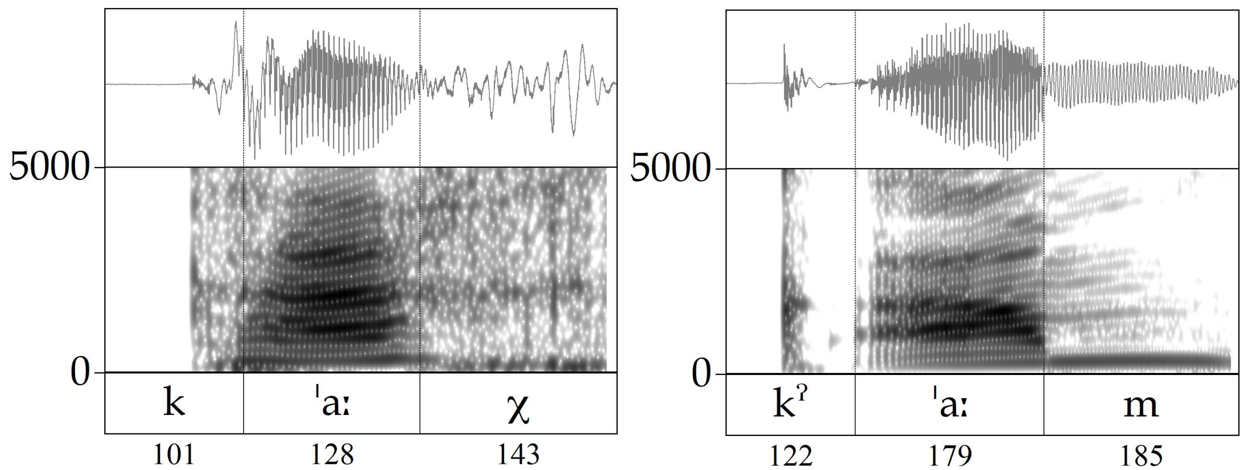
In our phonetic description of consonants we focus on plain and glottalized stops. For commentary on the phonetics of other consonants in Mayan languages, see Bennett (2016), England & Baird (2017), and references there.

3.1 Glottalization

Glottalized consonants are the most studied aspect of the phonetics of Mayan languages (e.g. Campbell 1973, Kingston 1984, Pinkerton 1986, Russell 1997, Burnett-Deas 2009, Frazier 2009a, Shosted 2009, Wagner & Baker-Smemoe 2013, Herrera Zendejas 2014, Kuang 2019; see also Bennett 2016, England & Baird 2017). One of main takeaways of this literature, as well as the numerous descriptive grammars that consider glottalization in detail, is that there is extensive variation in the realization of glottalization across languages, dialects, speakers, and places of articulation in the Mayan family. Much of this variation is localized in the glottalized labial /ɓ̥/ and uvular /qˀ/ stops, which vary between implosive and ejective realizations, /ɓ̥/ tending to be implosive and /qˀ/ tending to be ejective. When realized as implosive, both /ɓ̥/ and /qˀ/ are typically voiceless [ɓ̥ ʠ̥] in Uspanteko, though /ɓ/ is sometimes voiced intervocalically (sections 3.2 and 3.3).

There are some phonetic regularities across glottalized consonants in Uspanteko, be they realized as ejective or implosive. In particular, glottalization tends to be marked by creakiness, or other kinds of laryngealized non-modal phonation, on adjacent vowels and sonorant consonants (Bennett 2016). This is evidenced in pairs like [ˈkaːχ] ‘sky’ and [ˈkˀaːm] ‘cord, twine’ (Fig. 3). In [ˈkˀaːm] ‘cord, twine’, the onset of the vowel following [kˀ] shows weak and irregular voicing corresponding to creaky voice (Gordon & Ladefoged 2001, Keating et al. 2015). This creakiness is noticeably absent on the vowel following [k] in [ˈkaːχ] 'sky'.[3]

Figure 3: Contrast between plain /k/ and ejective /kˀ/: *kaaj* [ˈkaːχ] 'sky' vs. *k'aam* [ˈkˀaːm] 'cord, twine' (speaker 9 PA 2018). X-axis shows segment durations in ms, y-axis shows frequency range of spectrogram in Hz.



Relatedly, f0 is lowered following [kˀ]: the spacing between glottal pulses is wider at the onset of the vowel than at the midpoint, indicating reduced f0 at the CV transition (this is easiest to see in the spectrogram). In contrast, f0 is relatively unperturbed following plain [k]: the spacing between glottal pulses is regular and close at the CV transition, and similar to the spacing at vowel midpoint. Lastly, the amplitude rise time on the vowel is longer following [kˀ] than [k], as can be seen by comparing amplitude at vowel onset vs. midpoint (e.g. Russell 1997, Wright et al. 2002). All of these phonetic effects are consequences of coarticulatory creakiness on the vowel, reflecting some degree of additional glottal constriction.

Along with coarticulatory creakiness, [k kˀ] are also distinguished phonetically by the intensity and quality of their release phases: the burst for [kˀ] is louder, and is followed by a period of silence corresponding to sustained glottal closure after the oral stop release. Additionally, the release phase for [kˀ] is overall longer than the release phase for [k] (about 71 ms vs. 38 ms), though the release noise associated with [kˀ] is perhaps shorter (about 28 ms vs. 38 ms).

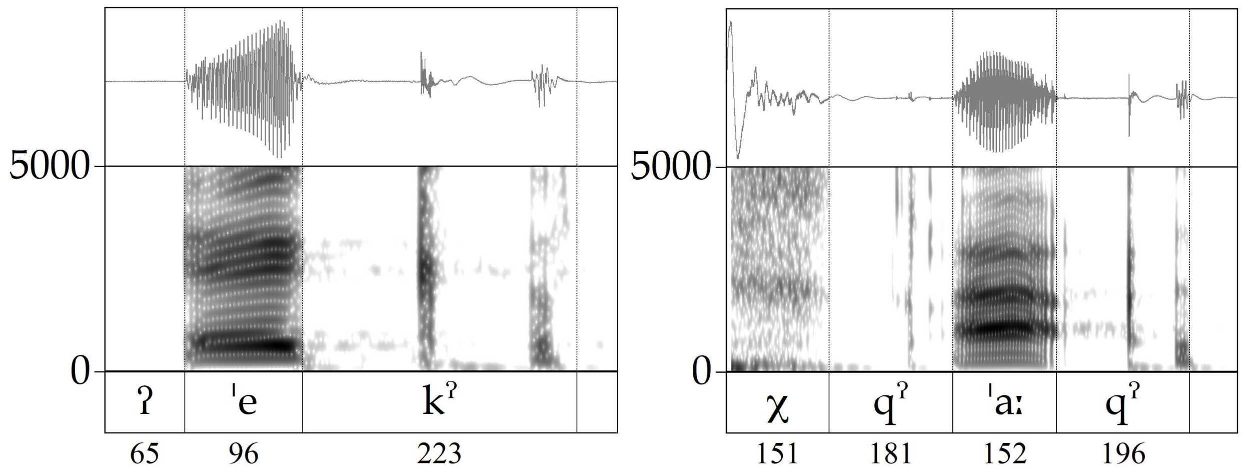
The phonetic differences described above reliably distinguish plain vs. ejective stops in Uspanteko, at least in careful speech (we discuss implosives below in sections 3.2 and 3.3). In spontaneous speech, some of these phonetic cues may be less salient (e.g. the intensity of release bursts and duration of release phases may be reduced in ejectives). Given the extensive phonetic variability associated with glottalized stops in Mayan languages, it seems worthwhile to verify the reliability of these phonetic differences across a larger sample of spoken Uspanteko, from a range of speech styles and genres.

Another sporadic difference between plain stops and ejectives is that ejectives are sometimes realized with a brief interval of voicing following the release of glottal constriction (Fig. 4). Brief

[3]We use the term 'creakiness' with two caveats. So-called 'creaky' voice may have a range of distinct phonetic manifestations (Keating et al. 2015), and coarticulatory laryngealization in Mayan languages does not always involve the irregular, low-frequency vocal fold vibration found in prototypical creaky voice.

voicing after ejective release is most often observed in word-final position.

Figure 4: Brief voiced intervals following glottal release in word-final ejective /kˀqˀ/: *ek’* [ˈʔekˀ] ‘chicken’ and *jq’aaq’* [ˈχqˀaːqˀ] ‘its fire, light’ (speaker 9 PA 2018).

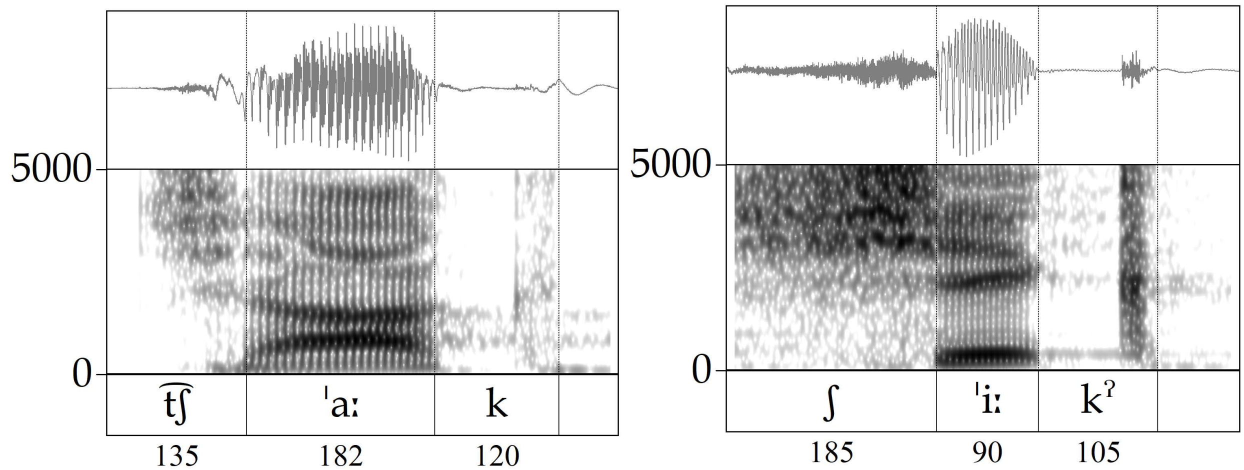


We suspect that these short intervals of voicing at stop release owe to mechanical, aerodynamic factors (Westbury & Keating 1986). If the glottis is tightly constricted during the production of an ejective, air pressure may build-up below the glottis during stop closure (Demolin 2011). When the oral constriction is released, oral air pressure will begin to drop, provided that the glottis remains closed (see Pinkerton 1986, Kuang 2019 for oral pressure traces illustrating exactly this phenomenon in Mayan languages). At this point, sub-glottal air pressure may be substantially higher than oral air pressure, especially if there is a long lag between the release of the oral constriction and the release of the glottal constriction, as in Fig. 4. When the glottal constriction is released, a large disparity between sub-glottal air pressure (high) and oral air pressure (low) will drive rapid airflow through the glottis, encouraging brief passive voicing. In the absence of actual aerodynamic data this proposal remains speculative, but nonetheless strikes us as a plausible explanation for the occasional short bursts of voicing found at ejective release in Uspanteko.[4]

To reiterate, these voicing bursts only *sometimes* occur after glottal release in ejectives. Ejectives are frequently produced without voiced intervals following release, even in final position (Fig. 5). Voiced intervals are never observed for plain stops (Fig. 5), which lack the sub-glottal pressure build-up which may be responsible for occasional, transient voicing after glottal release in ejectives.

[4]A reviewer suggests that our aerodynamic proposal predicts that passive voicing should be a characteristic of ejective releases in *all* languages. However, the articulation of ejectives varies widely across languages (and even speakers), which makes it hard to generalize from the phonetics of ejectives in Uspanteko to other cases (e.g. Lindau 1984, Kingston 1984, 2005, Warner 1996, Wright et al. 2002, etc.). We also suspect that passive voicing associated with ejective release may be underreported, as most phonetic research on ejectives only considers CV contexts, where passive voicing at release would be hard to observe (and in some languages, ejectives only occur in CV contexts, e.g. Fallon 2002).

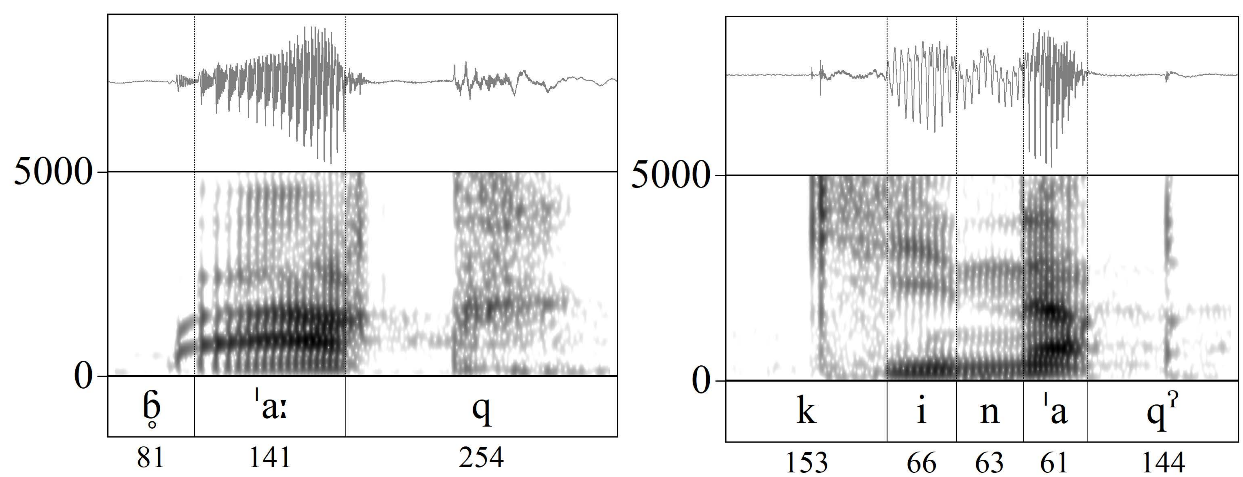
Figure 5: Lack of post-release voicing for word-final plain /k/ and ejective /kˀ/: *chaak* [ˈt͡ʃaːk] ‘work, job’ and *xiik’* [ˈʃiːkˀ] ‘hawk’ (speaker 2 JCT 2018).



3.2 Uvular stops /q qˀ/

The uvular stops /q qˀ/ are sometimes realized with frication noise during the transition from a preceding vowel (Fig. 6). This is particularly true for plain /q/, which is commonly realized with a noisy, affricate-like release in coda position as well (Fig. 6). Even in pre-vocalic position, plain /k q/ are often produced with fairly long and noisy releases (Figs. 6, 7; see also Fig. 33 below).[5]

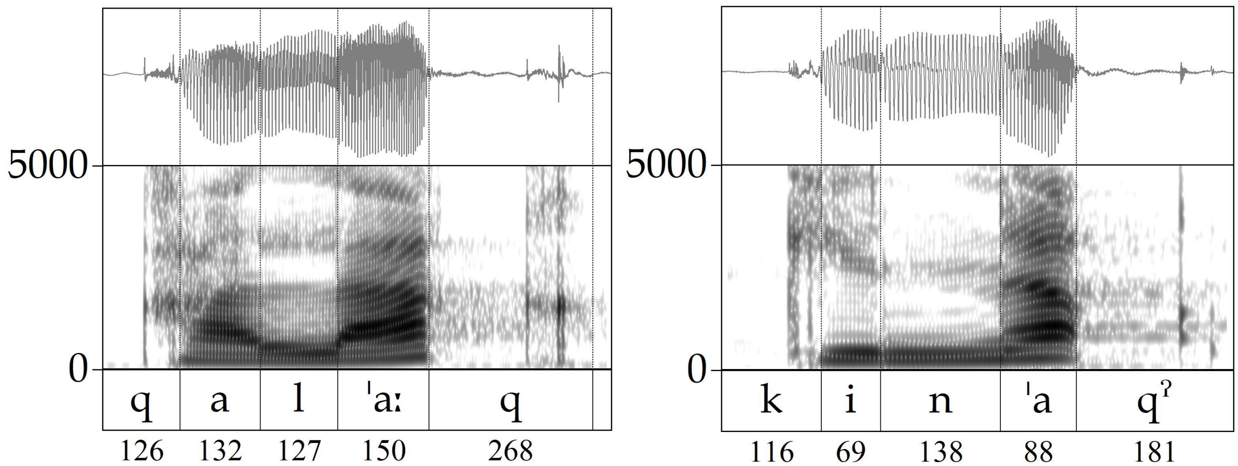
Figure 6: Frication noise preceding and following closure for plain /q/, but not ejective /qˀ/: *b’aaq* /ɓ̥aːq/ → [ˈɓ̥aːᵡq͡χ] ‘bone’ vs. *kinaq’* [ki.ˈnaqˀ] ‘bean’ (speaker 6 JMS 2018).



