

# Tonal variability and marginal contrast: Lexical pitch accent in Uspanteko\*

Ryan Bennett<sup>1</sup>, Robert Henderson<sup>2</sup>, and Megan Harvey<sup>2</sup>

*University of California, Santa Cruz<sup>1</sup>, University of Arizona<sup>2</sup>*

## Abstract

Uspanteko (Mayan) is unique among the languages of Guatemala in having a full-fledged system of lexical tone. Tone is thoroughly integrated into the morphology of the language, and triggers several predictable phonological alternations. The Uspanteko tone system is also relatively simple, involving at most two contrastive categories. However, tone in Uspanteko shows a high degree of phonetic variability, and there is no consensus as to what tones are phonetically or phonologically active in the language. This paper argues that at least some of this unclarity owes to the effect of intonation, which can obscure lexical tone on vowels. A phonetic study attempting to control for intonation suggests that lexical tone in Uspanteko involves a privative [H]~∅ contrast on short vowels, and either a [H]~∅ or [H]~[L] contrast on long vowels. The relationship between the phonetics of tone and its low functional load in Uspanteko is also discussed.

**Key terms:** Uspanteko, Mayan, pitch accent, intonation, functional load, marginal contrast, phonetics, fieldwork

## 1 Uspanteko

Uspanteko belongs to the K'ichean branch of the Mayan language family (Bennett et al. 2016, Aissen et al. 2017 and references there). It is spoken in the central highlands of Guatemala, in the city of San Miguel Uspantán and in several surrounding villages, particularly Las Pacayas (Fig. 1; Us Maldonado no date(b)).

\*We thank the Uspanteko speakers who participated in our study, and all of 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 Patzán, Juana Bernadina Ajpop Tiquiram, and Tomás Alberto Méndez López for their help over the years. Portions of this work were presented at *Sound Systems of Latin America* (SSLA III), *International Congress on the Phonetic Sciences* (ICPhS 2019), the *Conference on Indigenous Languages of Latin America* (CILLA 2019), the 6th *NINJAL International Conference on Phonetics and Phonology*, and UC San Diego. For helpful comments, we thank Sharon Rose, Scott Myers, John Kingston, Nina Hagen Kaldhol, Shin Ishihara, Marc Garellek, Gorka Elordieta, Christian DiCanio, Gabriela Caballero, and Brandon Baird. This material is based upon work supported by the National Science Foundation under Grant Nos. 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.

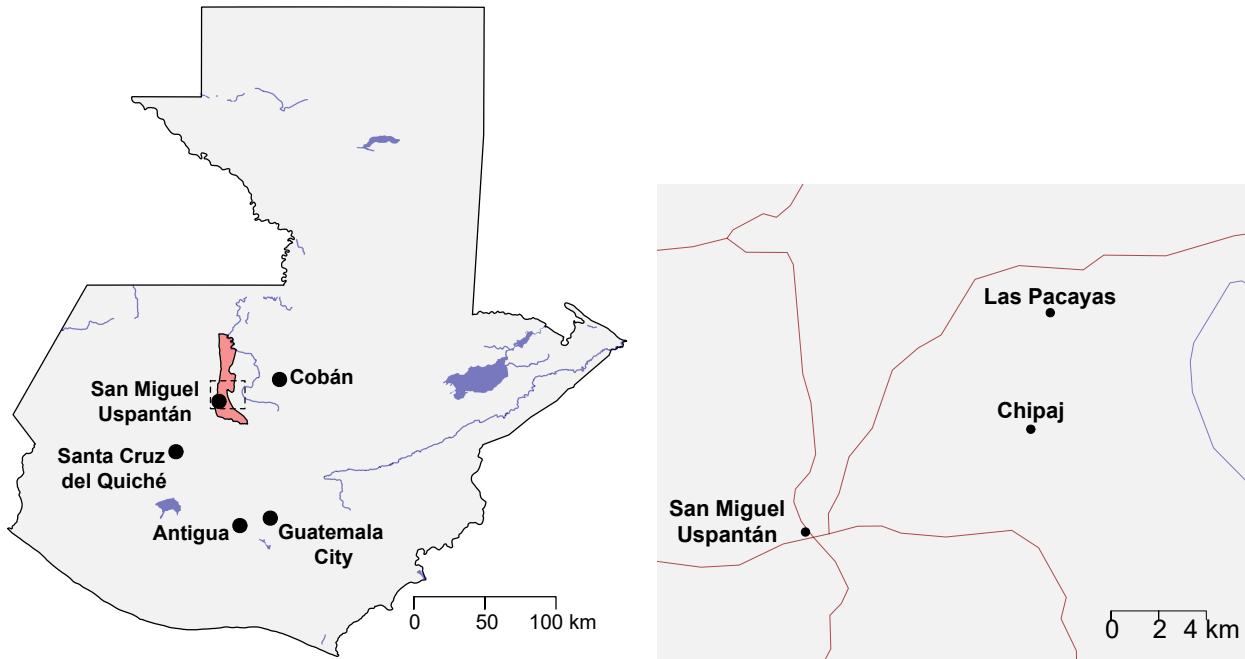


Figure 1: To the left: map of Guatemala, with the municipality of Uspantán shaded. Dashed lines indicate inset area to the right. To the right: Inset showing communities with >200 native speakers of Uspanteko, according to Us Maldonado (no date(b)), with major roads shown.

There are currently somewhere between 1500-4000 native speakers of Uspanteko (Richards 2003, Us Maldonado no date(b)). Multilingualism is quite prevalent in Uspantán, and speakers of Uspanteko typically speak Spanish and K'iche' as well, and less frequently Q'eqchi' or Poqomchi'. To our knowledge there are no monolingual speakers of Uspanteko. The language is endangered: many children in the Uspanteko area are now learning Spanish and/or K'iche' as their first languages, as these are the languages most typically used in the public sphere in the Uspantán area. (K'iche', which has over 1 million speakers, is something of a lingua franca in the central and western highlands of Guatemala.)

## 1.1 Word-level prosody in Uspanteko

Uspanteko is one of the few Mayan languages to have innovated a robust, grammaticalized system of lexical tone (Bennett 2016, England & Baird 2017, DiCanio & Bennett To appear).<sup>1</sup> The tone system is intertwined with word-level stress, vowel length, and morphology, as described below.

All descriptions of Uspanteko phonology agree that there are two tonal categories in the language. However, sources differ in how these two tones are characterized. Campbell (1977) reports

<sup>1</sup> Along with Uspanteko, the other Mayan languages with lexical tone are Yucatec and Mocho'. These three languages are geographically and genetically distant from each other, suggesting independent innovation of tone rather than shared inheritance. The tonal system of Yucatec is rather different from the tonal systems of Uspanteko and Mocho', consistent with independent innovation. Several Mamean languages spoken along the border between Guatemala and Mexico appear to be undergoing tonogenesis at present, conditioned by pitch perturbations associated with glottal stop [?]. More controversially, tone has been reported for Venustiano Carranza Tsotsil and Southern Lacandon, though the facts here are rather unclear. See Herrera Zendejas (2014), Bennett (2016), England & Baird (2017), Sobrino Gómez (2018), DiCanio & Bennett (To appear) for details and references.

a contrast between high and low tones, while Grimes (1971, 1972) reports a contrast between falling and rising tones. Bennett & Henderson (2013), Bennett et al. (2019), and Bennett et al. (submitted) stake out a third view, arguing that tone in Uspanteko involves a privative contrast between the presence vs. absence of a high tone (see Can Pixabaj 2007 for a similar proposal). This analysis essentially assimilates tone in Uspanteko to a kind of lexical pitch accent (e.g. Hyman 2006, 2009). For the purposes of this section we adopt the privative  $[H] \sim \emptyset$  analysis of Bennett & Henderson (2013), and return to a more detailed evaluation of this issue in the following sections.

The basic stress system of Uspanteko is straightforward. In toneless words, stress falls on the word-final syllable, essentially without exception. There are no secondary stresses. This pattern of stress assignment is exemplified by the toneless words in Fig. 2, and is the same pattern of stress assignment found in other K'ichean-branch Mayan languages, none of which have tone (DiCanio & Bennett To appear, Bennett 2016, England & Baird 2017).<sup>2</sup> As discussed below, stress is phonetically cued by increased duration, greater intensity, and possibly by the anchoring of intonational tones, though this remains to be fully established (see too Baird 2014a,b, 2018 on the closely-related language K'iche', and Adell 2019 on Ixil). Vowel length is phonologically contrastive, but long vowels are restricted to stressed, word-final syllables (Fig. 2). This phonotactic restriction on long vowels gives rise to alternations like *chaak* [tʃa:k] 'work (NOUN)' vs. *tichakuun* [ti.tʃa.'ku:n] '(s)he works'.

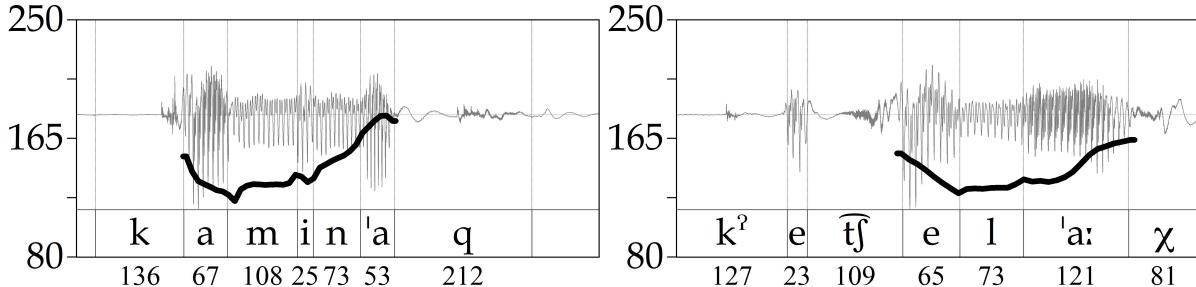


Figure 2: *kaminaq* [ka.mi.'naq] 'deceased (person)' vs. *k'echelaaj* [k?e.tʃe.'la:χ] 'forest' (speaker 6 JMS 2018). Y-axis marks f0 in Hz, X-axis marks duration in ms.