[5] Can Pixabaj (2007:Ch. 2) reports that plain stops are allophonically aspirated before consonants and word-finally — essentially, in coda position. Comparable patterns of allophonic aspiration are often reported for other Mayan languages (Bennett 2016, England & Baird 2017). In our own experience with Uspanteko and the related Mayan language Kaqchikel, aspiration of plain stops (and affricates) mostly occurs in utterance-final position, and even then, only variably (see e.g. Fig. 32 below). Unreleased and/or unaspirated stops are quite common in coda position, contrary to standard descriptions. See Sobrino Gómez (2018:p.92-5) and Adell (2019:Ch. 2) for similar observations in more distantly related Mayan languages.

These noisy transitions probably reflect the fact that the dorsum is a slow-moving articulator: the formation and release of dorsal stops may involve extended phases in which oral constriction is incomplete, but narrow enough to produce frication noise. Glottalized [kˀ qˀ] lack these noisy transitions, likely because glottal closure during [kˀ qˀ] inhibits frication by reducing airflow through the oral tract.[6]

Figure 7: Long, noisy release intervals for dorsal /k q/: *qalaaq* /qalaːq/ → [qa.ˈlaːqᵡ] 'our dish, bowl' vs. *kinaq'* /kinaqˀ/ → [ki.ˈnaqˀ] 'bean' (speaker 5 DEIP 2018). Mid-frequency noise during stop closures reflects ambient environmental sound, not speech.

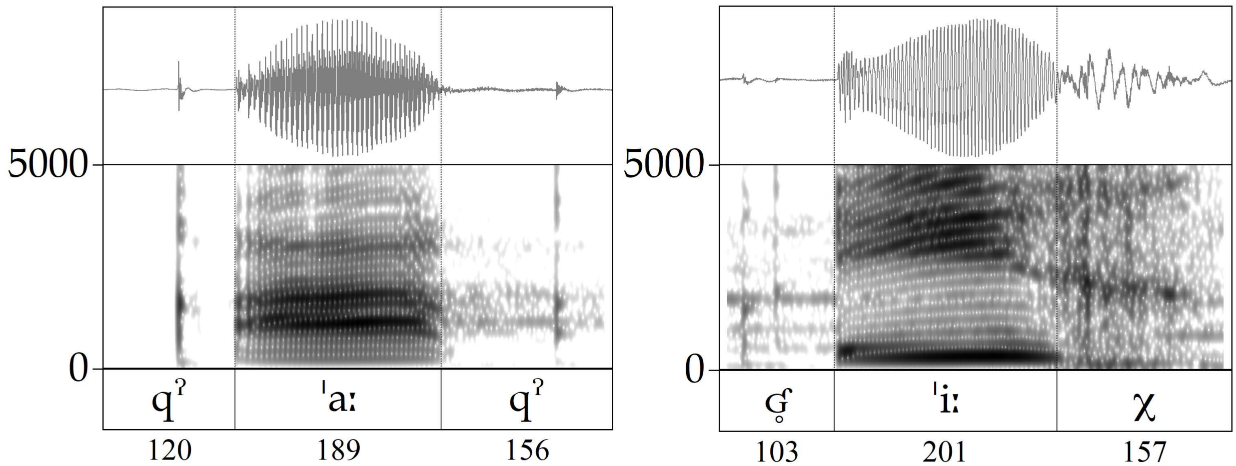


As noted above, the glottalized uvular /qˀ/ is often realized as ejective [qˀ], but also as the voiceless implosive [ʠ̥]. This variation can occur in the speech of a single speaker, and seems unconditioned in that [qˀ] and [ʠ̥] variants occur in essentially the same phonetic environments (Fig. 8).[7]

[6]Shigeto Kawahara points out that the relatively small volume of air behind a dorsal constriction may lead to greater oral air pressure during closure for dorsal stops than for stops at other places of articulation. This increase in oral air pressure could also contribute to frication at stop release for dorsals.

[7]Implosives can be acoustically distinguished from ejectives and plain stops by the lack of a clear release burst, particularly at CV transitions (see e.g. Lindau 1984, Pinkerton 1986, Henton et al. 1992, Clements & Osu 2002). Though a release burst is sometimes present for implosives, it always involves an initial period of ingressive airflow, which appears as a negative pressure impulse on the waveform (e.g. Fig. 9 and elsewhere). Implosives, unlike ejectives, may also be produced with voicing during closure.

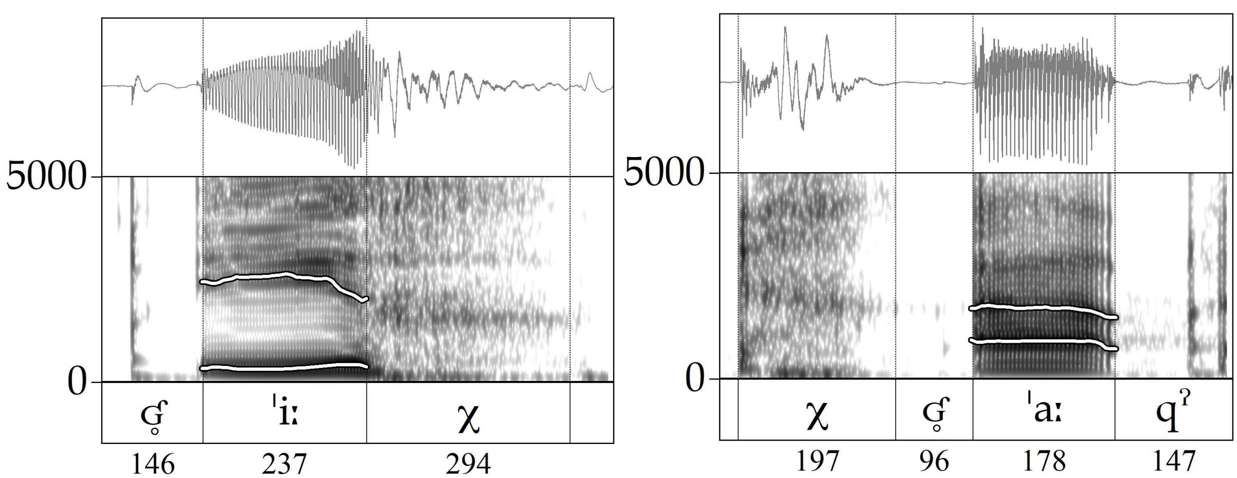
Figure 8: Variation between ejective and implosive realizations of /qˀ/: *q'aaq'* /qˀaːqˀ/ → [ˈqˀaːqˀ] 'fire, light' vs. *q'iij* /qˀiːχ/ → [ˈʛ̥iːχ] 'sun, day' (speaker 5 DEIP 2018). Mid-frequency noise during stop closures reflects ambient environmental sound, not speech.



Ejective [qˀ] is produced with a clear release burst, followed by a period of silence corresponding to glottal closure. Implosive [ʛ̥] lacks an egressive release burst (Clements & Osu 2002). Both [qˀ] and [ʛ̥] allophones can occur with coarticulatory creakiness on adjacent vowels and sonorants.

When implosive, the glottalized uvular /qˀ/ → [ʛ̥] is sometimes auditorily quite similar to [ʔ]. Fig. 9 illustrates: the formant transitions out of /qˀ/ → [ʛ̥] and into the following vowel are relatively flat, as found for glottal stop (e.g. Borroff 2007 and Fig. 18 below); this contrasts with the more dynamic formant movements (particularly F2 lowering) observed during the transition from the vowel into the following uvulars [χ] and [qˀ] (e.g. Alwan 1986, Reetz & Jongman 2011:Ch.10).

Figure 9: Relatively flat CV formant transitions in /qˀ/ → [ʛ̥]: *q'iij* /qˀiːχ/ 'sun, day' (speaker 4 DAP 2018) and *jq'aaq'* /χqˀaːqˀ/ 'its fire, light' (speaker 8 LLVM 2018), with approximate F1/F2 values highlighted.



In certain dialects of other K'ichean-branch Mayan languages, historical /qˀ/ is described as pharyngeal or pharyngealized (e.g. Larsen 1988, Patal Majzul et al. 2000:25-6, England 2001).

These innovative pronunciations may be related to the [ʔ]-like realization of implosive /qˀ/ → [ʛ̥] seen above.

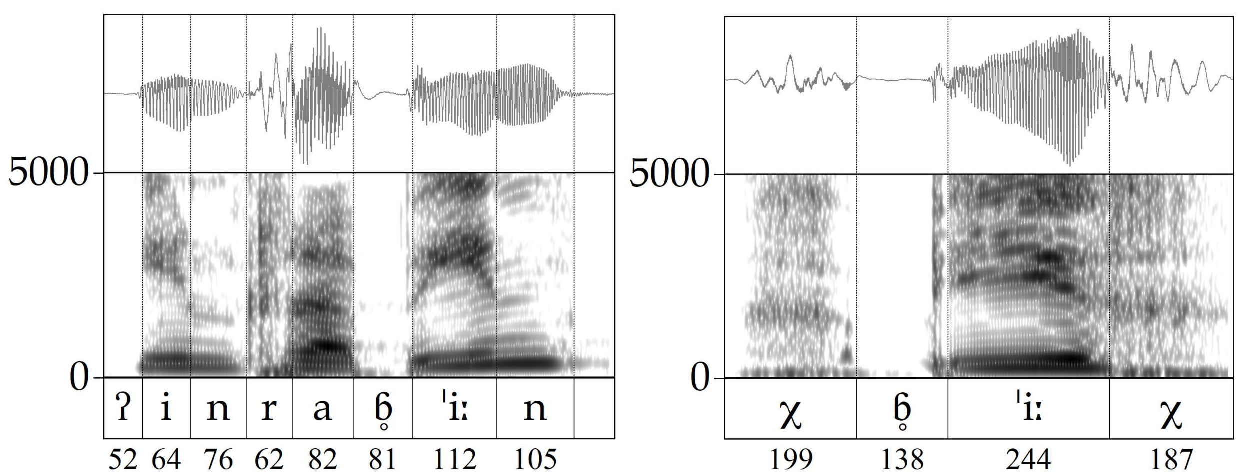
Ejective realizations of /qˀ/ may also have flat, steady formant transitions into a following vowel, as in e.g. Fig. 14 below. However, ejective [qˀ] is more easily distinguished from [ʔ] by its clear release burst, which may include acoustic cues to its uvular articulation (e.g. the duration, intensity, and spectral shape of the burst; Alwan 1986, Cho & Ladefoged 1999, Raphael 2005).

The flat formant transitions sometimes found after ejective [qˀ] and implosive [ʛ̥] probably reflect the fact that the tongue body can move towards the posture for a following vowel as soon as the uvular constriction is released, *before* the release of the glottal constriction. Formant transitions associated with tongue body movement may not be audible (or visible) if produced with simultaneous glottal closure, since a tight glottal constriction will sharply restrict airflow through the vocal tract.

3.3 Implosive /ɓ̥/

The glottalized labial in Uspanteko is normally produced as a voiceless implosive [ɓ̥] (Fig. 10).

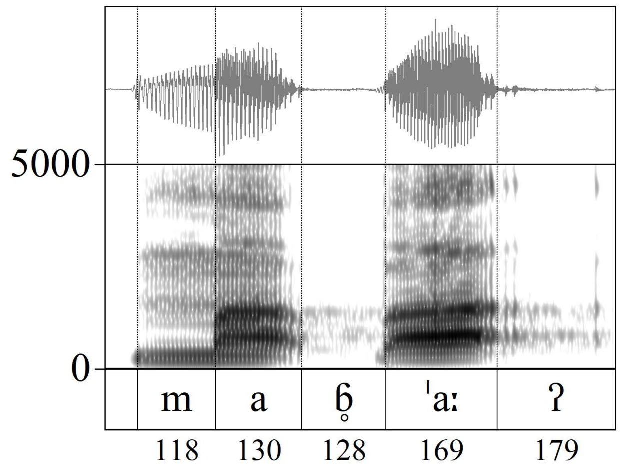
Figure 10: Voiceless implosive [ɓ̥]: *inrab'iin* [ʔin.ra.ˈɓ̥iːn] 'my daughter (of a man)' (speaker 1 FIES 2018) and *jb'iij* [ˈχɓ̥iːχ] 'his/her name' (speaker 4 DAP 2018).



Implosive [ɓ̥] usually lacks anything resembling a release burst, though sometimes a clear negative impulse can be seen in the waveform at the transition between stop closure and a following vowel. This negative impulse plausibly corresponds to ingressive airflow associated with implosion at the release of the oral constriction. A negative impulse of this type can be seen in Fig. 10 (right panel), and in Fig. 9 above for implosive /qˀ/ → [ʛ̥] (left panel).

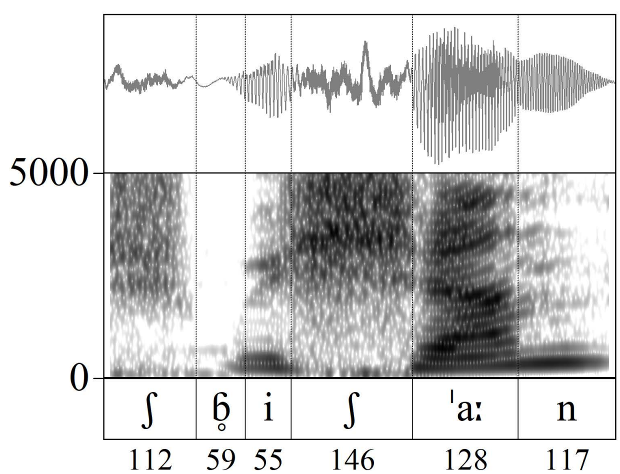
As with all other glottalized stops in Uspanteko, the glottalized labial /ɓ̥/ may condition creakiness on adjacent vowels and sonorants (Fig. 11, and also Fig. 6 above).

Figure 11: Creakiness preceding [ɓ̥]: *mab'aa'* [ma.ˈɓ̥aːʔ] 'poor' (speaker 4 DAP 2018).



Additionally, brief periods of voicing can sometimes be found at or just before the release of implosive [ɓ̥] (Figs. 10, 11, 12). We again assume that this transitory voicing is a mechanical by-product of increased transglottal airflow, which occurs when the glottal closure for the implosive is released, and the compressed air below the glottis begins to flow outward again.[8]

Figure 12: Brief voicing preceding [ɓ̥] release: *xb'ixaan* [ʃɓ̥i.ˈʃaːn] '(s)he sang' (speaker 1 FIES 2018).



Implosive /ɓ̥/ is sometimes realized as ejective [pˀ], particularly in word-final position (Fig. 13). Even in word-final position, ejective [pˀ] realizations of the glottalized labial vary with implosive [ɓ̥] (Fig. 14).

[8]Words like [ʃɓ̥i.ˈʃaːn] (Fig. 12) and *tk'ixib'* [tkˀi.ˈʃiɓ̥] '(s)he gets embarrassed' imply that onset clusters can contain consonants which disagree in their values for the feature [±CONSTRICTED GLOTTIS], *contra* Kehrein & Golston (2004). However, such examples are usually morphologically complex (e.g. /ʃ-ɓ̥iːʃ-aːn/ and /t-kˀiʃ-iɓ̥/), and their actual syllabification is not entirely clear (see section 5.1).

Figure 13: Ejective realizations of /ɓ̥/ in final position: *ojob’* /oχoɓ̥/ → [ʔo.ˈχopˀ] ‘cough’ and *jq’aab’* /χqˀaːɓ̥/ → [ˈχʛ̥aːpˀ] ‘his/her hand’ (speaker 9 PA 2018).