Recall that Uspanteko has two tonal categories, analyzed as  $[H]$  tone vs. the absence of tone in Bennett & Henderson (2013), Bennett et al. (2019). The  $[H]$  tone of Uspanteko has a restricted distribution, occurring only in stressed syllables. When the stressed vowel is long, the result is a simple  $[H] \sim \emptyset$  contrast in the word-final stressed syllable. Such a contrast is illustrated in Fig. 3, in which tonal ['ʃá:b] 'vomit' (on the right) is realized with a higher f0 than non-tonal ['ʃa:b] 'comb' (on the left).

The manifestation of tone is a bit more complex in words containing only short vowels. In words of this type, tone is realized on the penultimate syllable, and stress retracts to the position of tone (Figs. 4-10). Bennett & Henderson (2013) propose that tone in Uspanteko is always realized on the penultimate vocalic mora: this would be the first mora of a final long vowel [...  $\acute{V}_{\mu\mu} C_0 \#$ ], or the penultimate vowel when the final vowel is short [...  $\acute{V}_\mu C_0 V_\mu C_0 \#$ ] (see also Campbell 1977).

<sup>2</sup>Sound files corresponding to the phonetic diagrams in this paper are available online at [https://github.com/rbennett24/articles/tree/master/Uspanteko\\_intonation](https://github.com/rbennett24/articles/tree/master/Uspanteko_intonation). For more information on our fieldwork, see <http://pantek.us/>. Additional recordings of Uspanteko from our fieldwork are publicly available at the *Archive of the Indigenous Languages of Latin America* (AILLA; <https://ailla.utexas.org/>).

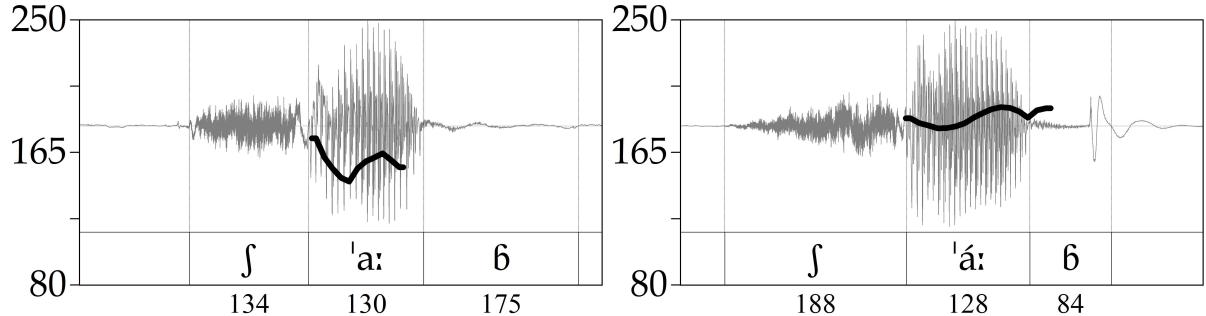


Figure 3: *xaab* ['ʃa:b] ‘comb’ (left) vs. *xáab* ['ʃá:b] ‘vomit’ (right) (speaker TAML 2019)

In the latter case, stress retraction to the penult ensures that tone will always coincide with the position of stress.

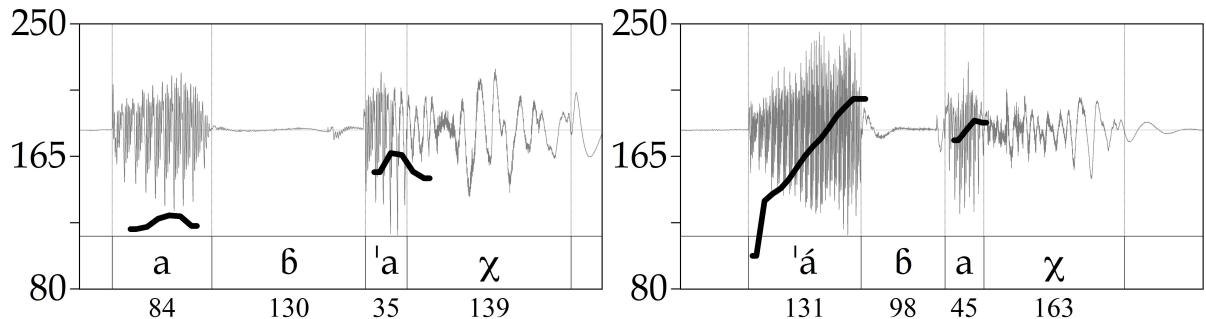


Figure 4: *ab'aj* [a.'bax̥] ‘stone’ vs. *áb'aj* ['á.bax̥] ‘your name’ (speaker 6 JMS 2018)

Tone and stress are phonetically separable in Uspanteko. The primary correlate of [H] tone is raised pitch on the tonal vowel.<sup>3</sup> The primary correlates of stress are duration and intensity, and secondarily vowel quality, which is slightly more peripheral for stressed vowels (Bennett et al. submitted and §3.5 below).<sup>4</sup> These phonetic differences between stress and tone are plainly visible in Fig. 5. In the non-tonal word [tu.'lul] (on the left), stress is cued by vowel duration, and somewhat more weakly by intensity. These same diagnostics indicate that stress has shifted to the penult in the tonal word ['ín.tsi?] (on the right). Furthermore, tonal ['ín.tsi?] has a clear rising pitch excursion on the accented penult, which is lacking from the accented syllable of the non-tonal word [tu.'lul]. Inspection of other comparable diagrams in this article, such as Figs. 4, 7, and 9, make it clear that the phonetic differences between tone and stress are highly systematic in Uspanteko (see also Bennett et al. submitted). (In section 1.2 we discuss the slight rising pitch seen on some non-tonal stressed vowels in examples like Figs. 2 and 5, which we attribute to intonational boundary tones.)

Tone is deeply tied up with morphology in Uspanteko. Lexical [H] tones primarily occur on nouns, and to a lesser extent adjectives and adverbs (1).

<sup>3</sup>The term ‘pitch’ refers to a perceptual dimension. We use it here as a slightly inappropriate synonym for the acoustic dimension of f0.

<sup>4</sup>Consonant duration may also play a role in cuing stress in Uspanteko (e.g. Figs. 4, 7, 9), but we have not yet investigated this possibility in any detail.

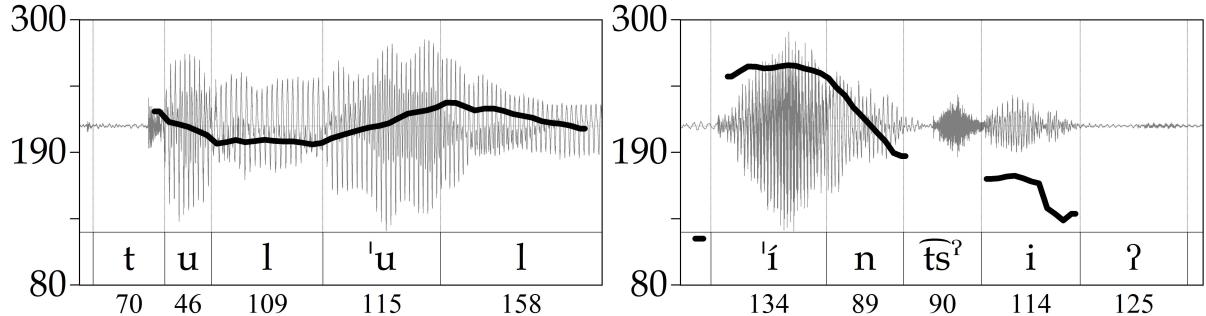


Figure 5: *tulul* [tu.'lul] ‘zapote (fruit species, *pouteria viridis*)’ vs. *íntz'i* ['ín.tsi?] ‘my dog’ (speaker JBAT 2011; Bennett & Henderson 2013)

- |                                                   |                                       |
|---------------------------------------------------|---------------------------------------|
| (1) a. <i>xíkin</i> ['jí.kin] ‘ear’               | e. <i>xílij</i> ['jí.liχ] ‘inside’    |
| b. <i>íxim</i> ['í.jim] ‘corn’                    | f. <i>lékej</i> ['lé.keχ] ‘up, high’  |
| c. <i>táq'aj</i> ['tá.q <sup>?</sup> aχ] ‘plains’ | g. <i>ójor</i> ['ó.xor] ‘in the past’ |
| d. <i>cháqej</i> ['tʃá.qeχ] ‘dry’                 | h. <i>íwir</i> ['í.wir] ‘yesterday’   |

Tone is far less common on verbs and other lexical categories.<sup>5</sup> The prevalence of tone on nouns owes in part to the fact that some highly productive nominal affixes introduce [H] tone to their stems (Table 1; see also Can Pixabaj 2007:39-49,89-95,110-2, etc.). Figs. 7, 9 illustrate tonal alternations on nouns triggered by the addition of tone-bearing affixes. (The form of the possessive prefixes varies depending on whether the stem begins with a vowel or consonant (Bennett 2016). Capital /V/ indicates a vowel of varying quality.)

Table 1: Some productive affixes associated with tone

Affix	Gloss	Type	Example
/in-, H/~/w-, H/	1SG.POSS	Inflectional	[ín.χal] ‘my corncob’
/q(a)-, H/	1PL.POSS	Inflectional	[qá.laq] ‘our plate/dish’
/a(w)-, H/	2.POSS	Inflectional	[á.piʃ] ‘your tomato’
/-V6, H/	Plural	Inflectional (certain animate nouns)	[aχ.tʃá.ki6] ‘workers’
/-6V1, H/	Instrumental/ locative	Derivational (noun-forming)	[k <sup>?</sup> áj.6al] ‘marketplace’
/-al-ik, H/	Adjectival participle	Derivational (adjective-forming)	[sa.íʃá.lik] ‘lost’

While affixation is a frequent and productive source of tone on nouns in Uspanteko, there are numerous morphologically *simple* roots which bear tone, as well as many simple roots (nominal and otherwise) which are lexically toneless (Figs. 3, 5, 6).

<sup>5</sup>Can Pixabaj (2007:41,49,88, etc.) reports that the ‘status suffix’ /-ik/ may introduce tone on intransitive verbs (on status suffixes in general, see Henderson 2012, Coon 2016 and references there). Most of the Uspanteko speakers we have worked with do not make use of this suffix, and some speakers identify /-ik/ as a borrowing from closely-related K’iche’, rather than being properly Uspanteko.

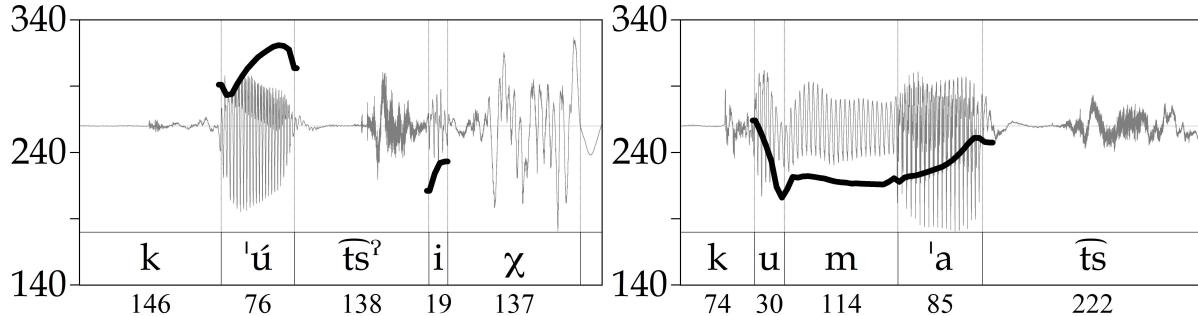


Figure 6: *kúts'ij* ['kú.ts?iχ] ‘flower’ vs. *kumatz* [ku.'mats] ‘snake’ (speaker 9 PA 2018)

Though the presence or absence of tone is morphologically conditioned, the *position* of tone is determined entirely on the basis of phonological principles. As noted above, the [H] tone is always realized on the penultimate mora of the phonological word, regardless of its morphological origin. As a result, [H] tones introduced by affixes are not necessarily realized on the morpheme they are lexically associated with. For example, when tonal possessive prefixes (Table 1) attach to monosyllabic stems like ['6a] ‘head’, tone will be realized on those possessive prefixes (Fig. 7; note that the 3.POSS prefix /iχ-/ in the lefthand diagram is *not* associated with tone). But when a possessive prefix introduces tone on a polysyllabic stem, it will be the stem rather than the prefix which hosts the [H] tone (Fig. 8).

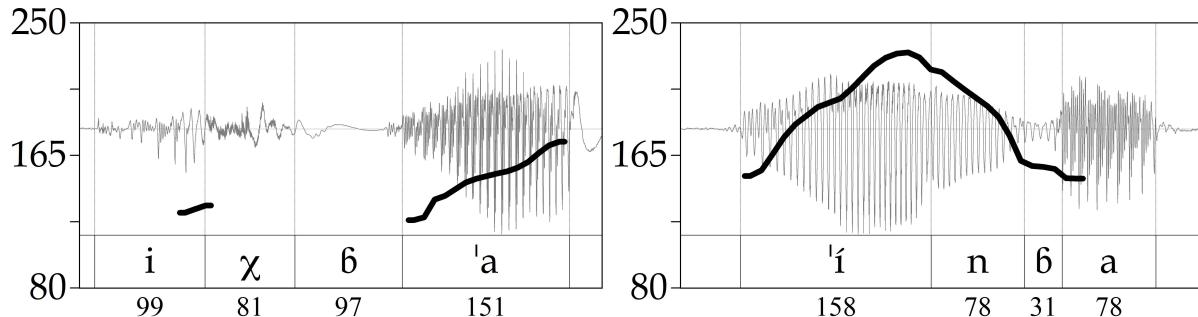


Figure 7: *ijb'a* [iχ.'6a] ‘his/her/its head’ vs. *ínb'a* ['í.n.6a] ‘my head’ (speaker 6 JMS 2018)

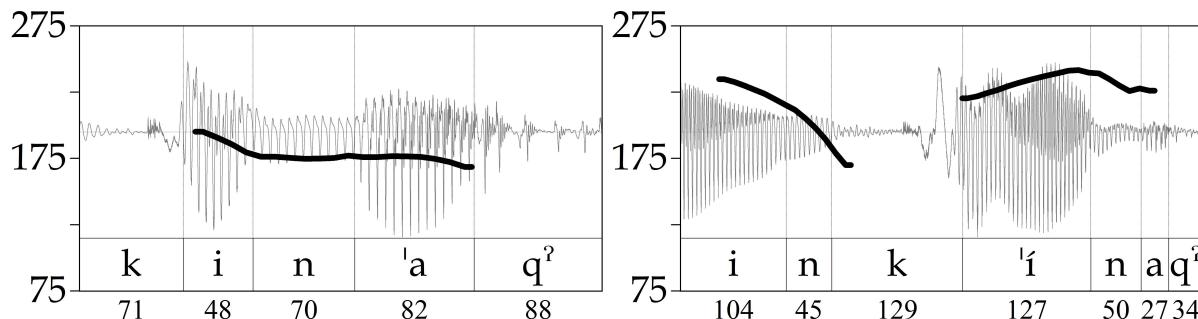


Figure 8: *kinaq* [ki.'naq?] ‘bean’ vs. *inkínaq* [in.'kí.naq?] ‘my bean’ (speaker 9 PA 2018)

The same is true for suffixes which introduce tone: if the vowel of the suffix is short, it will

assign [H] tone and stress to the preceding vowel, as with the plural suffix /-V6, H/ (Fig. 9; note the shortening of the stem vowel /i:/ in non-final position).

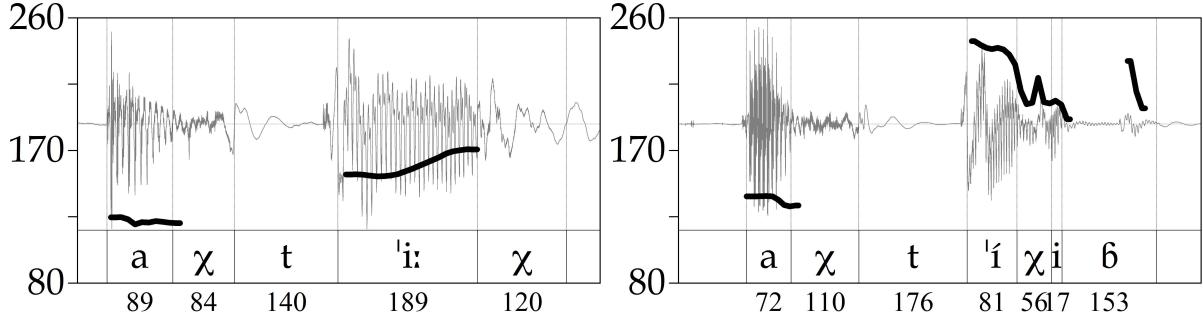


Figure 9: *ajtijj* [ax.'tiχ] ‘teacher’ vs. *ajtijib* [ax.'tí.χib] ‘teachers’ (speaker TAML 2019)

Similarly, some possessive prefixes associated with tone consist of just a single consonant. These prefixes cannot themselves host the tone they are associated with, even in principle, and so tone necessarily migrates to the nominal stem (Fig. 10).

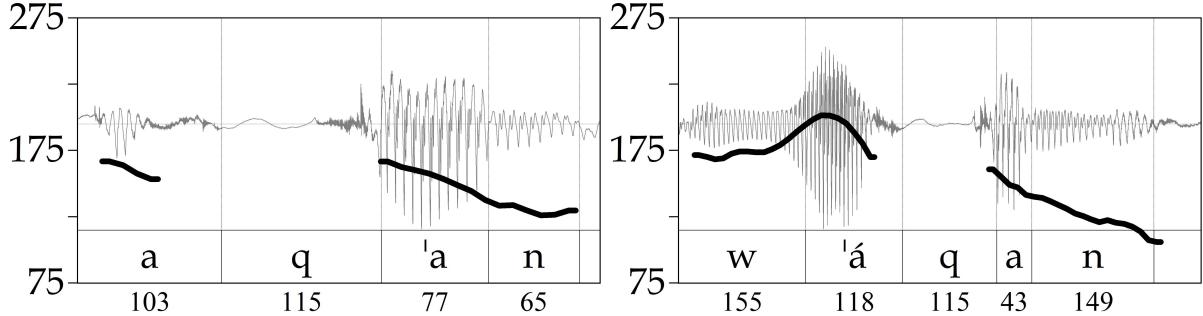


Figure 10: *aqan* [a.'qan] ‘leg’ vs. *wáqan* ['wá.qan] ‘my leg’ (speaker JBAT 2014)

Finally, tone which is specified on roots may also shift under suffixation to satisfy the phonological conditions on tone placement, e.g. *kútz'ij* ['kú.ts<sup>?</sup>iχ] ‘flower’ (Fig. 6) vs. *jkutz'ijil* [χku.'ts<sup>?</sup>í.χil] ‘its flower (as in a flower painted on something)’ (Can Pixabaj 2007:76,94).

Lastly, the deletion of unstressed final vowels can render the placement of tone on penultimate short vowels opaque, e.g. /saxab, H/ → ['sáxb] ‘shoe’. For detailed discussion see Can Pixabaj (2007:27-8, 51-2, 67-8), Bennett & Henderson (2013), and Bennett (2016).

## 1.2 Determining the tonal inventory

To this point we have assumed Bennett & Henderson’s (2013) privative [H]~∅ analysis of the Uspanteko tone system. This analysis builds on earlier descriptions of the Uspanteko tone system, but also differs from those descriptions in substantive ways. Grimes (1971, 1972) characterizes tone in Uspanteko as a binary contrast between rising [LH] tone and falling [HL] tone on long vowels. Campbell (1977) also proposes a binary contrast on long vowels, but assumes simple high [H] and low [L] tones, rather than contours. Neither Grimes nor Campbell report a tonal contrast on short vowels, but they do observe stress shift to the penult, which we claim is driven by the presence of an [H] tone in that position. Can Pixabaj (2007) adopts a more complex system, with a

privative [HL]~∅ contrast on stressed long vowels; [H] tone on stressed, penultimate short vowels; and no tone at all on short vowels in final stressed syllables.

The brief, schematic description in Kaufman (1976:19-20,100-2) assumes a three-way [HL]~[H]~∅ tone inventory for long vowels, and a privative [H]~∅ inventory for short vowels, with the proviso that only one tone may occur per word. Kaufman also transcribes some non-final long vowels.<sup>6</sup> Not all of the tones proposed by Kaufman are directly contrastive: the falling [HL] tone only occurs on long vowels in final syllables, while non-final long vowels are realized with [H] tone instead, unless they are toneless. Toneless words are assigned a default word-final accent. Kaufman treats this word-final default accent as being on a par (at least phonetically) with lexical [H] tone on non-final vowels. Lastly, the earliest descriptions of Uspanteko in Stoll (1884, 1887, 1888, 1896) note some cases of non-final stress, but do not describe tone.