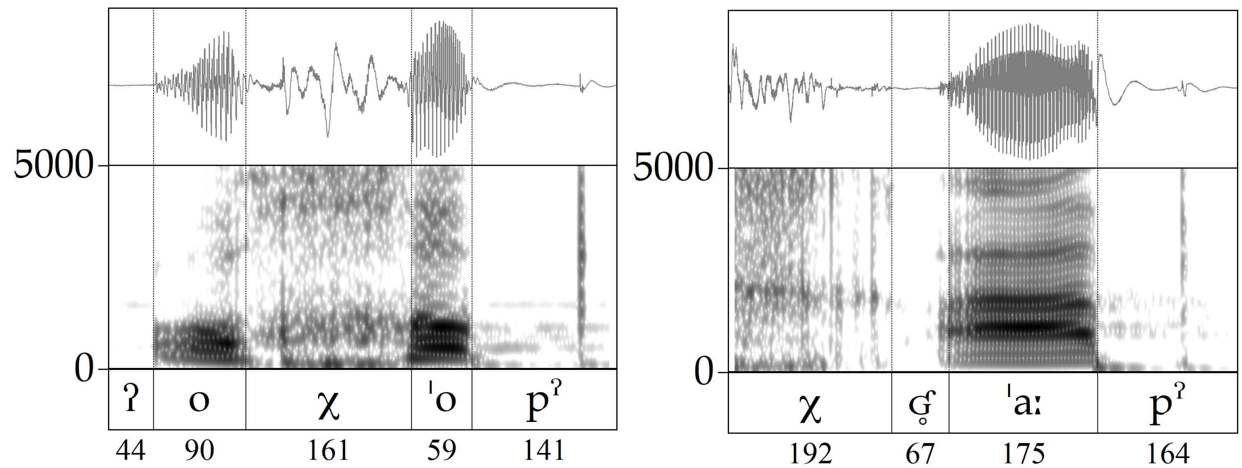
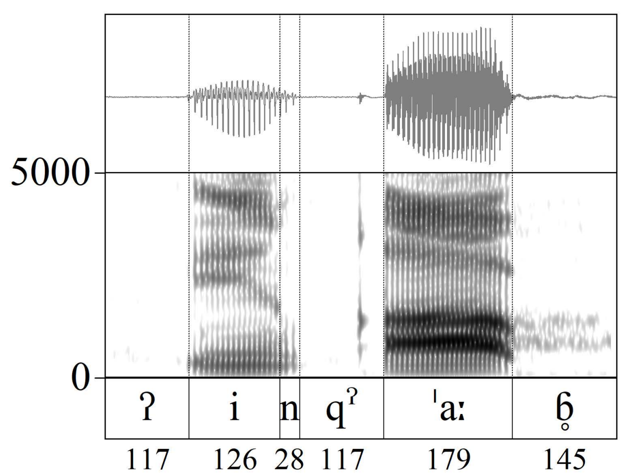
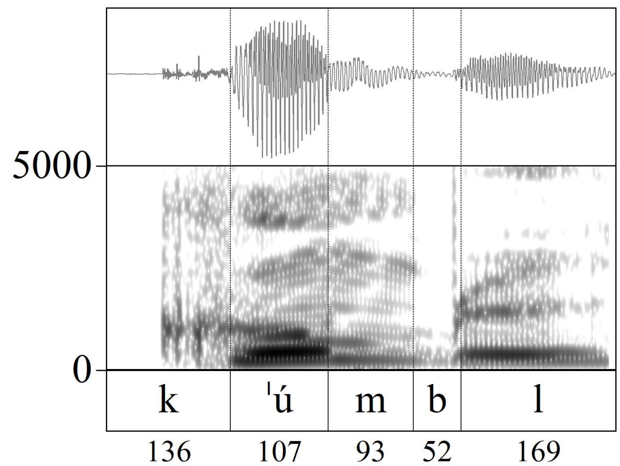


Figure 14: Implosive realization of /ɓ̥/ in final position: *inq’aab’* /inqˀaːɓ̥/ → [ʔin.ˈqˀaːɓ̥] (speaker 2 JCT 2018).



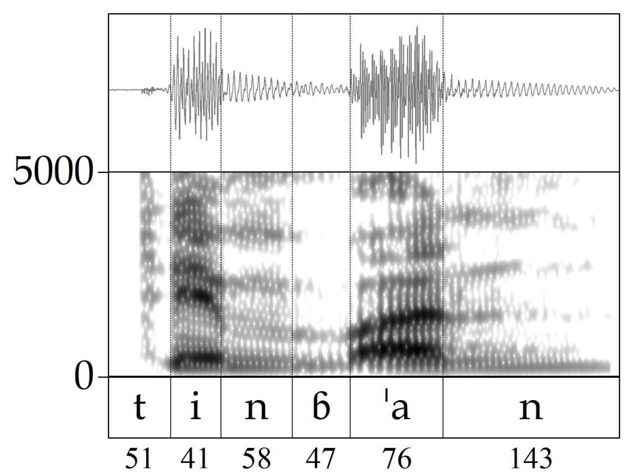
Glottalized /ɓ̥/ is occasionally produced as something closer to a plain voiced stop [b] (Fig. 15). This tends to occur between voiced sounds, particularly voiced consonants, and is more likely in rapid or casual speech.

Figure 15: Plain [b] realization of /ɓ̥/: *kúmb'al* /kúmɓ̥al/ → [ˈkúmbl] 'medicine' (speaker 4 DAP 2018).



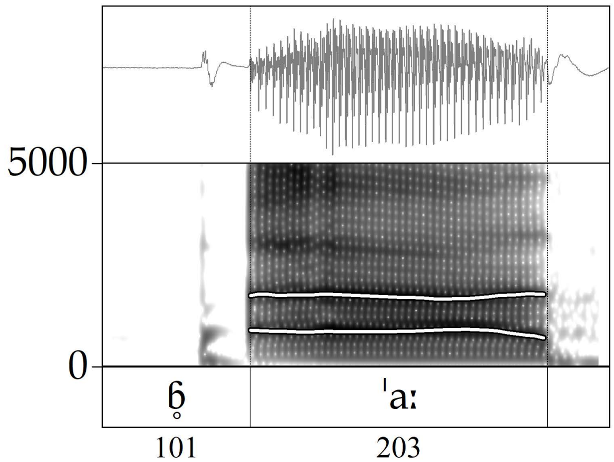
Plain [b] renditions of /ɓ̥/ are relatively infrequent, and seem best analyzed as an example of lenition or hypoarticulation. Indeed, [b]-like realizations of /ɓ̥/ seem to be on a cline of reduction that also includes voiced [ɓ] variants produced in essentially the same environments during running speech (Fig. 16). So while Fig. 15 includes a weak [b]-like release burst absent from Fig. 16, both examples show weak, irregular voicing during stop closure, suggesting a similar laryngeal articulation.

Figure 16: Voiced [ɓ] realization of /ɓ̥/: *tinb'an* /tinɓ̥an/ → [tin.ˈɓan] 'I do it' (speaker VTM 2019).



Like /qˀ/, /ɓ̥/ is sometimes auditorily similar to [ʔ] (section 3.2). This can be seen in Fig. 17: again, the formant transitions from /ɓ̥/ to the following vowel are relatively flat, resembling the transitions for [ʔ].

Figure 17: Relatively flat CV formant transitions in [ɓ̥]: *b'aa* /ɓ̥aː/ 'head' (speaker 8 LLVM 2018), with approximate F1/F2 values highlighted.



In a number of Mayan languages both /qˀ/ and /ɓ̥/ have sometimes merged with [ʔ], at least sporadically: Comalapa Kaqchikel, for example, has [ˈʃʔe] and [nu.ˈqˀaʔ] for historical [ˈʃɓ̥e] '(s)he went' and [nu.ˈqˀaɓ̥] 'my hand' (e.g. Chacach Cutzal 1990, Patal Majzul et al. 2000:25-6, García Matzar & Rodríguez Guaján 1997:30). We speculate that mergers between /qˀ ɓ̥/ and [ʔ] may have been facilitated by [ʔ]-like realizations of both /qˀ/ and /ɓ̥/ (Figs. 9, 17).

3.4 Glottal stop /ʔ/

Glottal stop /ʔ/ is phonemic in Uspanteko, as evidenced by pairs like (2).[9]

(2) Contrastive /ʔ/

a. *jaa* /χaː/ 'house' vs. *jaa'* /χaːʔ/ 'water'
b. *mewaa* /mewaː/ 'fasting' vs. *mab'aa'* /maɓ̥aːʔ/ 'poor'
c. *keem* /keːm/ 'a weaving' vs. *kee'm* /keːʔm/ 'ground ADJ'
d. *kan* /kan/ 'staying in place' vs. *ka'n* /kaʔn/ 'animal'
e. *jki'aal* /χ-kiʔ-aːl/ 'its sweetness' vs. *jpimaal* /χ-pim-aːl/ 'its thickness'

Along with phonemic glottal stop, an epenthetic glottal stop also occurs at the beginning of words which are underlyingly vowel-initial (see Bennett 2016, 2018, England & Baird 2017). Epenthesis can be diagnosed by alternations like those in (3), which show that word-initial glottal stops often disappear under prefixation. Fig. 18 illustrates both phonemic /ʔ/ and epenthetic word-initial [ʔ].

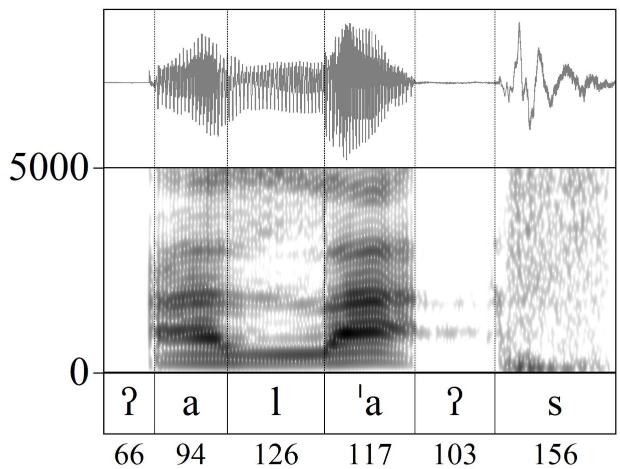
[9] There is extensive lexical variation in the quality and length of phonemic vowels in the Uspanteko community, so that e.g. some speakers have *ja* /χa/ for *jaa* /χaː/ 'house', *ja'* /χaʔ/ for *jaa'* /χaːʔ/ 'water', *meb'a'* /meɓ̥aʔ/ for *mab'aa'* /maɓ̥aːʔ/ 'poor', and so on. Compare e.g. Figs. 21 and 23.

Similarly, whether or not individual roots or affixes introduce high tone (section 5) also varies between speakers. Compare e.g. [ku.ˈt͡sˀiːʔχ] ∼ [ˈkú.t͡sˀiχ] 'flower': both variants are widely attested in Uspanteko, though some speakers characterize the non-tonal form [ku.ˈt͡sˀiːʔχ] as reflecting linguistic influence from K'iche', a closely-related language spoken by many Uspanteko speakers. See Bennett et al. (2022, ms.) for additional discussion of these patterns of lexical variation.

(3) [ʔ] ∼ ∅ alternations indicating [ʔ] epenthesis

a. *íxim* [ˈʔí.ʃim] ‘corn’
b. *wíxim* [ˈwí.ʃim] ‘my corn’

Figure 18: Stop realization of /ʔ/, with full closure, in pre-consonantal position: *ala’s* /alaʔs/ → [ʔa.ˈlaʔs] ‘doll’ (speaker 9 PA 2018).



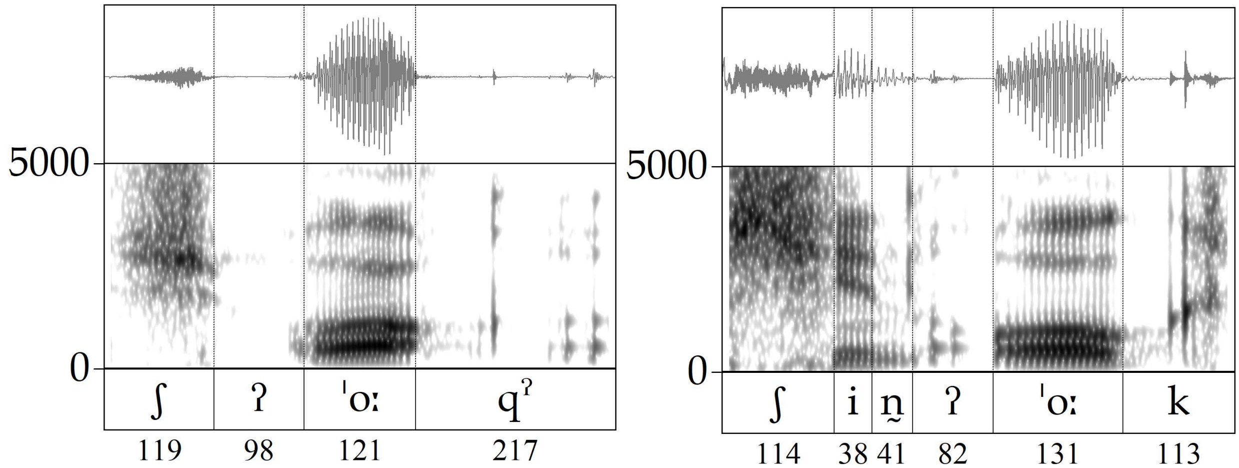
Some word-initial phonetic glottal stops do not alternate with zero, suggesting that they are underlying and phonemic rather than inserted. For example, *aab’* [ˈʔaːɓ̥] ‘hammock’ retains its initial glottal stop under possession, as in *in’aab’* [ʔin.ˈʔaːɓ̥] ‘my hammock’. This implies that [ʔ] is underlying rather than inserted in this noun.

Supporting evidence for this claim comes from prefixal allomorphy. Possessive prefixes take different forms when attaching to vowel-initial vs. consonant-initial stems. The noun *aab’* [ˈʔaːɓ̥] ‘hammock’ takes possessive allomorphs like [ʔin-] ‘my’ that otherwise only occur with consonant-initial stems, not vowel-initial stems (e.g. *inb’aatz’* [ʔin-ˈɓ̥aːt͡sˀ] ‘my thread’ vs. [ˈw-íʃim] ‘my corn’ (3)). This is consistent with treating the non-alternating [ʔ] in *aab’* [ˈʔaːɓ̥] ‘hammock’ as underlying. See Bennett (2016, 2018) and Kaufman (2015) for more discussion.

Word-initial glottal stop can be realized as a full stop and/or creakiness on adjacent sonorants, as in Fig. 18 and other examples in section 3.3 above. Still, word-initial glottal stop is not always phonetically salient, especially in running speech. However, epenthetic word-initial glottal stop is sometimes retained under prefixation, and in these cases the glottal stop is quite clear (Fig. 19).[10]

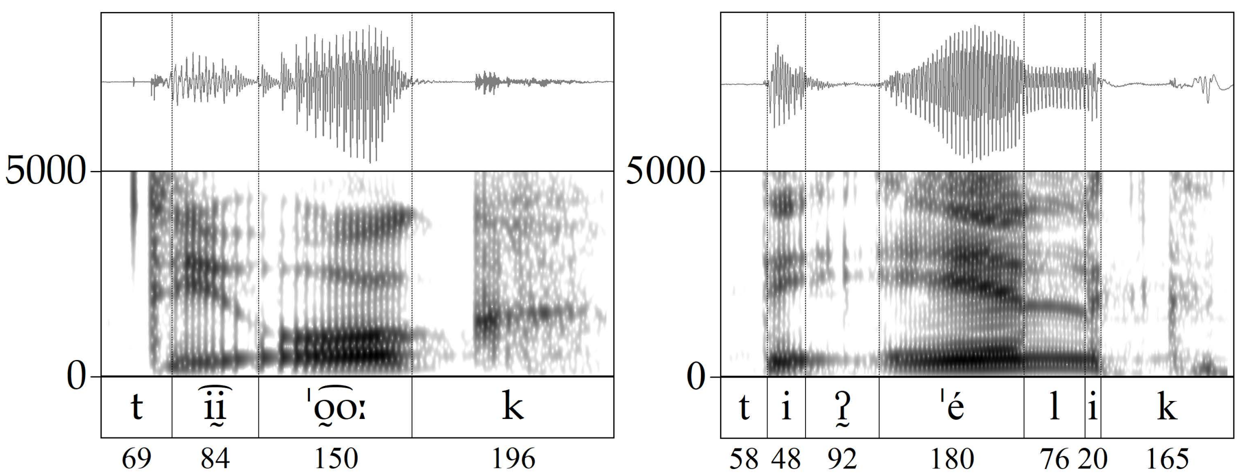
[10]The conditions under which prefixation co-occurs with epenthetic glottal stop are not well-described for Uspanteko. See Barrett (2007), Kaufman (2015), Bennett (2016, 2018), Coon (2017) for parallel patterns in other Mayan languages.