These descriptions essentially agree that Uspanteko possesses two tonal categories on long vowels, and an [H] tone on penultimate, accented vowels. But there is disagreement as to (i) the phonetic values associated with each tonal category, and (ii) whether the tonal system involves a privative contrast between the presence vs. absence of tone, or a binary contrast between two specified tones. Finding empirical evidence to resolve this issue is not straightforward. First, the coarse pitch patterns on long vowels are often compatible with several different analyses. Consider the leftmost diagram in Fig. 11. The pitch contour on this instance of [tʃú:n] is phonetically falling, but this phonetic fact alone underdetermines the corresponding phonological representation. Is this vowel specified for a falling [HL] contour as such, or does the f0 trace reflect a level [H] specification, with a gradual fall towards neutral f0 following the achievement of the [H] target (Bennett & Henderson 2013)? And if [tʃú:n] is lexically specified with an [HL] tone, should we expect a falling f0 contour to be an invariant property of this word across different utterances? If so, what do we say about the many tokens of this item which *lack* a falling pitch contour, such as the rightmost diagram in 11? Which properties of these f0 contours reflect the basic phonological specification of lexical tone, and which are due to the influence of contextual factors?

The same issues arise with respect to the question of privative vs. binary contrast. This is essentially a question about tonal underspecification: are all stressed (long) vowels specified for tone, or only those stressed vowels which are associated with raised f0? Consider Fig. 3: the contrast in pitch levels between *xaab'* ['ʃa:b] ‘comb’ and *xáab'* ['ʃá:b] ‘vomit’ can of course be interpreted as a binary [H]~[L] contrast, given the differences in pitch height in these two words. But these f0 differences can just as easily be taken as the realization of a privative [H]~∅ contrast,

---

<sup>6</sup>Short vowels in Uspanteko are substantially lengthened in accented penults, but do not neutralize in duration with true phonological long vowels (Bennett et al. submitted and section 3.5 below). We suspect that most of the non-final, [H]-toned ‘long’ vowels transcribed by Kaufman (1976) are in fact phonological short vowels that have been phonetically lengthened under tone. The same can be said for many, if not all of the non-final long vowels reported by Grimes (1971, 1972) and Campbell (1977).

The Uspanteko speakers we have worked with have clear intuitions about vowel length in stressed final syllables, where length is robustly contrastive. When asked for judgments about vowel length in non-final syllables, they either report that non-final vowels are short, or have difficulty identifying vowel length in those positions. Furthermore, if non-final long vowels were permitted in Uspanteko — as reported by Grimes (1971, 1972), Kaufman (1976) and Campbell (1977) — the systematic shortening of long vowels in suffixed forms like Fig. 9 (e.g. [ax.'ti:χ]~[ax.'tí.χib]) is mysterious and calls for explanation (for more examples of this type, see e.g. Can Pixabaj 2007:68,87-8).

One possibility is that non-final long vowels *were* permitted in Uspanteko, but have been lost in the 50 years separating our fieldwork from the work of Grimes, Kaufman and Campbell. The occurrence of non-final, unstressed long vowels is a point of systematic variation both within and across K'ichean-branch Mayan languages (e.g. Campbell 1977, Dayley 1985, Larsen 1988, Bennett 2016).

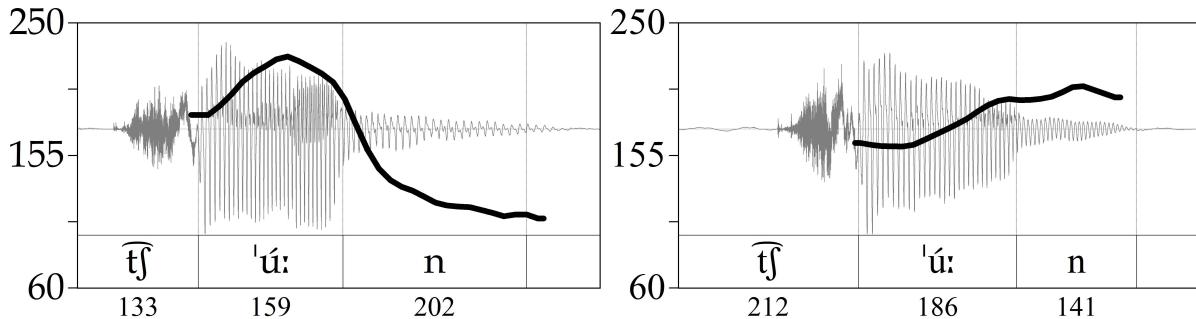


Figure 11: Two renditions of *chíun* [tʃú:n] ‘calcium, lime’ (speaker TAML 2019)

on the assumption that tonally unspecified vowels are realized lower in the speaker’s pitch range than vowels specified with an [H] tone.

The upshot is that surface phonetic forms of isolated words are a poor guide to tonal specification. Better evidence for binary contrast would come from grammatical patterns which show that two distinct tones need to be phonologically represented (e.g. Myers 1998 and references there). Were there phonological rules in Uspanteko which clearly referred to two distinct tones, we would have strong evidence for binary specification.

As it stands, we are aware of only two grammatical generalizations involving tone in Uspanteko: the requirement that [H] tone be realized on the penultimate mora, and the requirement that [H] tone coincide with stress. Since both of these generalizations concern just the [H] tone, they cannot be taken as evidence for binary tone specification. Of course, such patterns do not *falsify* the claim that Uspanteko makes use of a binary tone contrast, since a second tone (e.g. [L]) could be phonologically contrastive without also being implicated in phonological rules. The grammatical behavior of tone thus fails to settle the issue of binary vs. privative tonal contrast in Uspanteko.

Making matters worse, even the tonal properties of individual words cannot be taken for granted. Descriptive sources on Uspanteko achieve surprisingly little consensus on which words belong to which tonal categories, a fact already noted by Fox (1978:65). Some examples are shown in Table 2 below.<sup>7</sup>

As Table 2 illustrates, it is not difficult to find numerous discrepancies across these sources. Some of these differences are probably analytical—Grimes’ [HL] and [LH] tones, for instance, might reasonably be equated with Campbell’s [L] and [H] tones, respectively. But there is a troubling lack of consistency in how words are assigned to tonal classes in these fieldworker descriptions. Grimes’ [LH] tone corresponds to both [L] and [H] tones in Campbell (1977); Campbell’s [H] tone corresponds to both [HL] and [LH] in Grimes (1972), and to both [H] and [HL] in Kaufman (1976); Can Pixabaj’s toneless vowels correspond to both [H] and [L] in Campbell (1977); and so on. The utter lack of systematic correspondence between tonal categories in these sources makes it extremely hard to assess competing proposals about the tonal inventory of the language.

Some of the heterogeneity across these sources likely reflects genuine phonological and lexical variation across speakers of Uspanteko. Inter-speaker linguistic differences are indeed widespread in the Uspanteko community. It may also be that the tone system underwent changes between the time of earlier sources like Grimes (1972), and more contemporary work like Can Pixabaj

<sup>7</sup>Méndez’s (2007) Uspanteko dictionary marks tone, and largely agrees with Can Pixabaj (2007) in how it classifies words into tone categories. Another dictionary, Us Maldonado (no date(a)), does not mark tone.

Table 2: Differing tonal categories across Uspanteko sources (Grimes 1972, Kaufman 1976, Campbell 1977, Can Pixabaj 2007, Bennett & Henderson 2013)

Item	Grimes	Kaufman	Campbell	Can Pixabaj	Our fieldwork
[po:p] ‘petate’	[LH]	—	[L]	∅	∅
[a:q?] ‘tongue’	[LH]	[H]	[L]	∅	∅
[t̪se:?] ‘tree’	[LH]	[H]	[H]	∅	∅
[ku:k?] ‘squirrel’	[HL]	—	[L]	[H]	∅ ~ [H] across speakers
[ba:q] ‘bone’	[HL]	[H]	[H]	∅	∅
[q?i:χ] ‘sun’	—	[HL]	[L]	∅	∅
[t̪si:(?)] ‘mouth’	[LH]	[HL]	[H]	Short, ∅ [t̪si?]	∅
[t̪ʃary] ‘ashes’	—	[HL]	[L]	[H]	[H]

(2007). But in our view, sociolinguistic and diachronic variation are not sufficient to explain the wide divergences found across firsthand descriptions of the tonal system of Uspanteko.<sup>8</sup>

We suspect that research on Uspanteko phonology has been significantly confounded by the influence of intonation on the phonetic realization of lexical tone (see also Bennett et al. 2019, and Pike 1946 on tone in Yucatec Maya). Fig. 12 provides another example of the tone contrast on long vowels, using the same minimal pair seen earlier in Fig. 3. These items were elicited in final position in a wordlist, and the phonological contrast between tonal categories is phonetically preserved in this context (i.e. f0 is higher for [ʃá:b] ‘vomit’ than for [ʃa:b] ‘comb’, just as in Fig. 3).

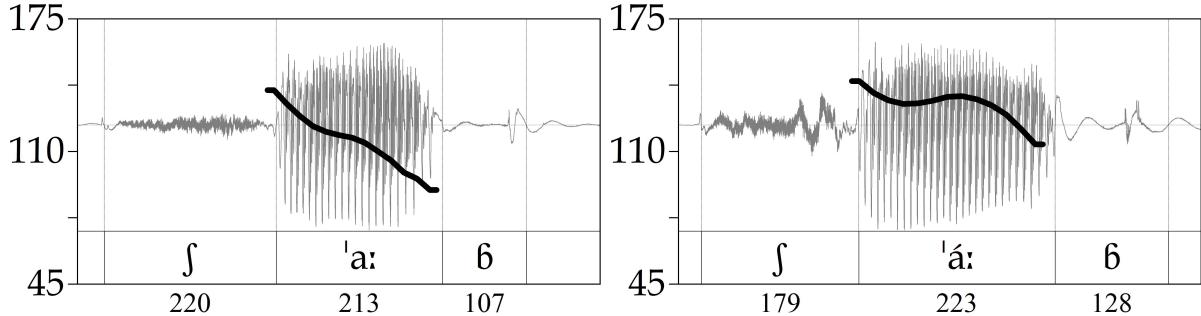


Figure 12: *xaab* [ʃa:b] ‘comb’ (left) vs. *xáab* [ʃá:b] ‘vomit’ (right), produced as final items in wordlist (speaker MH 2016). The lexical tone contrast is phonetically preserved.

Fig. 13 shows these same items, produced by the same speaker in the same recording session,

<sup>8</sup>It is also relevant that different sources on Uspanteko emphasize different levels of description. Bennett & Henderson (2013) are most concerned with the grammatical logic of the tone system, and the principles which regulate the distribution of tone and stress. Other sources are more oriented toward a surface-level description which includes concrete phonetic details of how tone is realized, but less analysis of where those phonetic details come from (what Grimes 1972:45 calls ‘systematic phonetics’, following Chomsky 1964).

but now in medial position in a wordlist. In this context the lexical tone contrast is completely masked by a rising intonational contour which is superimposed on both items. Auditorily, the pitch contours in Fig. 13 are almost indistinguishable, suggesting that the lexical tone contrast has been completely neutralized.

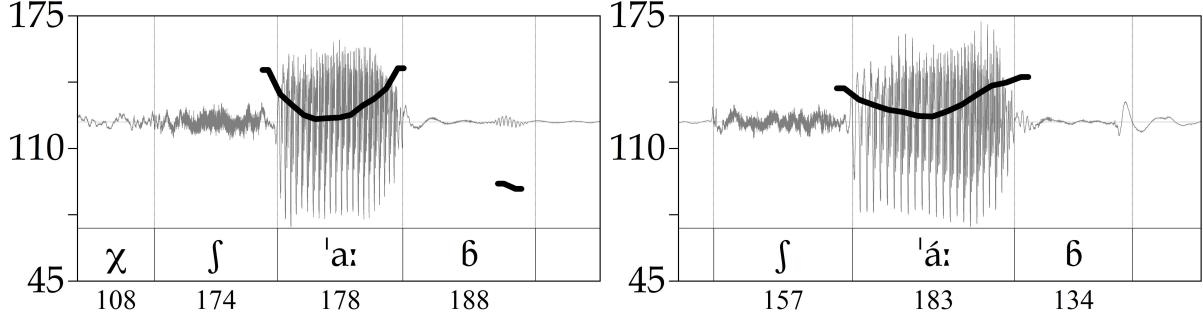


Figure 13: *jxaab*’ [χʃa:b] ‘his/her comb’ (left) vs. *xáab*’ [ʃá:b] ‘vomit’ (right) as medial items in wordlist, with rising intonation (speaker MH 2016). The lexical tone contrast is phonetically neutralized.

These examples illustrate a well-known pitfall of studying tone: isolation forms may not provide reliable information about lexical tone, because the pitch contours on isolated words can be significantly affected by intonational patterns associated with phrases and utterances (e.g. Pike 1948, Himmelmann 2006, Himmelmann & Ladd 2008, Hyman 2014, Jun & Fletcher 2014, Snider 2014, Yu 2014). Bennett & Henderson (2013) and Bennett et al. (2019) are the only studies of Uspanteko phonology which explicitly describe the methods used to elicit tone. Both of those studies tried to minimize the influence of intonation on the pitch patterns of individual words. We do not know if similar elicitation techniques were used in other research on Uspanteko phonology, or whether those studies instead relied on isolation forms which were potentially influenced by intonational pitch contours. (For more recent wordlist data, see Bennett et al. submitted.)

Recall that a major disagreement in the description of Uspanteko concerns whether tone should be defined using pitch levels, pitch contours, or some combination of the two. One possibility is that the contours described by Grimes (1971, 1972), Kaufman (1976) and Can Pixabaj (2007) — and the disagreements between them as to what the contours actually *are* (Table 2) — reflect additional pitch variability introduced by higher-level intonation. As in other languages, intonation in Mayan languages is often expressed with large rising or falling pitch contours (Berinstein 1991, Baird 2014a,b, 2018, Bennett 2016, England & Baird 2017, DiCanio & Bennett To appear and references there). Utterance-final rising intonation is common for both interrogative and declarative sentences, and is illustrated for Uspanteko in Fig. 14.

The same utterance-final rising contour can in fact be observed on some of the single-word examples already presented in this article. Consider Figs. 2, 5 (lefthand side), 7 (lefthand side), 9 (lefthand side), 11 (righthand side), and 13. All of these items show some form of rising contour, though they differ in how sharply the rise is implemented. Some of these items were elicited in isolation or in wordlists. Other items were elicited using frame sentences, which often encourage isolation-type prosody on target items. In all of these cases, it seems plausible that the observed rises are not inherent properties of these words themselves — they are not lexical tones — but rather represent the influence of utterance- or phrase-final intonation on phonetic form (see also

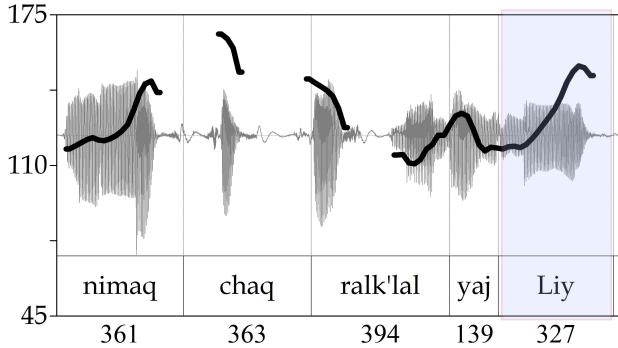


Figure 14: *Nimaq chaq ralk'lal yaj Liy* ‘Maria’s sons are very large.’ (speaker 4 P, 2016)

Bennett et al. submitted). This is especially clear in Figs. 12 and 13, where actual alternations in pitch shape can be observed depending on the sentential context of the items.

It thus seems worth considering whether the word-level contour tones described in Grimes (1971, 1972) and Kaufman (1976) might be better understood as some combination of lexical and intonational melodies, rather than directly reflecting lexical tone as such. The extensive variation in how tones are transcribed for individual words across sources (Table 2) seems to us to raise exactly the same possibility.

Examples like Figs. 11-13 suggest that intonation may have an extensive influence on how lexical tone contrasts are phonetically realized in Uspanteko. This certainly presents challenges for the study of stress and tone. At the same time, the precise details of how tone and intonation interact in Uspanteko has the potential to shed light on the phonological representation of lexical tone. It has been shown for a range of other languages that intonational patterns distinguish between toneless vowels and vowels which are lexically specified for tone (e.g. Pierrehumbert & Beckman 1988, Myers 1998, Remijsen & van Heuven 2005, Riad 2006, Remijsen et al. 2014). Finding comparable evidence in Uspanteko would provide support for the privative [H]~Ø analysis of tone developed in Bennett & Henderson (2013), Bennett et al. (2019). In the remainder of the article we discuss a production study designed to probe exactly this question.

## 2 Production study of tone and intonation

The goal of our study was to examine word-level prosody in Uspanteko under different intonational and discourse conditions. This was done by means of a production study in which native speakers of Uspanteko produced target words in a series of sentential contexts, using a question-answer elicitation method (e.g. Himmelmann 2006, Himmelmann & Ladd 2008, Bennett & Henderson 2013, Clopper & Tonhauser 2013, Baird 2014a, 2018, Hedding to appear).

### 2.1 Items

Target items were selected to cross two factors: tonal specification ([H] vs. Ø, following Bennett & Henderson 2013), and length of the accented vowel (short [V] vs. long [V:]; Table 3). There were twelve target items in the study, three in each of the cells in Table 3. A full list of the target items used in our study is provided online at [https://github.com/rbennett24/articles/tree/master/Uspanteko\\_intonation](https://github.com/rbennett24/articles/tree/master/Uspanteko_intonation).

Table 3: Sample items by condition

	<b>Short [V]</b>	<b>Long [V:]</b>
<b>No tone</b>	/k <sup>?</sup> e'ten/ ‘hot’	/qa'po:p/ ‘our sleeping mat’
<b>Tone</b>	/'qálaq/ ‘our plate’	/qa'χó:q <sup>?</sup> / ‘our corn husk’

## 2.2 Methodology

As discussed in section 1.2, utterance-final position is often associated with large falling or rising pitch contours in Uspanteko. Rising pitch contours (Fig. 14) are particularly prevalent, in both declarative and interrogative sentences. In order to explore the effect of utterance-final intonation on the phonetic realization of word-level prosodic contrasts, target items were elicited in both sentence-final and sentence-medial position.

In many languages the phonetic realization of stress, tone, and intonation can be affected by the structure of the larger discourse in which a word occurs. Semantic and pragmatic focus are often cued by manipulating prosodic parameters like pitch, duration, and intensity (e.g. Xu 1999, Gussenhoven 2004, Ladd 2008a, Kügler & Genzel 2012, Féry 2013, Féry & Ishihara 2016, Di-Canio et al. 2018, Wagner to appear, Hedding to appear, and references there). This is also true for Mayan languages (see Bennett 2016, England & Baird 2017, DiCanio & Bennett To appear for details and citations). Baird (2014a, 2018) reports that increased segmental duration, earlier timing of intonational events, and pitch range expansion are all phonetic reflexes of focus in K’iche’, particularly for words which are focused *in situ* (focused elements often undergo discourse fronting in Mayan languages; Aissen 1992, 2017). K’iche’ is closely-related to Uspanteko, and is spoken by most people in the Uspanteko area. We therefore expect that the information structure of the discourse could have an effect on the phonetic realization of tone and stress in Uspanteko.

We manipulated the discourse context of our target items by means of a question-answer elicitation method. A native speaker of Uspanteko read from a list of pre-prepared question prompts, and participants responded by translating a pre-prepared answer from Spanish to Uspanteko.<sup>9</sup> These questions were of two types. To elicit a target word under focus, we used a WH-question as a prompt (2). The target word appeared in the answer as the correlate of the WH-word — that is, the target word could have occurred as a valid answer to the question on its own. In the typology of semantic focus, this corresponds to ‘informational narrow focus’ (on different types of focus, see Gussenhoven 1983, Féry 2013, Féry & Ishihara 2016). As a shorthand we will simply call this the ‘Focus’ condition.

- (2) Target item focused, in sentence-medial position

- a. **Q:** NEN kan xawiil li ch'aat? ‘WHAT did you see on the bed?’
- b. **A:** Xinwiil SUQ'UK' li ch'aat. ‘I saw a LOUSE on the bed.’