Figure 19: Phonetically salient epenthetic [ʔ] in post-consonantal position: *x'ooq'* [ʃʔoːqˀ] '(s)he cried' vs. *xin'ook* [ʃin̰ʔoːk] 'I entered' (speaker TAML 2020).



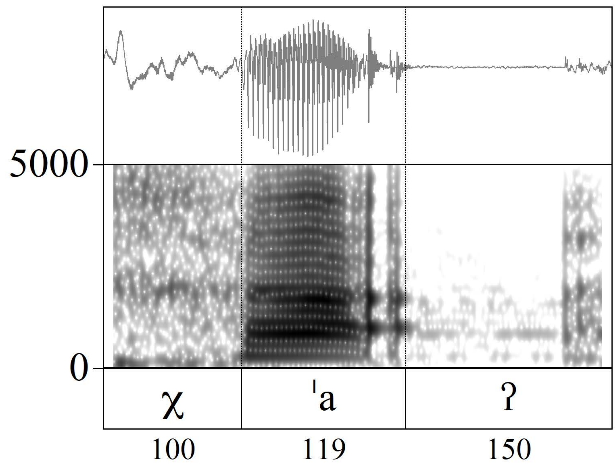
After consonants, glottal stop is typically realized with full closure, often with creakiness on neighboring vowels and sonorants, as in Fig. 19. Between vowels, glottal stop may be realized as a full stop, but is more commonly realized as creakiness on the vowels themselves, or as an interval of creaky voicing with significantly reduced amplitude reflecting glottal constriction between the two vowels (Fig. 20). Note again that creakiness often involves lowering of f0, as is apparent from the wide spacing of voicing striations in the spectrograms in Fig. 20, along with reduced amplitude.

Figure 20: /ʔ/ realized as creakiness and/or partial closure between vowels: *ti'ook* /tiʔoːk/ → [t͡iḭ.ˈo̰͡oːk] '(s)he enters' (speaker TAML 2020) and *ti'élik* /tiʔélik/ → [tiˈʔ̰élik] '(s)he leaves' (speaker 6 JMS 2018).



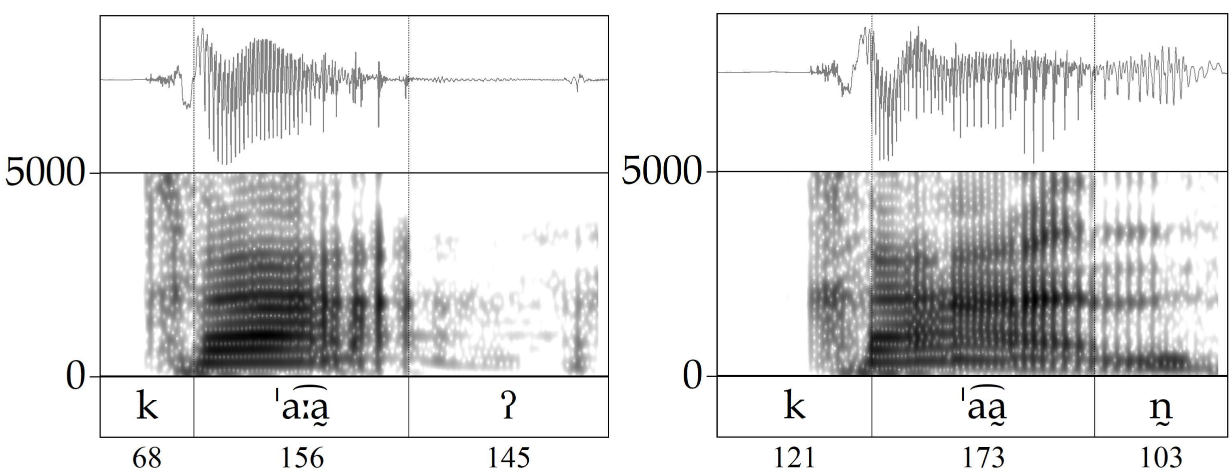
Glottal stop is commonly found in two other environments, /Vʔ#/ and /VʔC#/. Three different phonetic outcomes for /ʔ/ are typical in these environments. First, /ʔ/ may be realized as a true stop, as in Figs. 18, 19 and 21. In final position, this variant of /ʔ/ includes a clear release burst, along with possible creaky voice on the preceding vowel (Fig. 21; see also Fig. 11).

Figure 21: Stop realization of /ʔ/, with full closure, in final position: *ja’* /χaʔ/ → [ˈχa͡a̰ʔ] ‘water’ (speaker 8 LLVM 2018).



Second, /ʔ/ may be realized primarily as extensive creakiness on the preceding vowel, and/or any following sonorant consonant. This is very common for /Vːʔ#/ and /V(ː)ʔC#/ sequences, as in Fig. 22 (see also Fig. 2 above). The glottal stop itself may or may not have an audible release in these cases.

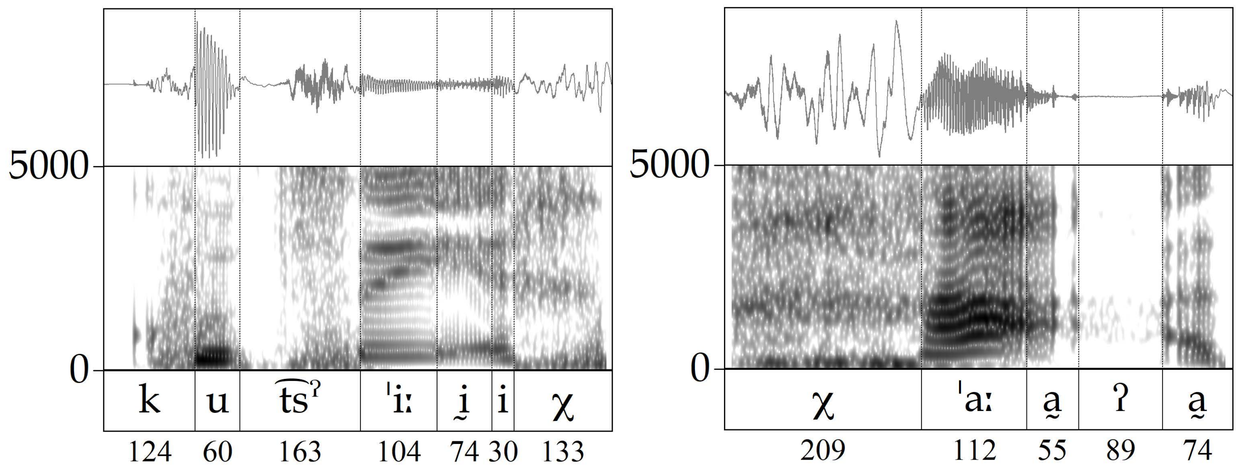
Figure 22: Creaky realizations of /ʔ/ in final and pre-consonantal position: *kaa’* /kaːʔ/ → [ˈkaː͡a̰ʔ] ‘grinding stone’ and *ka’n* /kaʔn/ → [ˈka͡a̰n̰] ‘animal’ (speaker 3 ACAL 2018).



Impressionistically, extensive creakiness of this sort is less common following short vowels in final position, /Vʔ#/. It may be that glottal stop is phonetically and phonologically more like a vowel feature in /Vːʔ#/ and /V(ː)ʔC#/ sequences, and more like an independent consonant in /Vʔ#/ sequences (see also sections 5.1.5 and 5.2 on the fact that /ʔC#/ coda clusters only occur in stressed final syllables, much like long vowels). If this is correct, it seems plausible that /ʔ/ is realized as a vowel feature rather than a consonant in /V(ː)ʔC#/ due to a restriction on the size, weight, and/or composition of syllable rimes in Uspanteko. For further discussion of the consonantal vs. featural status of [ʔ] in Mayan languages, see Bennett & Henderson (2013), Bennett (2016, 2018), England & Baird (2017) and references there. This is a clear topic for future investigation.

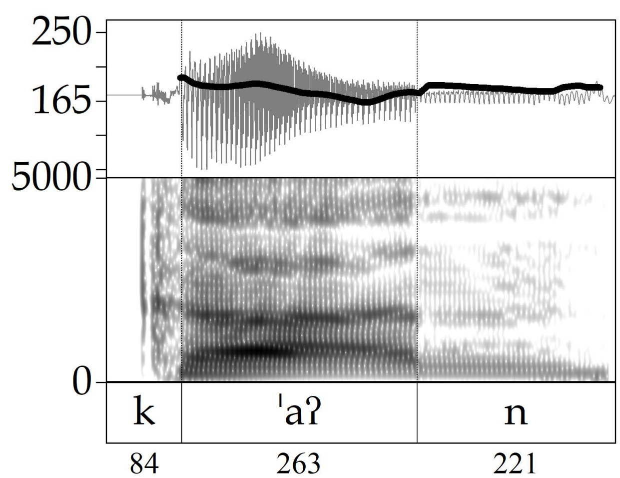
Lastly, /Vʔ#/ and /VʔC#/ sequences may be realized with a ‘rearticulated’ or ‘broken’ vowel. Auditorily, these sound like a modal-voiced vowel that has been interrupted by a glottal stop. Phonetically, the glottal interruption is usually just creaky voice, though true stop realizations do occur as well (Fig. 23).

Figure 23: /ʔ/ realized as vowel ‘rearticulation’ in final and pre-consonantal position: *kutz’ii’j* /kut͡sˀiːʔχ/ → [ku.ˈt͡sˀiː͡ḭiχ] ‘flower’ and *jaa’* /χaːʔ/ → [ˈχaː͡a̰ʔa̰] ‘water’ (speaker 7 JVC 2018). Diagrams are segmented to emphasize changes between modal and non-modal portions of vowel+/ʔ/ sequences.



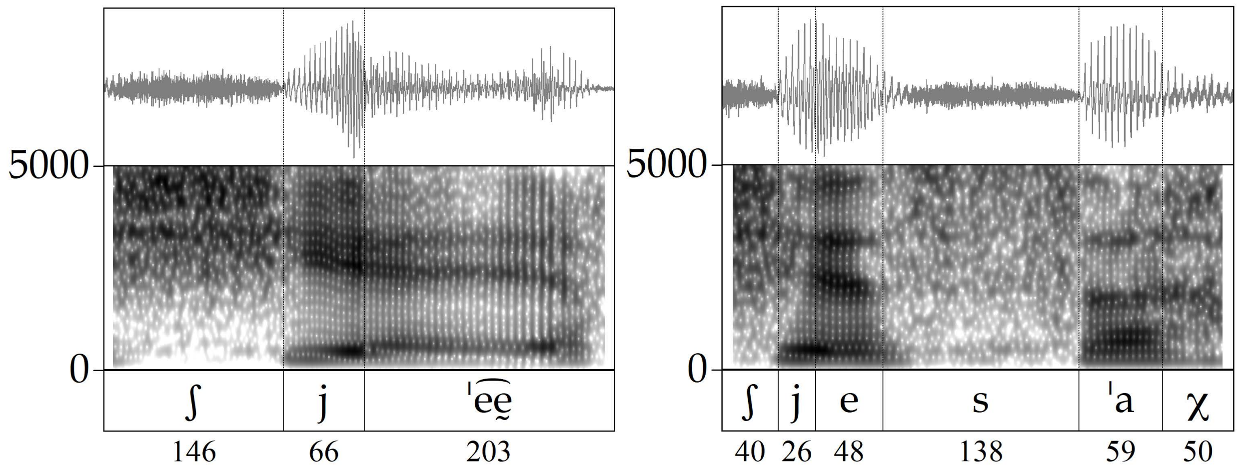
There are some cases where laryngealization associated with /ʔ/ is audible, but not readily apparent as creak in the corresponding audio recording (Fig. 24). Such weak laryngealization may involve dips in intensity and/or f0, without any of the other potential correlates of non-modal phonation (see Gerfen & Baker 2005, Keating et al. 2015).

Figure 24: /ʔ/ realized as weak glottalization in pre-consonantal position: *ka’n* /kaʔn/ ‘animal’ (speaker 4 DAP 2018). f0 superimposed on waveform, with scale in Hz.



Much of what we have said about the phonetics of [ʔ] concerns stressed syllables. In unstressed syllables, [ʔ] may be substantially weakened, sometimes to the point of apparent deletion (Fig. 25).

Figure 25: Apparent /ʔ/-deletion in unstressed positions: *xye'* /ʃ-jeʔ/ → [ˈʃjeḛ͡] '(s)he gave it' vs. *xye'saj* /ʃ-jeʔ-saχ/ → [ʃje.ˈsaχ] 'it was given' (speaker 36 2020).



We are unsure whether coda glottal stop is phonologically deleted in unstressed syllables, or simply phonetically reduced. Understanding the phonetics and phonology of word-medial [ʔ], especially in coda position and in unstressed syllables, is an area of future research.

On the phonetics of glottal stop in other Mayan languages, see Frazier (2009a,b, 2013), Baird (2011), Baird & Pascual (2011), Bennett (2016), England & Baird (2017), Sobrino Gómez (2018), and references there. On glottal variability more generally, see Borroff (2005, 2007), Garellek (2013, 2014), Keating et al. (2015), Whalen et al. (2016), Davidson (2021), Garellek et al. (to appear), and references there.

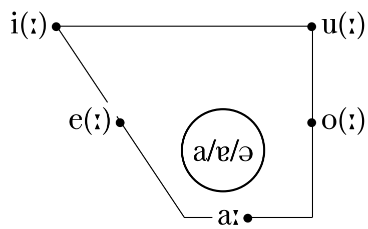
3.5 Other phonetic observations

For reasons of space, we do not discuss the phonetics of other consonants or consonant types in Uspanteko in this paper. On the phonetics of rhotics in Mayan languages, see Romero (2009), Bennett (2016), England & Baird (2017), and references there, as well as Solé (2002). On the phonetics of the dorsal fricative /x/ ∼ /χ/, see Redmon & Jongman (2018), whose phonetic observations about such fricatives accurately characterize the phonetic properties of these sounds in Uspanteko and K'ichean-branch Mayan languages.

4 Vowels

Uspanteko has a fairly common phonemic vowel system: a five-vowel /a e i o u/ inventory, with a length contrast for all vowel qualities (Grimes 1972, Campbell 1977, Maddieson 1984, Can Pixabaj 2007). Length contrasts are restricted, as long vowels can only occur in word-final stressed syllables (section 5). Additionally, short [a] is quite centralized relative to other short vowels, an observation we verify below.

Figure 26: Uspanteko vowel inventory, including common inter-speaker and/or context-free phonetic variation.



(4) Short and long vowels in final syllables

a. *am* /am/ 'spider'
b. *al* /aːl/ 'heavy'

c. *k'ex* /kˀeʃ/ 'harm, damage'
d. *k'eek'* /kˀeːkˀ/ 'stingy, miserly'

e. *ojob'* /oχoɓ̥/ 'a cold'
f. *q'ojoom* /qˀoχoːm/ 'marimba'

g. *k'im* /kˀim/ 'straw'
h. *q'iij* /qˀiːχ/ 'sun, day'

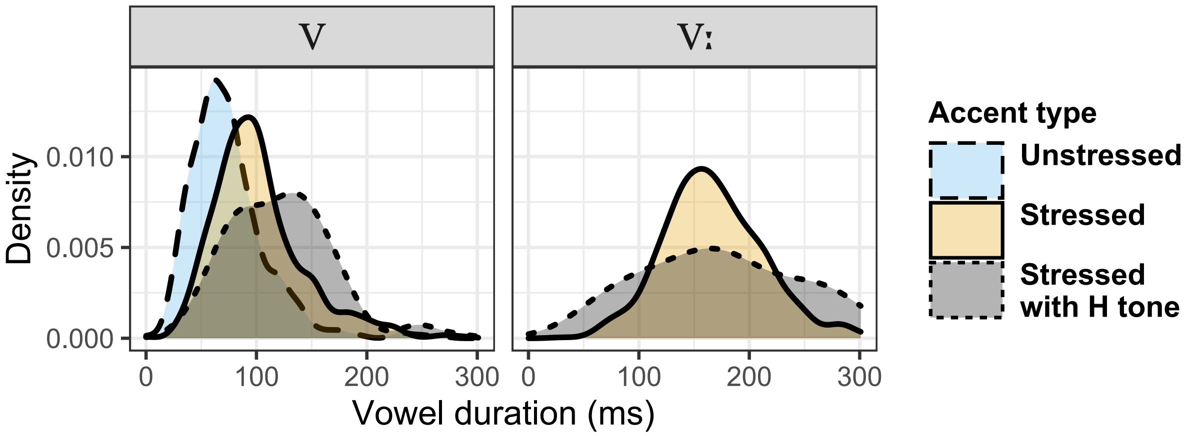
i. *jul* /χul/ 'hole'
j. *muuj* /muːχ/ 'shade'

4.1 Vowel length and vowel duration

The phonemic vowel system /a(ː) e(ː) i(ː) o(ː) u(ː)/ is common in the Mayan family (Bennett 2016, England & Baird 2017). Still, the phonetic realization of this vowel inventory varies even among K'ichean-branch Mayan languages. For example, in closely related K'ichean languages like Tz'utujiil (Dayley 1985), K'iche' (Baird 2010), and Q'eqchi' (Berinstein 1991), long vowels are about twice as long as their short counterparts (see also Sobrino Gómez 2010, Herrera Zendejas 2014 on other Mayan languages). But in Uspanteko — a language which may have diverged from other K'ichean languages fairly early on (e.g. Campbell 1977) — long vowels are less clearly differentiated from short vowels in terms of their duration.

Fig. 27 reports average vowel duration in Uspanteko, grouped by vowel length and accent type (see section 2 on data collection for this analysis). Vowels longer than 300 ms were excluded from this analysis (7 tokens, 0.3% of the data). Here we focus on how vowel length and stress influence duration, and return to the effect of lexical high tone on duration in section 5.3.4.

Figure 27: Vowel duration by phonological vowel length and accent type. Short vowels may be stressed or unstressed, long vowels are always stressed.



In this data set, phonemic long vowels, which are always stressed (section 5), have an average duration of 167 ms. In contrast, stressed short vowels have an average duration of 105 ms. Duration thus clearly distinguishes phonemic long and short vowels ($p < .001$, by two-sided *t*-test).

Unstressed short vowels are reduced relative to stressed short vowels, with an average duration of 74 ms ($p < .001$). This is particularly true for short vowels in post-tonic, unstressed syllables (e.g. *ínpi̱x* [ˈʔímpi̱ʃ] 'my tomato'), which average 60 ms in our data compared to the 75 ms average of pre-tonic short vowels (e.g. *ki̱naq'* [ki̱.ˈnaqˀ] 'bean'; $p < .05$). For related discussion on pre-tonic vs. post-tonic position, see Bennett et al. (ms.).

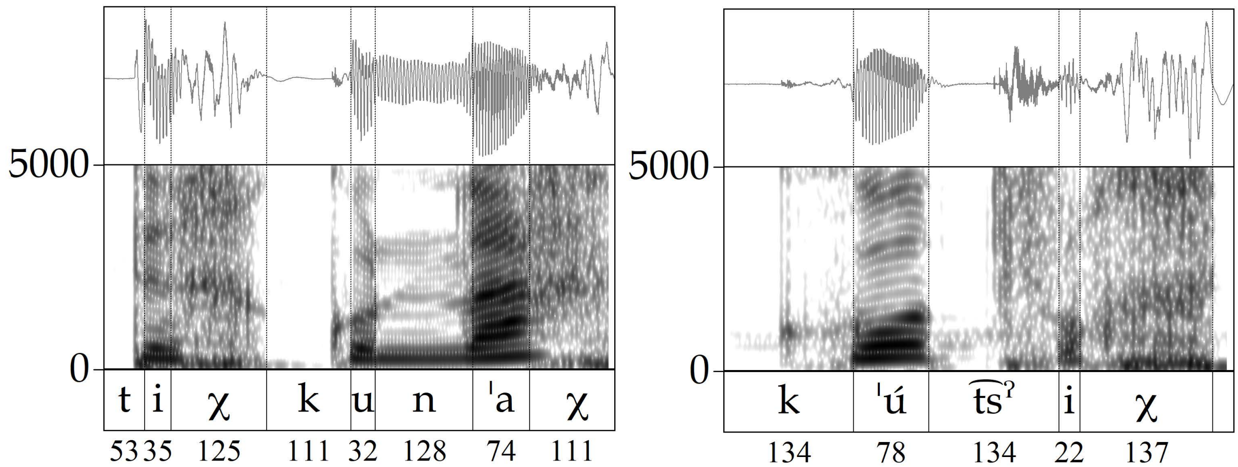
4.1.1 Vowel duration in a Mayan context

Vowel length contrasts in Mayan involve durational differences of various sizes. The surveys in Bennett (2016) and England & Baird (2017) report durational ratios ranging from 1.25:1 to 2:1 for long vs. short vowels in Mayan languages. Proportionally, stressed long vowels in Uspanteko seem to be about 62% longer than stressed short vowels, at least in non-tonal, word-final syllables (section 5). This amounts to a ratio of about 1.6:1, somewhere in the middle of the durational ranges reported for other Mayan languages.

Berinstein (1979) examines the correlates of stress in two other K'ichean languages, Kaqchikel and Q'eqchi'. She reports that vowel duration is a correlate of stress in Kaqchikel, but not in Q'eqchi'. She attributes this difference to the fact that Q'eqchi' has true vowel length contrasts, which may inhibit the use of duration as a cue to stress. Kaqchikel makes use of centralization ('tense-lax') contrasts in its vowel system instead, such as /a e i o u/ vs. /ə ɛ ɪ ɔ ʊ/, though such contrasts did develop historically from earlier length contrasts (e.g. Campbell 1977, Bennett 2019). (See also Vogel et al. 2016, Lunden et al. 2017, van Heuven & Turk 2021 for critical discussion.)

Uspanteko does not quite follow the predictions of Berinstein's (1979) work, as stressed short vowels do seem to be longer than unstressed short vowels (there are no unstressed long vowels, so nothing can be said about cues to stress for long vowels specifically; section 5). However, the phonetic differences between stressed and unstressed short vowels may reflect the fact that unstressed short vowels are often heavily reduced in Uspanteko, sometimes to the point of deletion (Fig. 28; see the right panel of Fig. 20 for another example, and Bennett et al. ms. for extensive discussion).

Figure 28: Unstressed vowel reduction in pre-tonic (left) and post-tonic (right) positions: *tijkunaj* [tiχ.ku.ˈnaχ] '(s)he cures him/her' and *kútz'ij* [ˈkú.t͡sˀiχ] 'flower'(speaker 9 PA 2018)



4.2 Vowel quality as a function of vowel length and stress

It common for length contrasts to be augmented by a quality difference, with short vowels being more centralized than their long vowel counterparts. This correlation between length and centralization has been observed in a number of Mayan languages, belonging to several different major subgroups (e.g. Du Bois 1981, England 1983, Dayley 1985, Edmonson 1988, Barrett 1999, Baird 2010; see also Bennett 2016, England & Baird 2017).

However, it has also been reported that some Mayan languages implement vowel length contrasts almost entirely by means of duration, without any significant differences in quality between long and short vowels (e.g. England 2001, England & Baird 2017). Uspanteko appears to be a language of this type, with only very limited centralization of most short vowels (Figs. 29, 30). The phonetic results presented here are in keeping with our own auditory impressions as fieldworkers: the qualities of short /e i o u/ are very similar to the qualities of long /eː iː oː uː/, while short /a/ shows a tendency to raise and/or centralize relative to long /aː/.

To assess vowel quality for short and long vowels, formants were measured by averaging values for F1, F2, and F3 over the middle 20% of each vowel, using a custom Praat script (Boersma & Weenink 2020). We used a vowel-intrinsic normalization method — F3-normalization (F1/F3 and F2/F3 for each vowel) — in order to pool formant measurements across speakers (Monahan & Idsardi 2010 and references there). The F3-normalized data is highly correlated with the output of two alternative formant normalization methods, Lobanov's *z*-score normalization (F1: $r = 0.95$, F2: $r = 0.95$; Lobanov 1971) and Barreda-Neary log-additive regression normalization (F1: $r = 0.96$, F2: $r = 0.96$; Barreda & Nearey 2018) (see too Hillenbrand et al. 1995, Adank et al. 2004, Johnson 2020). It is also highly correlated with the original data as measured in Hz (F1: $r = 0.96$, F2: $r = 0.94$), Bark (F1: $r = 0.96$, F2: $r = 0.95$), and ERB (F1: $r = 0.96$, F2: $r = 0.95$), suggesting that our speakers had similar vowel spaces and vocal tract lengths. To remove outliers and potential measurement errors, F3-normalized formant values were converted to *z*-scores, and tokens were excluded from analysis if they had *z*-scores for F1/F3 or F2/F3 which were greater than 2.5 *z*-units from the mean value for vowels of the same quality (pooling over length, stress, and tone). This procedure trimmed 88 tokens (3.6% of the data).

Figure 29: F3-normalized vowel spaces separated by vowel length and stress. Data ellipses include 68% of the tokens (≈ 1 SD) for each vowel category.

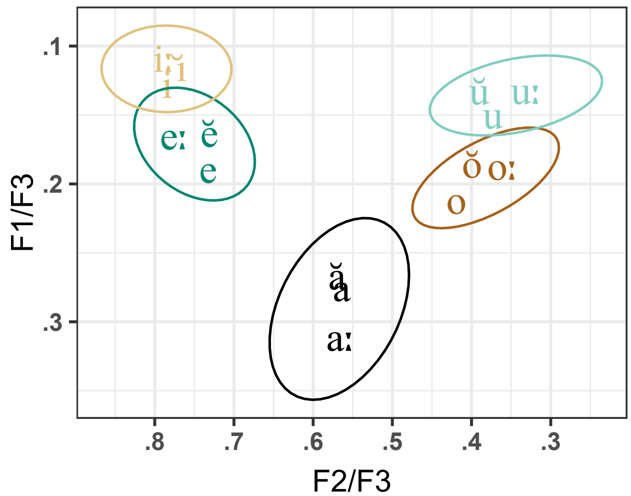
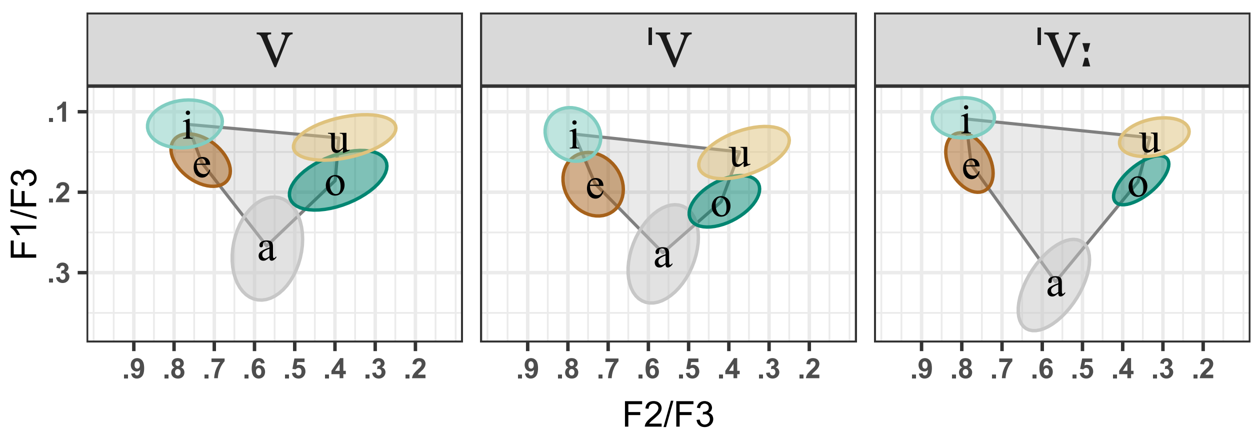


Figure 30: F3-normalized vowel spaces pooled across vowel length and stress. Data ellipses include 68% of the tokens (≈ 1 SD) for each vowel category.



Overall, vowel quality does not vary widely with differences in stress or phonemic vowel length (Figs. 29, 30). Long, stressed vowels [ˈVː] are somewhat more peripheral and more tightly clustered than short vowels, which show a tendency toward slight centralization regardless of stress. The short low vowel /a/ is often quite audibly centralized, sounding something like [ɐ] or [ə] when unstressed (Bennett & Henderson 2013). For some speakers, stressed short /a/ is also quite centralized, so that e.g. *pach* /pat͡ʃ/ 'friend, partner' is pronounced as [ˈpat͡ʃ] by many speakers, but as something closer to [ˈpɐt͡ʃ] or [ˈpət͡ʃ] by others.

5 Prosody

A fairly comprehensive description and phonological account of the word-level prosody of Uspanteko can be found in Can Pixabaj (2007), Bennett & Henderson (2013), Bennett et al. (2022), and

Bennett et al. (ms.). These sources describe a system of default word-final stress, which interacts in complex ways with a separate system of tonal contrast, based on the presence or absence of a high tone [H]. Interactions between stress and tone lead to cascading effects in foot structure, syncope, and utterance-level prosody. We focus here on word-level prosody, and direct readers to Bennett et al. (2022) for some discussion of phrasal prosody and its interaction with word-level stress and tone in Uspanteko.

5.1 Syllable Structure

Syllable structure in Uspanteko is typically CV(C), with a number of important caveats and exceptions we outline below. An example of this basic template is shown in (5).

(5) Basic $[\text{CV(C)}]_\sigma$ syllable template
   a. *ajmuqunelib'* /aχ=muq-un-eːl-iɓ̥/ → [ʔaχ.mu.qu.ˈné.liɓ̥] 'gravediggers'
   b. *tichomorsaaj* /t-t͡ʃom-or-saːχ/ → [ti.t͡ʃo.mor.ˈsaːχ] '(s)he thought it'

5.1.1 Vowel-final roots and suffixes

Most roots in Uspanteko are /CVC/ in shape, and most suffixes end in a consonant. These tendencies, which are shared by Mayan languages more generally, contribute to a preponderance of words ending in coda consonants (e.g. Du Bois 1985, Can Pixabaj 2007:Ch. 3, Us Maldonado 2010:Ch. 1, Bennett 2016, England & Baird 2017, DiCanio & Bennett 2021)

Still, there are a relatively small number of roots which end in a vowel. In most cases vowel-final roots have long vowels (6), but several such roots do have short vowels as well (7).

(6) Some root-final long vowels
   a. *b'aa* /ɓ̥aː/ 'gopher'
   b. *jee* /χeː/ 'tail'
   c. *ch'oo* /t͡ʃˀoː/ 'rat'
   d. *kii* /kiː/ 'maguey'
   e. *quu* /quː/ 'our necklace'
   f. *b'ee* /ɓ̥eː/ 'road'

(7) Some root-final short vowels
   a. *b'a* /ɓ̥a/ 'head' (sometimes *b'aa* /ɓaː/ 'head')
   b. *chu* /t͡ʃu/ 'stinky'
   c. *neri* /neri/ 'here'
   d. *mewa(a)* /mewa(ː)/ 'fasting'

These words are sometimes described as ending in [h], e.g. Grimes (1972) transcribes *b'ee* 'road' as both [ɓeː] (p.33) and [ɓeːh] (pp.21-2, 46-7, 84), and Campbell (1977:38) suggests that "Final h̲ is optionally deleted for some speakers". We agree that vowel-final words sometimes occur with phonetic [h], but dispute the claim that [h] is phonemic or underlying, at least synchronically. First, [h] does not otherwise occur in Uspanteko, though /χ/ is sometimes weakened to the point that it is confusable with [h] (e.g. Fig. 31, right panel). Second, [h] primarily occurs in utterance-final position, and then only variably.[11] These facts suggest that putative [h] may simply reflect

[11]This is reminiscent of the distribution of aspiration on plain stops and affricates; see footnote 5 and AnderBois

laryngeal adjustments associated with pause or non-speech breathing, rather than constituting a true segment (see also Du Bois 1985, Myers & Hansen 2007, AnderBois 2011). For an example of the [h]-like noise in question, see Fig. 38 below.