Baird (2014a, 2018) finds that contrastive focus is more prosodically marked than broad focus in K’iche’ (‘broad focus’ involves focus on the entire expression rather than a sub-part, as in e.g. an answer to the question ‘What happened?’). Informational narrow focus — the focus type used in our study — falls between broad and contrastive focus on the ‘strength’ scale (Féry 2013).

---

<sup>9</sup>We used Spanish prompts because literacy in Uspanteko is generally low, and even literate speakers are often more comfortable reading in Spanish.

The counterpart of the focus condition was elicited using polar ‘yes-no’ questions. In this condition the target item was itself mentioned in the question, as in (3). In the corresponding answer the target word is then discourse-given, in the sense of having been previously mentioned in the discourse. The target word is additionally pragmatically backgrounded because it does not by itself provide the information which the yes-no question is seeking.

- (3) Target item discourse-given, in sentence-final position
  - a. **Q:** *Tiqasu' qaxoot?* ‘Do we clean our **comal**?’
  - b. **A:** *Ji'n, tiqasu' qaxoot.* ‘Yes, we clean our **comal**.’

For convenience, we will call this the ‘Given’ condition, recognizing that other researchers might prefer different terminology (e.g. ‘previously mentioned’).

There were 48 total question-answer pairs in the study, consisting of twelve target words (vowel length (2)  $\times$  tone (2)  $\times$  3 items each = 12) produced in sentences reflecting each combination of discourse status and position ( $2 \times 2 = 4 \times 12 = 48$ ). Each speaker went through the list of question-answer pairs at least once, often repeating the same question-answer pair in order to guarantee that we had recorded at least one fluent, natural rendition. Overall these speakers produced between 57-113 usable tokens each (mean = 79, median = 69, SD = 21), yielding a total of 946 word tokens (= 1532 vowel tokens) for analysis. 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. A waveform and pitch track for an example response are given below in Fig. 16.

### 2.2.1 Methodological issues

The question-answer methodology we used in this study is not particularly naturalistic. First, it involves a scripted translation task, which is quite unlike a regular discourse. Second, the answers themselves are unlike the responses typically found in actual Uspanteko conversations. In the Given condition, for example, a natural response would normally involve the omission of discourse-given material (i.e. ‘pro-drop’), rather than repetition of the target item (4) (Brody 1984, Du Bois 1987, England 1991, England & Martin 2003).

- (4) a. **Q:** *Wi' tinik laj qálaq?* ‘Is there meat on our plate?’
- b. **A:** *Ji'n (wi').* ‘Yes (there is).’
- c. **Our study:** *Ji'n, wi' tinik laj qálaq.* ‘Yes, there’s meat on our plate.’

Similar issues arise for the Focus condition. In Mayan languages focused elements frequently undergo discourse fronting to the left periphery (5) (Aissen 1992, 2017, Can Pixabaj & England 2011).

- (5) a. **Q:** *Nen rik'il tiqajach qaaw re chwee'q?* ‘With what will we serve our food tomorrow?’
- b. **A:** *[Rikil li qálaq] tiqajach \_\_\_\_.* ‘It’s with our plate that we’ll serve it.’
- c. **Our study:** *Tiqajach rik'il li qálaq.* ‘We’ll serve it with our plate.’

In this case the issue is somewhat less severe. New information focus is a relatively weak type of focus, and need not trigger discourse fronting in Mayan languages (Féry 2013, Aissen 2017). Further, *in situ* focus is attested as a focus strategy in a number of diverse Mayan languages,

including K'iche' (Velleman 2014a,b), Tseltal (Polian 2013:773ff), and Yucatec Maya (Kügler & Skopeteas 2006, 2007, Kügler et al. 2007, Gussenhoven & Teeuw 2008, Verhoeven & Skopeteas 2015). More locally, responses to WH-questions which employ *in situ* focus are indeed possible in Uspanteko, and are judged acceptable by our consultants. And since *in situ* focus is more prosodically marked than focus fronting in several Mayan languages (Kügler & Skopeteas 2006, 2007, Kügler et al. 2007, Baird 2014a, 2018, England & Baird 2017), *in situ* focus may be a better testing ground for exploring the interaction of tone and intonation. The limited ecological validity of these materials should nonetheless be kept in mind when interpreting the results (section 3).

## 2.3 Participants

Twelve native speakers of Uspanteko participated in this study. Eight of these speakers were recorded in 2017, and four in 2018 using the same elicitation materials. Bennett et al. (2019) report on preliminary results with just the eight speakers recorded in 2017, and analyze different aspects of the the data than what is analyzed here. Speaker ages ranged from 24-59 (mean = 40, median = 41, SD = 9.5). Seven speakers were female, and five male. Eight of the speakers were from the town of San Miguel Uspantán, three from the village of Las Pacayas, and one from the village of Chipaj (see map in Fig. 1). One additional participant recorded in 2017 had trouble completing the task, and their data is not reported here.

## 2.4 Data analysis

The sentences were manually transcribed, and transcriptions were then converted from the Uspanteko orthography to a phonetic transcription using a custom Python script. These phonetic transcriptions were then semi-automatically time-aligned with their associated audio recordings using the Montreal Forced Aligner (McAuliffe et al. 2017). The forced alignment model was trained with the default settings of the Montreal Forced Aligner, and included speaker-specific training of model parameters. Visual inspection of automatic alignments suggested surprisingly high accuracy, but the segment-level alignments were still hand-corrected for the target words.

Pitch contours on target items were then analyzed in Praat (Boersma & Weenink 2016). The recordings were downsampled to 16kHz, then pitch values were automatically extracted with a script specifying by-speaker pitch ranges following the recommendations of De Looze & Rauzy (2009), Keelan et al. (2011). Time-normalized pitch measurements were produced by averaging pitch values in Hz over  $1/9$  intervals of the duration of each vowel.

Pitch values for each speaker were then *z*-score normalized.<sup>10</sup> 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 1.2% of the remaining *z*-score normalized pitch data.

All plots in this article were drawn with the GGPlot2 package in R (Wickham 2009, R Development Core Team 2019). Scripts used for data preparation and analysis are available online at [https://github.com/rbennett24/articles/tree/master/Uspanteko\\_intonation](https://github.com/rbennett24/articles/tree/master/Uspanteko_intonation).

---

<sup>10</sup>The output of *z*-score normalization was highly correlated with some alternative methods for normalizing pitch values across speakers: semitone transformation relative to each speaker's mean pitch in Hz ( $r = 0.98$ ) (Zhang 2019); Hz divided by the size of each speaker's pitch range as estimated by the De Looze & Rauzy (2009), Keelan et al. (2011) formula ( $r = 0.96$ ); and range normalization using 2% and 98% estimates of floor and ceiling values in Hz ( $r = 0.99$ ) and in semitones ( $r = 0.99$ ) (Bardiaux & Mertens 2014). See also Ladd (2008a:192-202). Converting the raw Hz values to semitones, log(Hz), or ERB prior to *z*-score normalization has effectively no consequences for the results ( $r > 0.99$  for *z*-scores in all three cases).

## 2.5 Expectations

Little is known about intonation in Uspanteko. That fact, along with the unclarity surrounding the phonetic realization of tone, makes it hard to have clearly statable hypotheses about the results of this production study. However, we can state some soft expectations to guide the overall analysis, which is essentially exploratory and descriptive in nature. The following predictions assume that tone in Uspanteko involves a privative [H]~Ø contrast (Bennett & Henderson 2013), rather than any of the alternative possibilities set out in section 1.2:

(6) **Guiding expectations for data analysis:**

- a. When intonation is controlled for, vowels with [H] tone should have higher f0 than stressed, non-tonal vowels. (Section 3.1)
- b. Vowels with [H] tone will not necessarily show a consistent, fixed f0 shape (as we might expect if they were instead specified with [HL] or [LH] contours). (Section 3.4)
- c. Tone contrasts should be clearest in medial position, but may be masked in final position under the influence of intonational boundary tones (particularly (L)H% rises). (Section 3.1)
- d. Focus should expand the overall pitch range — as it does in K'iche' (Baird 2014a, 2018) — thereby enhancing the f0 differences between tonal and non-tonal vowels. (Sections 3.1, 3.2)
- e. Points (6c) and (6d) imply that tonal contrasts should be most phonetically salient in sentence-medial position under focus. (Sections 3.1, 3.2)
- f. Focus may affect the f0 of tonal vowels (which are specified with an [H] target) to a greater extent than the f0 of non-tonal vowels. This assumes that focus has a greater effect on f0 for vowels which are phonologically specified with an abstract tonal or intonational target, when compared to vowels lacking such a target. (See also Elordieta 2007, 2008, Elordieta & Hualde 2014 on Basque and Sugiyama 2011 on Japanese.) (Section 3.2)

## 3 Results

### 3.1 Pitch distinctions by vowel length

Fig. 15 shows loess-smoothed time-normalized f0 contours for tonal and non-tonal long vowels, across all four combinations of discourse status (given/Previously mentioned vs. new information focus) and sentential position (sentence-medial vs. sentence-final). Several things are apparent from this plot. First, tonal distinctions on long vowels are preserved in all four conditions. Still, the magnitude of the f0 differences between tonal and non-tonal vowels is not particularly large: differences in mean f0 across the four cells range from 0.31-0.57 z-units. We return to a discussion of the magnitude of the f0 distinctions associated with tone in section 3.5.

Comparing the left and right columns in Fig. 15, we see that focus involves f0 raising (see below for a supporting statistical analysis). It may be that focus leads to an overall expansion of the pitch range, as in Mandarin and other languages (Xu 1999, Hartmann 2008). The relative tonal and intonational sparseness of Uspanteko makes it difficult to distinguish between these two interpretations (for related discussion, see e.g. Roettger 2017 on Tashlhiyt Berber, Borise to appear on Caucasian languages, and Baird 2014a, 2018 on K'iche').