5.1.2 Initial /ʔ/ insertion and hiatus

There are many roots and prefixes which begin with vowels in Uspanteko, but as noted in section 3.4, there are no surface vowel-initial words: all words which begin with an underlying vowel receive an epenthetic initial glottal stop (8) (see also Fig. 33). Evidence that surface forms like (8a) are underlyingly vowel-initial comes from patterns of allomorphy: ergative and possessive agreement prefixes vary in form depending on whether the following stem is vowel-initial (8b) or consonant-initial (8c) (Can Pixabaj 2007, Bennett 2018, and section 3.4 above).

(8) [ʔ]-epenthesis and prefixal allomorphy with C-initial vs. V-initial noun stems

a. *aaq'* /aːqˀ/ → [ˈʔaːqˀ] 'tongue'
b. *raaq'* /r-aːqˀ/ → [ˈraːqˀ] 'its tongue'
c. *jriil* /χ-riː-l/ → [ˈχriːl] 'its spiciness'

Glottal stop epenthesis (8a) implies that all syllables must have an onset in Uspanteko, an assumption which is corroborated by the lack of word-internal V-V hiatus in the language (9).

(9) Hiatus avoidance via [ʔ]-insertion

a. *k'aa* [kˀaː] 'bitter'
b. *jk'a'iil* /χ-kˀaː-iːl/ → [χkˀa.ˈʔiːl] 'its bitterness'

See Can Pixabaj (2007:Ch. 2) for other examples of hiatus avoidance in the language.

5.1.3 Prefixation

While roots generally begin with a single consonant, complex clusters can arise word-initially as the result of prefixation (10).

(10) Word-initial clusters derived by prefixation

a. *jqul* /χ-qul/ 'its neck'
b. *xk'ayeej* /ʃ-kˀaj-eː-χ/ '(s)he sold it'
c. *tqil* /t-q-il/ 'we see it'

Word-initial clusters derived by prefixation, including clusters with combinations of glottalized and non-glottalized consonants, can be seen in Figs. 4, 8, 10, 12, 13, 19 and 25 above.

There are few, if any clear diagnostics for syllabification in Uspanteko. Consequently, we are unsure if clusters like (10) constitute complex onsets, or extrasyllabic consonants. Additionally, word-initial clusters are sometime avoided via epenthesis of [i] (11).

(11) Variable vowel epenthesis to resolve word-initial consonant clusters

a. *(i)jb'a* [(i)χ-ˈɓ̥a] 'its head'
b. *t(i)tze'n* [t(i)-ˈt͡seʔn] '(s)he laughs'

(2011).

The location of the epenthetic vowel varies with the type of cluster, normally preceding [#χC] clusters (11a) and otherwise following the first consonant in the cluster (11b). This suggests that epenthetic [i] isn't just an open transition between consonants in a word-initial cluster. As [#χC] clusters typically begin with the third-person ergative/possessive prefix /χ-/, there may also be some degree of morphological conditioning involved here.

Prefixation also produces surface contrasts between the plain affricates [t͡s t͡ʃ] and stop + fricative [ts tʃ] sequences in initial position (12). The clusters [ts tʃ] are audibly distinct from the corresponding affricates [t͡s t͡ʃ], possibly due to differences in duration and/or articulatory coordination (e.g. Shaw 2022).

(12) Plain affricate [t͡ʃ] vs. stop + fricative [tʃ] cluster
   a. *chiim* /t͡ʃiːm/ 'bag'
   b. *txim* /t-ʃim/ '(s)he ties it'

5.1.4 Underived complex onsets

A handful of roots begin with complex onsets, in which the first consonant is an obstruent and the second is an approximant (13).

(13) Some underived word-initial consonant clusters
   a. *pwaq* /pwaq/ 'money'
   b. *tloox* /tloːʃ/ 'pacaya (species of palm tree, *chamaedorea tepejilote*)'
   c. *syo'm* /sjoʔm/ 'a swing'
   d. *tras* /tras/ 'peach' (< Spanish *durazno*)

These clusters are uncommon, and a good proportion of them occur in words which are historically borrowed from Spanish. See also section 3 on palatalized velars.

5.1.5 Underived complex /ʔC/ codas

As discussed in section 3.4, some roots end in a /ʔC#/ sequence, e.g. *malka'n* /malkaʔn/ 'widow'. It is unclear whether these sequences should be analyzed as true coda clusters, or whether the glottal stop in word-final /ʔC#/ is instead a laryngeal feature on the preceding vowel.

There are at least two arguments for treating [VʔC#] as a laryngealized long vowel followed by a single coda consonant, [Vː^{ʔ}C#]. First, contrastive [. . . ʔC]$_{\sigma}$ coda clusters only occur in word-final stressed syllables, just like simple long vowels (section 5.2).[12] Second, morphologically-assigned tone (section 5.3) cannot typically be assigned to the penult in words ending in [ʔC] clusters (Can Pixabaj 2007, Bennett & Henderson 2013). In contrast, penultimate tone is normally possible for words with final short vowels, including words ending in simple [ʔ] (14).

[12] A reviewer asks whether the restriction limiting [. . . ʔC]$_{\sigma}$ coda clusters to word-final stressed syllables can be reduced to the more general pattern of coda [ʔ] reduction or deletion in unstressed positions (section 3.4). We think not: the general reduction of unstressed coda [ʔ] is variable, whereas coda [. . . ʔC]$_{\sigma}$ clusters are simply *never* observed outside of word-final stressed syllables.

(14) No penultimate tone with final [ʔC#]

a. *tz'i'* [ˈt͡sˀiʔ] 'dog'
b. *íntz'i'* [ˈʔín.t͡sˀiʔ] 'my dog'

c. *ka'n* [ˈkaʔn] 'animal'
d. *inka'n* [ʔin.ˈkaʔn], *[ˈʔín.kaʔn] 'my animal'

This restriction is parallel to final long vowels, which also resist the assignment of penultimate tone (15a,b), albeit somewhat more weakly, as penultimate tone is sometimes attested with concomitant vowel shortening (15c,d).

(15) Vowel shortening penultimate tone

a. *ch'aat* [ˈt͡ʃˀaːt] 'bed'
b. *inch'aat* [ʔin.ˈt͡ʃˀaːt] 'my bed'

c. *kaa'* [ˈkaːʔ] 'grinding stone'
d. *ínka'* [ˈʔín.kaʔ] 'my grinding stone'

Word-final [VʔC#] thus behaves similarly to a syllable containing a long vowel.

On the other hand, vowel length is apparently contrastive in words ending in a [ʔC#] cluster, implying that vowels before [ʔC#] are not uniformly long in a phonological sense (16) (see also Du Bois 1981:Ch 4.2 on Sacapulteco).

(16) Apparent vowel length contrasts before [ʔC#]

a. *ri'j* [ˈriʔχ] 'old'
b. *kutz'ii'j* [ku.ˈt͡sˀiːʔχ] 'flower'

However, descriptions of Uspanteko vary as to how vowel length is transcribed in this environment, and so the facts here are not entirely clear, even for individual words. It may be that [ʔ] is a moraic consonant in final [ʔC#] clusters, which would make it the only coda consonant that contributes to syllable weight in Uspanteko (section 5.2 and Bennett & Henderson 2013). In any event, the phonological status of [ʔC#] clusters and glottal stop more generally in Uspanteko deserves closer investigation. See Bennett & Henderson (2013), Bennett (2016), England & Baird (2017), DiCanio & Bennett (2021) for further discussion and references.

5.1.6 Syncope

Syncope, which is widespread in Uspanteko, variably targets unstressed short vowels in specific positions (Bennett & Henderson 2013, Bennett et al. ms.). When stress is final, syncope frequently targets the immediately pre-tonic syllable (17).

(17) Pre-tonic syncope

a. *chukuy* [t͡ʃu̲ˈkuj] ∼ [t͡ʃˈkuj] 'pine fruit'
b. *xqaq'asaj* [ʃqaqˀa̲ˈsaχ] ∼ [ʃqaqˀˈsaχ] 'we passed it'

When stress is penultimate, syncope instead targets the post-tonic syllable (18).

(18) Post-tonic syncope

a. *awáqan* [ʔaˈwáqa̠n] ∼ [ʔaˈwáqn] ‘your leg’
b. *xojwérik* [ʃoχˈwéri̠k] ∼ [ʃoχˈwérk] ‘we slept’

Post-tonic syncope in *kúmb’al* [ˈkúmɓ̥al] ∼ [kúmɓ̥l] ‘medicine’ can be seen in Fig. 15 above.

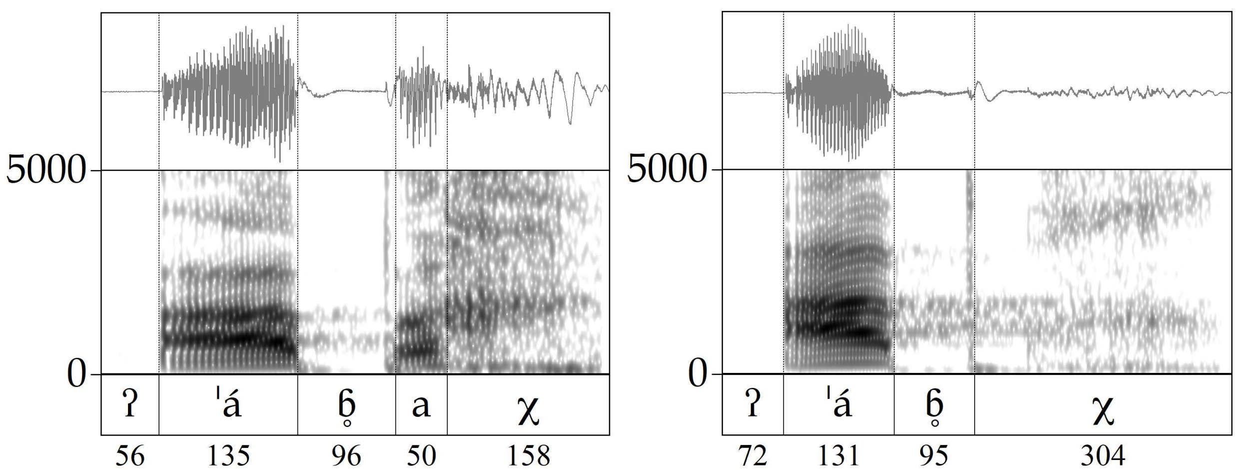
Bennett & Henderson (2013) and Bennett et al. (ms.) analyze vowel deletion in terms of foot structure (section 5.2): under the assumption that final stress involves an iamb [. . . (σˈσ)], and penultimate stress involves a trochee [. . . (ˈ$\acute{\sigma}\sigma$)], then syncope can be said to consistently target the weak branch of the foot.

Syncope appears to create complex consonant clusters (19), Fig. 31.

(19) Consonant clusters derived by syncope

a. *inmasaat* [ʔinmaˈsaːt] ∼ [ʔinmˈsaːt] ‘my deer’
b. *ínpix* [ˈʔímpiʃ] ∼ [ˈʔímpʃ] ‘my tomato’
c. *kinaq’* [kiˈnaq] ∼ [kˈnaq] ‘bean’

Figure 31: Apparent consonant clusters derived by syncope: *áb’aj* /áɓ̥aχ/ → [ˈʔáɓ̥aχ] ∼ [ˈʔáɓ̥χ] ‘stone’ (speaker 6 JMS 2018, and speaker 5 DEIP 2018).



However, Bennett et al. (ms.) argue that syncope does not involve actual vowel deletion. Instead, it is a species of extreme phonetic vowel reduction, which leads to acoustic forms that sound like the vowel has been deleted (on vowel reduction, see sections 4.1 and 4.1.1 above). Their evidence for this claim comes, in part, from the observation that weak vocal fold vibration associated with ‘deleted’ vowels is sometimes observable in electroglottographic recordings of Uspanteko even when those vowels are seemingly absent from the acoustic recording. Phonologically, then, the consonant clusters derived by syncope (19) may in fact be [CVC] sequences after all, but with a highly reduced vowel that is essentially inaudible, though weakly articulated.

5.1.7 Syllable-conditioned phonotactics

There are few, if any phonotactic or allophonic patterns in Uspanteko which are clearly conditioned by syllable structure — a state of affairs common in Mayan languages (Bennett 2016). Glottal stop insertion to avoid onsetless syllables is perhaps the best candidate for a truly syllable-based phonological rule in Uspanteko (sections 3.4, 5.1.2). Otherwise, all consonants can occur in either onset or coda position, and there are no allophonic rules which specifically target onset vs. coda consonants (or at least, none that do so consistently; see section 3). There do seem to be some syllable-based restrictions on combinations of consonants (e.g. sections 5.1, 5.1.4), but consonant clusters derived by prefixation (section 5.1.3) or syncope (section 5.1.6) defy those generalizations, which is one reason why the syllabification of such derived clusters is itself quite unclear.

5.1.8 Root co-occurrence restrictions

Mayan languages often have restrictions on which consonants can co-occur in a /CV(:)C/ root (Gallagher & Coon 2009, Bennett 2016). Typically, if both consonants are glottalized, they must be identical, as in *ch'iich'* /t͡ʃˀiːt͡ʃˀ/ 'metal, metallic object, machine' or *q'uuq'* /qˀuːqˀ/ 'quetzal (species of bird, *pharomachrus mocinno*)'. Labial *b'* /ɓ̥/ is unrestricted within roots, e.g. *ch'uub'* /t͡ʃˀuːɓ̥/ 'wasp'. A similar co-occurrence restriction holds for sibilant consonants: two sibilants in a /CV(:)C/ root must have the same place of articulation, as in *sotz'* /sot͡sˀ/ 'bat' or *choox* /t͡ʃoːʃ/ 'godmother'. See Gallagher & Coon (2009), Bennett (2016) for other similar restrictions in Mayan.

We have not yet verified that these restrictions hold across the Uspanteko lexicon, or that native speakers are sensitive to these root-based phonotactics (as assessed by well-formedness judgments, speech error patterns, or lexical decision tasks; see e.g. Berent & Shimron 2003, Rose & King 2007). Sound changes during the development of Uspanteko do seem to have created some exceptions to these patterns, such as *ch'uuk'* /t͡ʃˀuːkˀ/ 'elbow', which derives historically from */t͡ʃˀuːʔk/ or */t͡ʃˀuʔuk/ (Campbell 1977:41, Kaufman 2003:343). It is perhaps relevant that in other Mayan languages root co-occurrence restrictions may be weaker when the vowel of the root is long (e.g. Smith-Stark 1983, Edmonson 1988). This remains an area for future work on the phonology and morphology of Uspanteko.

5.2 Stress

Primary stress occurs by default on the rightmost syllable of the word in Uspanteko. There is no evidence of secondary stress. In these respects, the Uspanteko stress system resembles the stress systems of related K'ichean-branch Mayan languages, which also strongly tend toward fixed final stress (apart from loanwords, and a few lexical and morphological exceptions; e.g. Berinstein 1979, Henderson 2012, Baird 2014b, Bennett 2016, England & Baird 2017, Can Pixabaj 2017, and references there).

(20) Final stress in Uspanteko

a. *chaj* [ˈt͡ʃaχ] 'pine (Spanish *ocote*)'
b. *chaaj* [ˈt͡ʃaːχ] 'ash'

c. *wunaq* [wu.ˈnaq] 'man'
d. *amaaq'* [ʔa.ˈmaːqˀ] 'people, nation'

e. *xinmatzej* [ʃin.ma.ˈt͡seχ] 'I hugged it'
f. *xincholeej* [ʃin.t͡ʃo.ˈleːχ] 'I arranged it'

g. *xatinmatzej* [ʃa.tin.ma.ˈt͡seχ] 'I hugged you'
h. *xintz'aqatsaaj* [ʃin.t͡sˀa.qat.ˈsaːχ] 'I completed it'

As we have seen, stress is cued phonetically by duration on short vowels, and only marginally by vowel quality. There may of course be other phonetic cues to stress, such as intensity, voice quality, or consonant length (e.g. Gordon 1995, 2011, Sluijter & van Heuven 1996, etc.), but we have not systematically investigated such possibilities. We comment below on the role of f0 in Uspanteko word-level prosody (section 5.3.3).