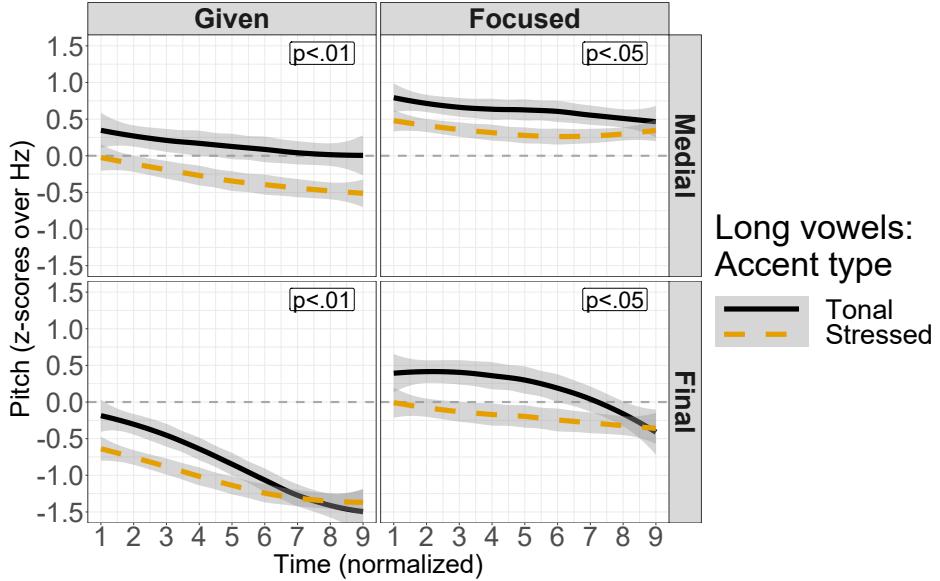


Figure 15: f0 trajectories (in z-scores over Hz) for long vowels grouped by discourse condition and sentential position. Grey bands indicate confidence intervals around the estimate of the position of the smoothed loess regression line at each time step. *p*-values refer to a comparison of mean f0 measurements for tonal vs. non-tonal vowels in each cell, using a one-sided Welch *t*-test for unequal variances.

Comparing the top and bottom rows of Fig. 15, we see that pitch values are lower in final position, suggesting a pattern of f0 declination across the sentence (Bennett et al. 2019). Declination can indeed be observed on many individual tokens in our study, such as Fig. 16, even for tokens showing final rising intonation (e.g. Fig. 14). Note as well that the tonal vowel in the focused target word *rixóqil* ‘his wife’ in Fig. 16 is realized with the highest f0 in the sentence.

The overall patterns of f0 contrast are somewhat different for short vowels (Fig. 17). The basic contrast between tonal and non-tonal vowels is preserved in two conditions: the Focused, Medial condition (upper-right;  $\Delta$  mean *z*-scores = 0.65); and somewhat more marginally in the Given, Final condition (lower-left;  $\Delta$  mean *z*-scores = 0.34). However, f0 values do not appear to be significantly different between tonal and non-tonal short vowels in the remaining two conditions. Otherwise, the same contextual effects observed for long vowels — declination across the sentence, with focus-related pitch raising — are also evident for the short vowel data in Fig. 17.

To confirm the broad trends observed in Figs. 15 and 17 we carried out a linear mixed effects analysis of mean f0 on stressed vowels using the LME4 package in R (Bates et al. 2019). This model included simple fixed effects for TONE, V LENGTH, SENTENTIAL POSITION, and DISCOURSE STATUS, A V HEIGHT predictor (high vs. non-high) was included to control for the fact that high vowels are often associated with raised pitch (e.g. Sapir 1989; on Uspaneko, see Bennett et al. submitted). The model also included all two-way and three-way interactions between TONE, DISCOURSE STATUS, SENTENTIAL POSITION and V LENGTH. Lastly, the model included random intercepts for ITEM and SPEAKER, which helps model differences in baseline pitch across participants. By-speaker random slopes for TONE were not included, as the limited amount of data available for some speakers led to convergence issues.

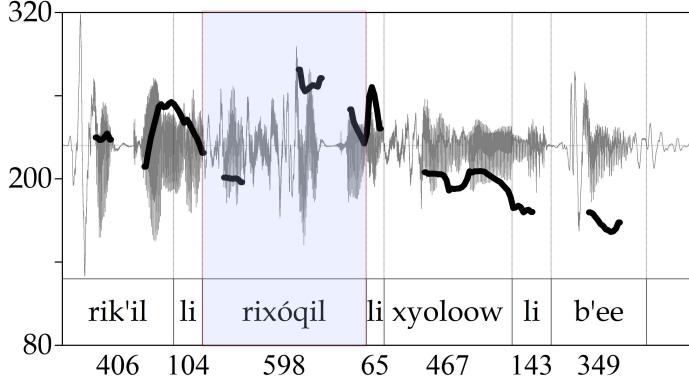


Figure 16: Declination and focus prominence in *Rik'il li RIXÓQIL li xyoloow li b'ee* ‘I saw him in the street with HIS WIFE’ (speaker 3 AP, 2017; Focused, Medial condition). Target word highlighted.

Step-down model criticism using the log-likelihood test with a threshold of  $\alpha = 0.05$  led to the omission of most predictors from the final model. Simple predictors were always retained when participating in a higher-order interaction, and model simplification was biased toward the elimination of higher-order terms. A summary of the final model is given in Table 4;  $p$ -values were estimated using the LMERTTEST package (Kuznetsova et al. 2019). The final model has fairly low collinearity between predictors ( $\kappa = 7.82$ ; see Baayen 2008:222). (Mean f0 is highly correlated with maximum f0 in our vowel data ( $r = 0.98$ ), and so our results are qualitatively similar if maximum f0 is taken as the dependent measure instead. Fitting the model over  $\log(\text{mean Hz})$  also produces highly similar results.)

Table 4: Final linear mixed-effects model for mean f0 in Hz

Predictor	$\beta$ (in Hz)	SE( $\beta$ )	$ t $	$p <$
Intercept	181.8	14.2	13.08	.001
SENTENTIAL POSITION (FINAL)	-20.3	1.7	11.75	.001
DISCOURSE STATUS (FOCUSSED)	10.6	1.7	6.33	.01
TONE (́)	8.6	2.7	3.13	.005
SENTENTIAL POSITION (FINAL) × DISCOURSE STATUS (FOCUSSED)	8.0	2.4	3.40	.001

This statistical model confirms our initial observations: focus is associated with pitch raising, and/or overall expansion of the pitch space; declination leads to pitch reduction in final position; and tone is associated with raised pitch, but only moderately so. Additionally, it appears that focus has a greater effect in sentence-final position than in sentence-medial position. This effect differs from the findings of Xu (1999), who reports that in Mandarin pitch range expansion associated with focus is attenuated in utterance-final position. We further explore the interaction of focus with sentence position, and its implications for the analysis of tone, in the following section.

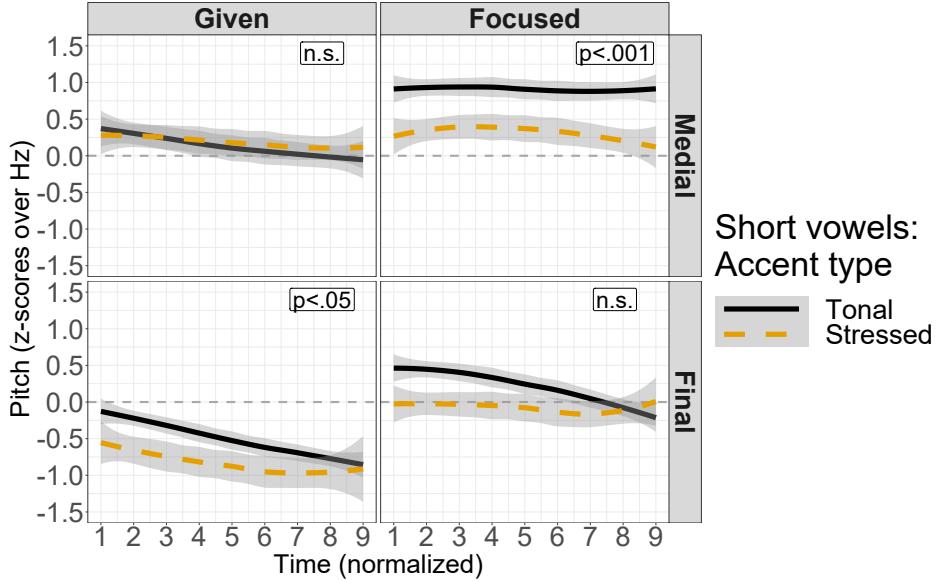


Figure 17: f0 trajectories (in z-scores over Hz) for short vowels grouped by discourse condition and sentential position (see Fig. 15 for other details).

### 3.2 Focus, phonological representation, and phonetic realization

In section 2.5 we speculated that focus could be a diagnostic for the phonological representation of ‘toneless’ vowels in Uspanteko. We saw in section 3 that the general effect of focus is to raise pitch and/or expand the overall pitch range. By hypothesis, the effect of focus should be sensitive to the phonological specification of tone: vowels which are specified for tone should show more sensitivity to focus than vowels which are not. The presumption here is that focus operates at a relatively abstract level, manipulating the phonetic realization of specified tones like [H] and [L], and leaving tonally unspecified regions relatively unaffected. (For related discussion, see Liberman & Pierrehumbert 1984, Pierrehumbert & Beckman 1988, Myers 1998, Remijsen & van Heuven 2005, Riad 2006, Ladd 2008a,b, Dilley 2010, Mixdorff et al. 2012, Remijsen et al. 2014, and references there.) On the other hand, if focus affects ‘toneless’ and tonal vowels equally in Uspanteko, this could provide support for a binary tonal analysis over a privative one (section 1.2).

We begin with the effect of focus prosody on short vowels (Fig. 17), and return to the analysis of long vowels below. Table 5 provides pairwise *t*-tests exploring the effect of prosody across all four combinations of tone (toneless [‘V’] vs. tonal [‘V̄’]) and position (sentence-medial vs. sentence-final). For short vowels, the effect of focus closely tracks the tonal specifications posited in the privative analysis of Uspanteko tone. In medial position, focus has an effect on tonal vowels only—toneless vowels show no focus-related pitch raising whatsoever. In final position, both toneless and tonal vowels show pitch raising under focus. We attribute this difference to the fact that lexically toneless vowels acquire an abstract pitch target—an intonational H% boundary tone—when occurring in sentence final position (e.g. Fig. 14 and Bennett et al. submitted). Focus prosody may then affect the phonetic realization of the non-lexical, intonational boundary H% in much the same way that it affects the realization of the lexical [H] tone.<sup>11</sup> (See Elordieta 2007,

<sup>11</sup>It would be inaccurate to imply that all of the utterances in our study are realized with the dramatic final rise seen in Fig. 14. Many productions instead show a slight upward contour, and/or raised pitch relative to preceding vowels,

2008, Elordieta & Hualde 2014 for a parallel phenomenon in Basque.)