There is also phonological evidence for final stress: long vowels, and thus vowel-length contrasts, are limited to word-final stressed syllables (Bennett et al. 2022). This again has parallels in other K'ichean-branch Mayan languages (e.g. Dayley 1985, Bennett 2016, 2019, Can Pixabaj 2017). This restriction is clearly illustrated by vowel length alternations that occur under suffixation: when an underlying lexical long vowel occurs outside the stressed final syllable, it is systematically shortened (21).

(21) Non-final long vowels undergo shortening
   a. *chaak* [ˈt͡ʃaːk] 'work'
   b. *tichakuun* [ti.t͡ʃa.ˈkuːn] '(s)he works'

The fact that long vowels and vowel-length contrasts are restricted to stressed final syllables is consistent with the well-known fact that, crosslinguistically, stressed syllables tend to support more contrasts than unstressed syllables (Trubetzkoy 1939, Beckman 1997, 1998, Smith 2005, Barnes 2006, etc.). Typologically speaking, final syllables are often poor hosts for vowel length contrasts (Barnes 2006:Ch. 3.7, Myers & Hansen 2007), so the fact that vowel length contrasts *only* occur in final syllables in Uspanteko is another good indication that those final syllables are stressed. Along the same lines, coda [ʔC] clusters are only attested in final stressed syllables, as in *kutz'ii'j* [ku.ˈt͡sʔiːʔχ] 'flower' (section 5.1.5 and Can Pixabaj 2007; see also Chacach Cutzal 1990, Bennett 2018:fn. 7 and citations there for parallel observations about Kaqchikel).

Major intonational contours also tend to align with final syllables, again implying that these are prominent positions (e.g. Hayes 1995; for Mayan languages, Gussenhoven & Teeuw 2008, Baird 2014a, Bennett 2016, England & Baird 2017, Adell 2019, DiCanio & Bennett 2021). Lastly, native speakers do have the intuition that stressed final syllables are more prominent than other syllables in the word.

Stress can also occur on the penultimate syllable, but only in words bearing lexical high tone, which we now turn to.

5.3 Lexical tone

5.3.1 Historical sources of lexical tone

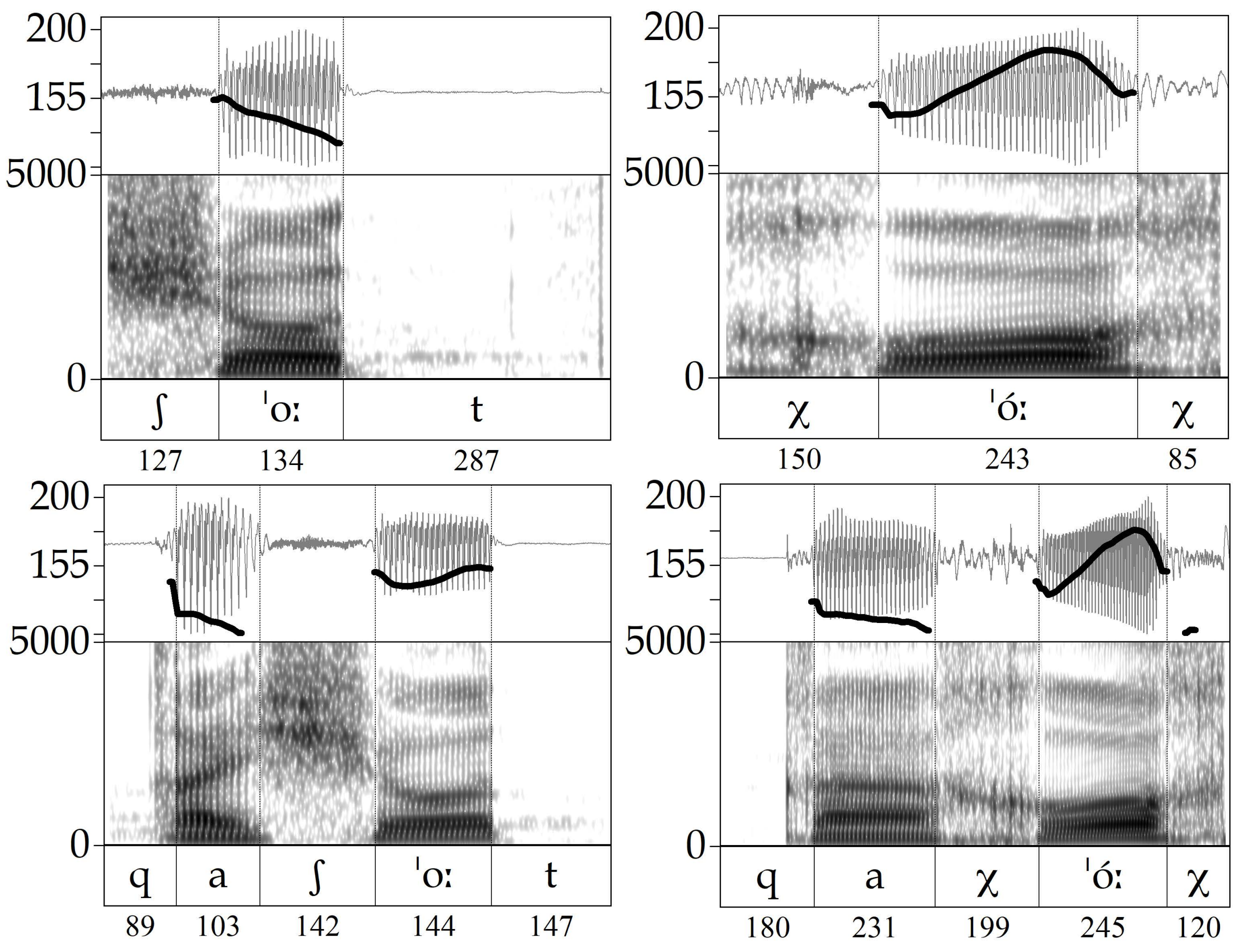
Uspanteko stands out from other K'ichean-branch Mayan languages in having innovated a system of contrastive, grammatically-controlled lexical tone (Grimes 1971, Campbell 1977, Can Pixabaj 2007, Bennett & Henderson 2013, Bennett et al. 2022). Historically, tone may have developed from pitch perturbations associated with the post-vocalic laryngeals [h] and [ʔ]. Post-vocalic [h ʔ] were then lost in some contexts, plausibly leading to the phonologization of tone. The same pathway of tonogenesis happened sporadically in a number of otherwise unrelated Mayan languages, and seems to be currently ongoing in several Mamean languages near the Guatemala-Mexico border; see Campbell (1977, 2017), Bennett (2016), England & Baird (2017), DiCanio & Bennett (2021), Bennett et al. (2022) for details and further citations.

Still, the precise historical development of tone in Uspanteko is somewhat obscure: most proposals regarding the development of tone only account for tonal long vowels, not tonal short vowels; and many roots and affixes associated with tone cannot be reconstructed to earlier forms containing laryngeals. Henderson et al. (to appear) speculate that contact with Ixil, a Mayan language of the Mamean branch, may have influenced the development of word-level prosody in Uspanteko, particularly penultimate stress and tone. Additionally, sources on Uspanteko differ fairly widely on what tones they report for particular roots, which complicates reasoning about tonogenesis; see Bennett et al. (2022) for details.

5.3.2 The synchronic system of lexical tone

Long vowels only occur in word-final stressed syllables (section 5.2). In final position, stressed long vowels may be toneless, or may bear a high tone [H] (22). As Fig. 32 illustrates, tonal long vowels have higher pitch than non-tonal long vowels, and may also have more dramatic pitch excursions (rises and falls). The slightly raised pitch on the final stressed syllable of non-tonal *qaxoot* [qa.ˈʃoːt] 'our comal' (Fig. 32, lower-left) arguably represents intonational prominence rather than any f0 effects associated with stress as such; see Bennett et al. (2022) and section 5.3.3 below for discussion.

Figure 32: Lexical tone contrasts on long vowels: *(qa)xoot* [(qa.)ˈʃoːt] '(our) comal' vs. *(qa)jóoj* [(qa.)ˈχóːχ] '(our) crow' (speaker 7 2016). f0 superimposed on waveform, with scale in Hz.



There are very few minimal pairs for tone on long vowels in Uspanteko. Further, as a result of lexical variation in the Uspanteko community, some speakers do not have any minimal pairs at all for tone on long vowels (Bennett et al. 2022). Still, there are various near-minimal pairs like Fig. 32 which show lexically-specific pitch differences that cannot be reduced to conditioning by the segmental or morphological environment (see Snider 2014, Herrera Zendejas 2014:Ch. 9 for related discussion). Such pairs firmly establish that Uspanteko has a system of lexical tone on long vowels, even if the functional load of tonal contrasts is low (Hyman 2006, 2009).

In words with final short vowels, the interaction of tone and stress is more complex. When the final vowel is short, tone can only occur on the penultimate syllable. Stress then retracts to coincide with tone (22).

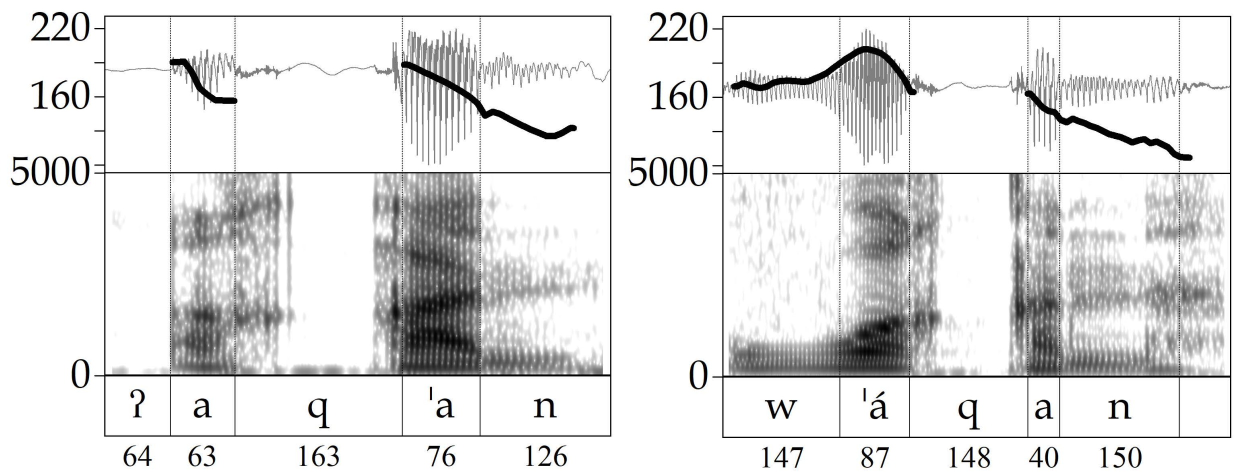
(22) Tone and stress on penultimate short vowels

a. *lékej* [ˈlé.keχ] ‘up, above’

b. *wáb’ix* [ˈwá.ɓ̥iʃ] ‘my cornfield’

Stress retraction is evident in alternations like Fig. 33: the position of stress is associated with greater duration and intensity; and high tone (right panel) is associated with raised f0. (See Figs. 31, 38 for other similar examples.)

Figure 33: Tone-driven stress retraction to penult: *aqan* /aqan/ → [ʔa.ˈqan] ‘leg’ vs. *wáqan* /wáqan/ → [ˈwá.qan] ‘my leg’ (speaker JBAT 2014).



Bennett & Henderson (2013) analyze the distribution of tone in Uspanteko by appealing to moras, a prosodic unit below the level of the syllable which distinguishes short vowels (1 mora) from long vowels (2 moras) (Trubetzkoy 1939, Hyman 1985, etc.). They propose that high tone [H] only occurs on the penultimate mora of the word. It follows directly that [H] tone will occur on final long vowels (which contain two moras), or will occur on the penultimate vowel when the final vowel is short.

Tone is associated with morphology in Uspanteko, as documented by Can Pixabaj (2007), Bennett & Henderson (2013), and Bennett et al. (2022). For example, the plural suffix /-Vɓ̥/ introduces high tone on the preceding syllable (23) (capital /V/ here stands for a vowel of varying quality; see also Fig. 33 for tone introduced by a possessive prefix).[13]

[13] In a sense, then, Uspanteko has 'grammatical tone' — specifically the sub-type of grammatical tone that co-occurs with overt segmental affixes, dubbed 'auxiliary prosodic exponence' by Rolle (2018).

(23) Morphologically-triggered tone
  a. *ajchaak* [ʔaχ.ˈt͡ʃaːk] ‘worker’
  b. *ajchakib’* [ʔaχ.ˈt͡ʃá.kiɓ̥] ‘workers’

Note that penultimate stress does not license long vowels (23), unlike final stress (section 5.2). If stress is analyzed with reference to foot structure in Uspanteko, this may reflect well-known quantitative asymmetries between iambic and trochaic feet: final, iambic stress allows both [. . . (LˈL)] and [. . . (LˈH)] footing; while penultimate, trochaic stress allows only [. . . (ˈLL)] footing (Hayes 1995; this assumes that coda consonants do not contribute to syllable weight in Uspanteko, following Bennett & Henderson 2013).

5.3.3 Phonetic analysis of lexical tone

Pitch contours on target items were analyzed in Praat (Boersma & Weenink 2020). The recordings were downsampled to 16kHz, then pitch values were automatically extracted in Hz with a script specifying by-speaker pitch ranges following the recommendations of De Looze & Rauzy (2009) and Evanini et al. (2011). Along with measurements of mean and maximum f0 for each vowel, time-normalized pitch measurements were produced by averaging pitch values over $^1/_7$ intervals of the duration of each vowel.

F0 measurements were *z*-score normalized for each speaker, so that the data could be pooled for analysis. Pitch measurements more than 2.5 *z*-units away from each speaker’s mean were treated as outliers and removed from the data. This resulted in the the elimination of 0.4% of the mean f0 measurements (8 tokens), 1.2% of the maximum f0 measurements (26 tokens), and 1.2% of the time-normalized f0 interval measurements (175 measurements). For all three measures, the *z*-score normalized data was closely correlated with the results of two other normalization methods: semitone transformation relative to each speaker’s mean pitch in Hz (Zhang 2019), and range normalization using 2% and 98% estimates of floor and ceiling values in semitones (Bardiaux & Mertens 2014) (lowest correlation $r = 0.96$; see also Ladd 2008:192-202).

Figure 34: Mean f0 for different vowel types (z-scores over Hz). Short vowels may be stressed or unstressed, long vowels are always stressed.

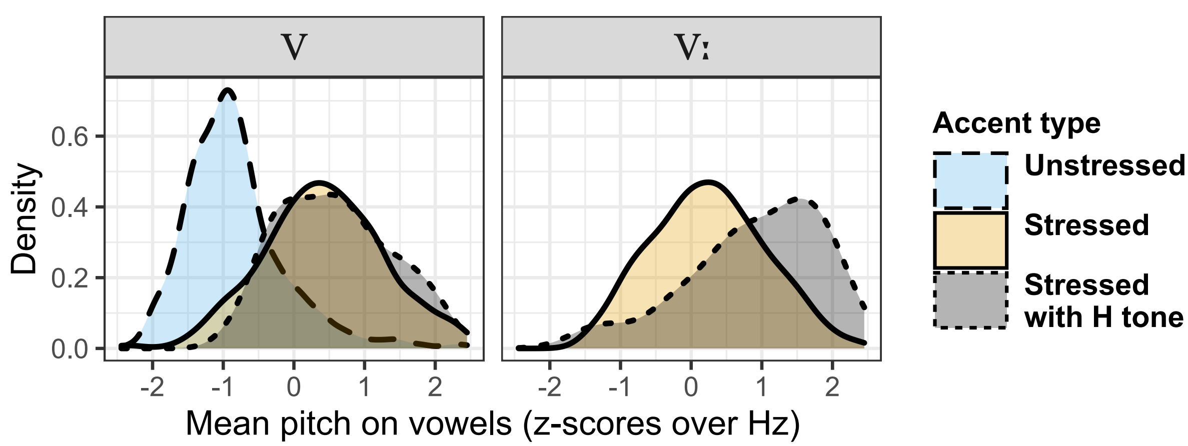
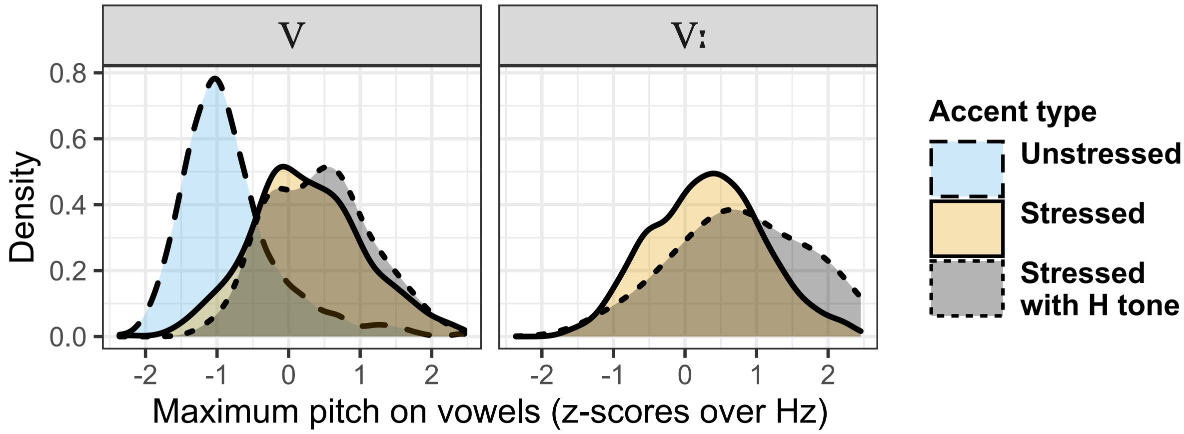


Figure 35: Maximum f0 for different vowel types (z-scores over Hz). Short vowels may be stressed or unstressed, long vowels are always stressed.



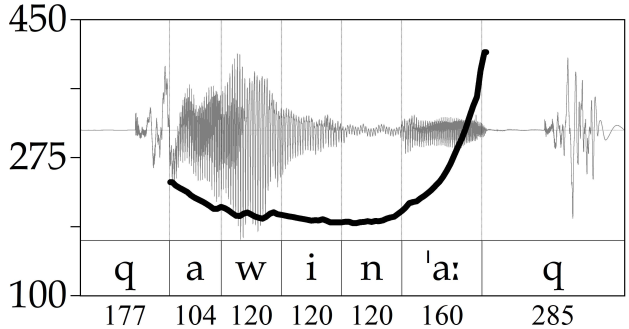
In our wordlist data, tonal vowels are not sharply distinguished by mean or maximum f0 (Figs. 34, 35). This is particularly true for short tonal vowels [ˈV́], which have f0 distributions which largely overlap those of non-tonal, stressed short vowels [ˈV] (that said, f0 differences between short [ˈV́] vs. [ˈV] are statistically significant by two-sided *t*-test: mean f0: Δ = 0.15 z-units, $p < .05$; maximum f0: Δ = 0.17 z-units, $p < .05$).[14] (There are just 15 tonal long vowels in this dataset, so we avoid making any quantitative claims about the phonetics of tone on long vowels here, though we do include this data in plots and statistical models.)

The modest f0 increase associated with tone in Figs. 34 and 35 arguably reflects the fact that *intonational* prominences may also occur on toneless vowels, leading to some degree of phonetic neutralization between tonal and non-tonal syllables (Bennett et al. 2019, 2022). Rising (L)H% contours often occur utterance-finally in K'ichean-branch Mayan languages, including Uspanteko (e.g. Berinstein 1991, Baird 2014a,b, Bennett 2016, England & Baird 2017, Bennett et al. 2022). These intonational rises occur in both declarative sentences and questions, and may be associated with the right-edge of clause-sized prosodic units (e.g. Intonational Phrases, or IPs; for detailed discussion of K'iche', see Nielsen 2005, Henderson 2012, Burdin et al. 2015, Baird 2018 and citations there; for more distantly related Mayan languages, see e.g. Clemens 2021, Royer 2022).

Final intonational rises are common in our wordlist data, likely as a result of eliciting words in a repeated frame sentence. In such tasks, the target word is pragmatically or metalinguistically focused, and may be produced with intonation characteristic of a full, independent utterance or IP (Pike 1948, Himmelmann 2006, Himmelmann & Ladd 2008, Hyman 2014, Jun & Fletcher 2014, Snider 2014, Yu 2014). A particularly dramatic example is shown in Fig. 36.

[14] Stated over semitones relative to each speaker's median, the values are: mean f0: Δ = 0.54, $p < .05$; maximum f0: Δ = 0.38, $p < .005$. For reference, Frazier (2009a, 2013) finds that lexical high tones in Yucatec Maya begin about 2 semitones above each speaker's average pitch at vowel midpoint for low-toned vowels. Kuang (2013) reports that tonal contrasts typically involve differences of at least 20-30 Hz, or 2-3 semitones.

Figure 36: Final intonational H% rise: *qawinaaq* [qa.wi.ˈnaːq] ‘our people’ (speaker 7 JVC 2018). Y-axis shows f0 in Hz.



These intonational rises plausibly obscure f0 differences between tonal and non-tonal vowels in Uspanteko, both in our specific wordlist data, and in the language more generally (Bennett et al. 2022).

Further evidence for an IP/utterance-final H% boundary tone in Uspanteko comes from the analysis of f0 on unstressed vowels. Fig. 37 shows f0 trajectories across vowels, grouped by stress, length, tone, and position in the word. These plots again show that f0 is somewhat higher for tonal than non-tonal vowels, though not by a wide margin. The key observation here is that unstressed short vowels [V̆] have a substantially raised pitch in final syllables (i.e. in words with penultimate accent, e.g. *kútz’i̱j* [ˈkú.t͡sˀi̠χ] ‘flower’). This is consistent with the presence of an H% boundary tone in final position, corresponding to the large final rise in examples like Fig. 36. An example illustrating an H% target on an unstressed, final vowel is shown in Fig. 38. (The rising f0 on tonal and non-tonal long vowels in Fig. 37 may also corroborate the presence of an H% boundary tone in much of our data.)

Figure 37: f0 trajectories for different vowel types (z-scores over Hz). Grey bands indicate confidence intervals around the estimate of the position of the smoothed loess regression line at each time step. Short vowels may be stressed or unstressed, long vowels are always stressed.

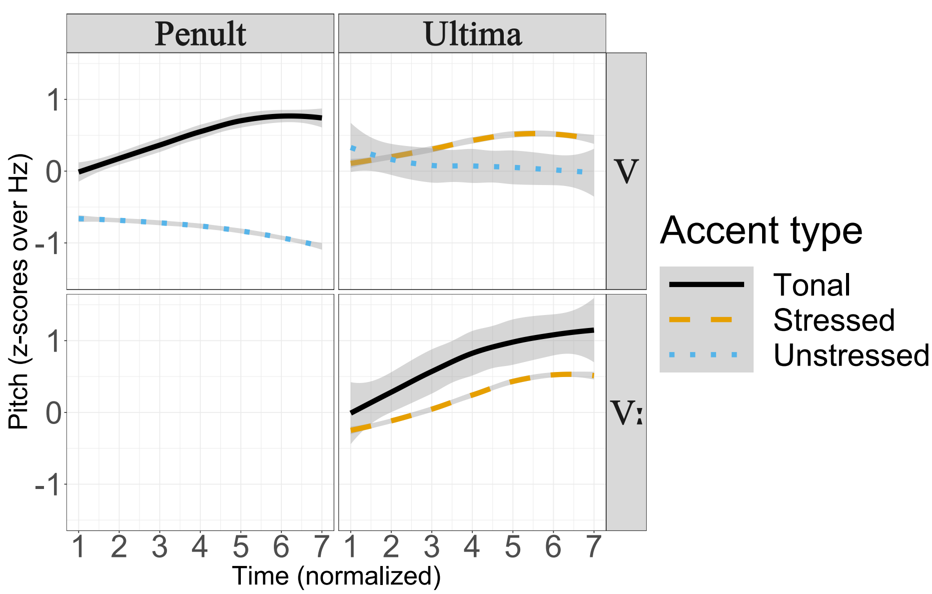
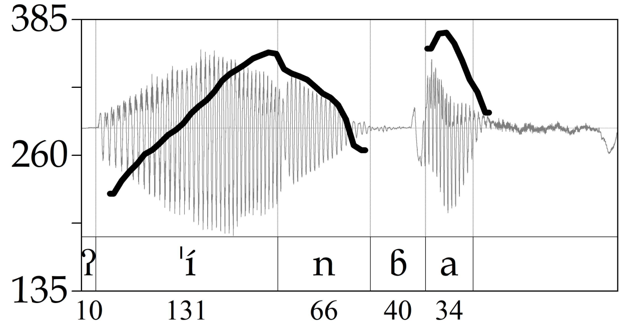


Figure 38: Final intonational H% on unstressed, final vowel: *ínb'a* [ˈʔín.ɓa] 'my head' (speaker 1 FIES 2018).



To assess the effect size of lexical tone on Hz in our study, we fit a linear-mixed effects model to predict mean vowel f0 using the `lme4` package in `R` (Bates et al. 2020). This model included fixed effects for STRESS (ˈσ vs. $\breve{\sigma}$), TONE ([H] vs. $\varnothing$), VOWEL LENGTH ([V] vs. [Vː]), VOWEL HEIGHT (low vs. mid vs. high), VOWEL POSITION (final σ in the word vs. non-final σ), and a TONE $\times$ VOWEL LENGTH interaction. The VOWEL POSITION predictor was intended to control for the H% boundary tone observed in Fig. 36. The VOWEL HEIGHT predictor was a control for the fact that high vowels are often produced with higher pitch than non-high vowels (e.g. Sapir 1989 and references there). This initial model also included a random intercept for SPEAKER, and a by-SPEAKER random slope for TONE. A random effect for WORD could not be included because some words only occur once in our corpus. Adding a by-speaker random slope for STRESS led to convergence errors during model comparison, so this random effect was not included in the model.

Step-down model criticism using the log-likelihood test with a threshold of α = 0.1 led to the omission of the STRESS predictor from the final model.[15] No further model simplification was possible, largely because the simple VOWEL LENGTH predictor could not be dropped from the model while the higher-order interaction TONE $\times$ VOWEL LENGTH was retained. A summary of this model is given in Tab. 2; *p*-values were estimated from the *t* statistic using an upper-bound 2386 degrees of freedom (2393 observations less the 7 fixed-effect parameters in the final model; Baayen 2008:297). The final model has very low collinearity between predictors (κ = 4.37). Very similar results emerge if maximum f0 is used as the dependent variable rather than mean f0, as maximum and mean f0 on vowels are highly correlated in our data ($r = 0.94$).

[15]The VOWEL POSITION predictor is correlated with accent type, because default stress is word-final, and non-final stress only occurs with tonal short vowels. To verify that dropping STRESS from the model improves fit better than dropping VOWEL POSITION, both models were compared using the Akaike information criterion (AIC; see e.g. Burnham & Anderson 2004, Burnham et al. 2011). The model omitting STRESS is clearly selected as the superior model by the AIC (dropping STRESS: AIC = 22,692; dropping VOWEL POSITION, AIC = 22,760; Δ_{AIC} = 68; models with lower AIC values receive more support, and a model with an AIC value more than 15 points higher than a competing model can be safely dismissed).

Table 2: Final linear mixed-effects model for mean f0 in Hz

Predictor	β (in Hz)	SE(β)	$\lvert t \rvert$	$p <$
Intercept	180	12.4	14.51	.001
TONE (V́)	54	3.98	13.51	.001
V POSITION (FINAL)	51	1.47	34.33	.001
TONE (V́) × V LENGTH (LONG)	-38	7.79	4.94	.001
V HEIGHT (HIGH VS. LOW)	24	1.3	18.67	.001
V HEIGHT (MID VS. LOW)	6	1.49	4.24	.001
V LENGTH (LONG)	-7	1.40	4.74	.001

The main takeaway from Tab. 2 is that tone *does* have a substantial effect on f0 (particularly for short vowels) once the intonational H% tone observed on isolation forms is controlled for. On the other hand, the effect of stress on mean f0 is essentially nil — the STRESS predictor was dropped from the final model. The apparent correlation between stress and raised f0 seems to be reducible to the fact that word-final stress often coincides with an intonational H% tone.

5.3.4 Vowel duration and tone

Stressed short vowels are significantly longer when bearing high tone (Fig. 27; [ˈV] mean = 102 ms, [ˈV́] = 122 ms, $p < .001$). Despite this lengthening, tonal short vowels remain phonetically shorter than true long vowels ([ˈVː] = 167 ms, $p < .001$). This suggests that tonal vowels in accented penults are still *phonologically* short — lengthening of [ˈV́] is a gradient phonetic effect, rather than a categorical, neutralizing process in the phonology proper.[16] It is relevant, we think, that vowel length is not contrastive in penultimate syllables, and so stressed short vowels have greater freedom to phonetically lengthen in this position without risk of neutralizing lexical contrasts (Berinstein 1979, Can Pixabaj 2007, Bennett & Henderson 2013, Bennett et al. 2022; for related discussion, see Vogel et al. 2016, Lunden et al. 2017, van Heuven & Turk 2021).

6 Conclusion

Uspanteko provides many phonetic and phonological phenomena which are either understudied, uncommon typologically, or uncommon within the Mayan family. Some of these phenomena — such as the inventory of derived vs. underlying clusters, the interaction between tone and stress placement, and the suprasegmental vs. segmental status of [ʔ] — should be of substantial interest to phonologists, as they push the limits of what is typologically expected under certain theories of phonological representation and derivation (e.g. Kehrein & Golston 2004, Marlo 2004, Duanmu 2010a,b, Kawahara & Shaw 2018; Hyman 2009, Bennett & Henderson 2013, Bennett et al. ms.; Macaulay & Salmons 1995; etc.).

Uspanteko also illustrates some phonetic patterns which deserve further attention. The phonemic inventory of Uspanteko is in some ways typical: many languages have /a(ː) e(ː) i(ː) o(ː) u(ː)/ vowel contrasts, and even glottalized stops and affricates are cross-linguistically widespread (e.g.

[16] We do not have enough tokens of tonal long vowels in this data set to meaningfully assess the effect of lexical high tone on the duration of long vowels. Using a different data set, Bennett et al. (2022) also find that short vowels are phonetically longer when bearing high tone, but tone does not comparably impact the duration of long vowels.

in a survey of 566 languages, Maddieson 2009 finds that 151 = 27% have phonemic ejectives or implosives). Still, some aspects of the the phonetics of glottalized consonants in Uspanteko seem typologically unusual, or at least underdescribed, outside the Mayan family (e.g. apparent free variation between voiceless implosive and ejective variants of /ɠ̥ qˀ/, or the voiced releases sometimes found with ejectives; Bennett 2016).

The lexical tone system of Uspanteko is especially interesting in this light. Tone is not common in Mayan languages, and the interdependence of tone and stress placement in Uspanteko is also typologically rare (e.g. van der Hulst et al. 2010, Bennett & Henderson 2013). Additionally, the phonetic implementation of tone is sometimes subtle in Uspanteko, in part due to interactions between tone and intonation. Tone also has a low functional load in the language, despite being deeply ingrained in its word-level phonology and morphology, which may also affect its phonetic implementation (Bennett et al. 2022).

At several points we've highlighted phonetic observations which seem relevant for understanding recurrent sound changes within the Mayan family. These include historical mergers between glottalized sounds (e.g. /ɠ̥ qˀ/ > /ʔ/), and the ongoing puzzle of tonogenesis in Uspanteko, which we only partially understand at present. We hope that these observations will prove valuable for historical linguists, beyond their interest for comparative phonetics and phonology.

There are many high-quality descriptions of the phonetics and phonology of Mayan languages, but such publications often lack phonetic illustrations of the sort provided here, or focus on just one specific aspect of a language's sound structure (e.g. glottalized consonants; see Bennett 2016, England & Baird 2017). We are grateful for the opportunity to provide a broader panorama on the phonetics and phonology of Uspanteko in this article.

A Appendix: vowel counts

Table 3: Distributions of vowel types in the wordlist corpus.

Vowel type	/a(ː)/	/e(ː)/	/i(ː)/	/o(ː)/	/u(ː)/	**Total**
V̆	230	79	69	270	95	743
ˈV	248	66	114	168	72	668
ˈV́	33	15	21	45	15	129
ˈVː	313	70	135	198	149	865
ˈV́ː	2	1	1	4	7	15
All	826	231	340	685	338	2420

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