Table 5: The effect of focus prosody on short vowels.  $p$ -values reflect one-sided Welch  $t$ -test for unequal variances

Comparison	Difference (z-scores)	$ t $	$p <$	Hypothesized tonal specification	Predicted by $[H] \sim \emptyset$ lexical tone contrast?
['V], medial	0.13	0.688	n.s.	$\emptyset$	✓
['V], final	0.81	5.16	.001	H%	✓
['V̄], medial	0.89	4.34	.001	[H]	✓
['V̄], final	0.77	5.62	.001	[H] and/or H%	✓

Focus prosody suggests a rather different analysis of tonal contrasts for long vowels (Fig. 15). As Table 6 indicates, focus prosody raises f0 for *all* combinations of lexical tone and sentential position (though the effect appears to be strongest for long vowels with lexical [H] tone). The key condition involves toneless ['V:] vowels in sentence-medial position. Under the privative analysis of Uspanteko tone, these vowels should carry neither a lexical tone nor an intonational boundary tone. And yet, focus prosody raises pitch on these vowels, consistent with the assumption that they *are* tonally specified, and not ‘toneless’ after all.

Table 6: The effect of focus prosody on long vowels.  $p$ -values reflect one-sided Welch  $t$ -test for unequal variances

Comparison	Difference (z-scores)	$ t $	$p <$	Hypothesized tonal specification	Predicted by $[H] \sim \emptyset$ lexical tone contrast?
['V:], medial	0.62	5.30	.001	$\emptyset$	✗
['V:], final	0.43	2.95	.01	H%	✓
['V̄:], medial	0.97	7.07	.001	[H]	✓
['V̄:], final	1.02	6.22	.001	[H] and/or H%	✓

If focus prosody does indeed provide evidence for the phonological specification of tone, then we are faced with the possibility that tonal specifications in Uspanteko vary with the length of the accented vowel. Short vowels may involve a privative  $[H] \sim \emptyset$  contrast, while long vowels host a binary contrast of some sort, perhaps  $[H] \sim [L]$ . A binary tone specification for long vowels may also help explain why long vowels show a robust tonal contrasts across all conditions in Fig. 15: long vowels simply have more tonal specifications, hence more tonal stability. We comment further on the relative *instability* of tonal contrasts on short vowels in the next section.

The phonological analysis of Uspanteko tone in Bennett & Henderson (2013) assumes a privative  $[H] \sim \emptyset$  contrast on the penultimate mora, for both long and short vowels alike (section 1.2). That analysis could be integrated with the present findings by assuming that long vowels must be

---

in final position (see plots in section 1.1 for some illustrations). We assume that even these slight f0 movements are intonational in nature, rather than e.g. reflexes of stress (see Bennett et al. submitted for a more detailed phonetic analysis of this claim).

specified for tone, and are assigned a default [L] tone in the absence of a lexical [H] tone (see Zec 1999, Zec & Zsiga 2010, Zsiga & Zec 2013 for a somewhat similar approach to Serbo-Croatian pitch accent). This is essentially the analysis of Campbell (1977), but amended to include a tonal component on non-final, accented short vowels. We speculate more on the exact phonetic specification of tonal categories in Uspanteko in section 3.4.

If ‘toneless’ long vowels are instead specified with an [L] tone, how does this lexical tone interact with the utterance-final H% boundary tone? Recall that the tonal contrast for long vowels is preserved in utterance-final position (Fig. 15). This might mean that the [L] tone resists overwriting by the phrasal H%. Alternatively, it may be that the [L] tone is replaced with a phrasal H% tone, but the phonetic realization of the phrasal H% is lower in f0 than a lexical [H], as reported for e.g. Japanese by Pierrehumbert & Beckman (1988). (See also Myers et al. 2018 on Luganda.)

### 3.3 The effect of givenness

As evident in Fig. 17, tonal contrasts on short vowels are most robust in the Focused, Medial condition (Fig. 17, upper right). This is as predicted if (i) short vowels host a privative [H]~∅ contrast, (ii) lexically toneless vowels do not acquire an intonational H% tone in sentence-medial position, and (iii) focus raises pitch on vowels specified with a lexical [H] tone or intonational H% tone (sections 2.5 and 3.2). The lack (or at least marginality) of tonal contrast in final position can be interpreted as the neutralization of the lexical [H]~∅ contrast to a [H]~H% contrast under the influence of a final H% boundary tone.

What remains to be explained is the lack of contrast in the Given, Medial condition (Fig. 17, upper left). Phonologically, this should correspond to a [H]~∅ contrast. And yet the phonetic facts seem to indicate surface-level neutralization of f0 distinctions in this environment.

We suspect that the lack of phonetic contrast in the Given, Medial context is at least partially due to the relative shortness of vowels in discourse-given words. Short vowels are about 10ms shorter when discourse-given (79ms vs. 88ms under focus,  $p < .001$  by one-sided Welch *t*-test for unequal variances). As emphasized by Xu & Sun (2002), it takes some time to phonetically implement a pitch rise, as the laryngeal articulations involved in raising f0 are relatively slow compared to those which lower f0 (see Myers et al. 2018 for a recent review). It may be that the phonetic shortening of stressed vowels leads to some degree of phonetic undershoot of f0 targets in the Given condition. Such undershoot would plausibly contribute to the phonetic neutralization of an underlying [H]~∅ contrast in this context. Long vowels are comparatively unaffected by shortening—their mean duration in the Given condition is still 109ms—and so we should not expect to see the same degree of undershoot.

Beyond the effect of duration, it may simply be that f0 is compressed on Given items (Table 4), as in Japanese, German, and many other languages (e.g. Ladd 2008a, Féry & Kügler 2008, Féry & Ishihara 2009, Kügler & Féry 2017 and references there). These effects appear to be weaker in utterance-final position, if the marginal significance of the tonal contrast on short vowels in the Given, Final condition is taken at face value.

### 3.4 The shape(s) of lexical tone

The results from focus prosody (section 3.2) suggest a binary tone opposition for long vowels in Uspanteko. But the phonological specification of these two tones remains to be settled—are they level tones, contour tones, or some combination of levels and contours (sections 1.2, 2.5)?

To investigate this issue, we carried out a quantitative analysis of the shape of f0 trajectories

on accented vowels, using a combination of principal component analysis and  $k$ -means clustering. Space restrictions prevent us from laying out this method in full detail, but we try to provide an intuitive explanation of how the procedure works below. For additional details and examples of these techniques, see e.g. Johnson (2008), Mielke (2012), Dillon et al. (2013), Shosted et al. (2015), Gubian et al. (2015), Dockum (2017), Bennett et al. (2018a), Bennett (2019).

The smoothed f0 plots provided in Figs. 15 and 17 imply that the distinction between tonal and non-tonal vowels in Uspanteko is primarily expressed by differences in f0 level, and not f0 shape. But those plots provide only aggregated, summary information. As such, we might worry that they obscure some structured token-to-token variability in the shape of f0, and that such f0 shape differences might also serve to distinguish tonal and non-tonal vowels.

We used principal component analysis (e.g. PCA; Jolliffe 2002) to analyze how f0 shape varies across accented vowels. The output of PCA tells us how f0 contours typically differ from each other in our data set, in terms of level, shape, and any other parameters which might systematically vary across tokens. PCA over z-score normalized f0 with the PRCOMP() function in R produces 9 principal components (PCs), which correspond to 9 typical dimensions of variation in f0 shape in our data set.<sup>12</sup> As Fig. 18 shows, the first three PCs account for about 99% of the variation in our data. These PCs have straightforward interpretations: PC1, which accounts for most of the variance in the data, corresponds roughly to pitch level; PC2 corresponds roughly to pitch slope; and PC3 corresponds roughly to concavity.

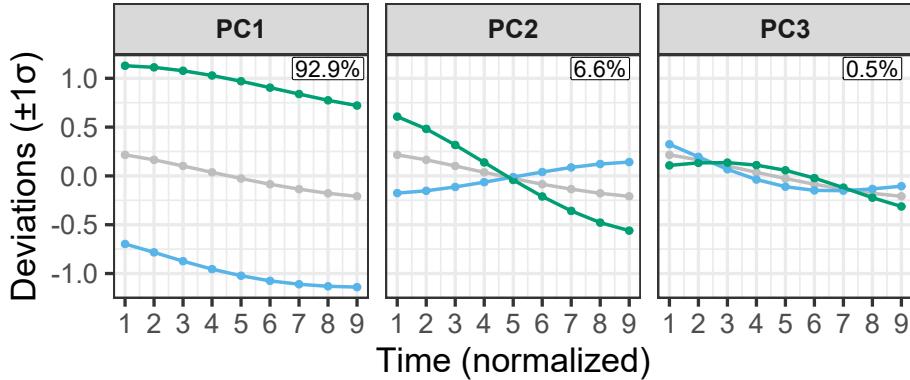


Figure 18: First three principal components. Mean f0 across the entire data set is represented by grey midline, and upper/lower lines show changes in each PC value in positive and negative directions.

PC1 is not particularly informative about the tonal specifications of individual vowels, as variation in pitch height in our data is also strongly conditioned by declination and focus-related pitch raising (Table 4). Here, we’re most interested in how f0 *shape* might distinguish between tonal and non-tonal vowels. To that end, we used  $k$ -means clustering to assess how many distinct, characteristic f0 shapes occur on accented vowels in our data.  $K$ -means clustering is an unsupervised clustering method, which can be used to classify vowels into discrete categories on the basis of

<sup>12</sup>PCA requires fully specified values at each measurement step for each vowel token. To fill in missing values we carried out data imputation using the function NA\_INTERPOLATION() from the R package IMPUTETS (Moritz & Gatscha 2019) with Stineman interpolation.

similar f0 shapes. The input to  $k$ -means clustering was the output of PCA, but with PC1 excluded, so that categorization would be carried out primarily on the basis of f0 shape rather than f0 height.

We ran the  $k$ -means algorithm multiple times, assuming that between 1 and 15 groups might be present in the data. Comparing models by means of the Bayesian Information Criterion, which is biased against finding too many groups, we found that a  $k$ -means model with four groups provided the best compromise between data fit and model complexity (i.e. the lowest BIC value). The four groups identified are shown in Fig. 19, represented with their characteristic pitch contours. It appears that accented vowels fall into four broad shape categories: flat f0, rising f0, slightly falling f0, and falling f0.

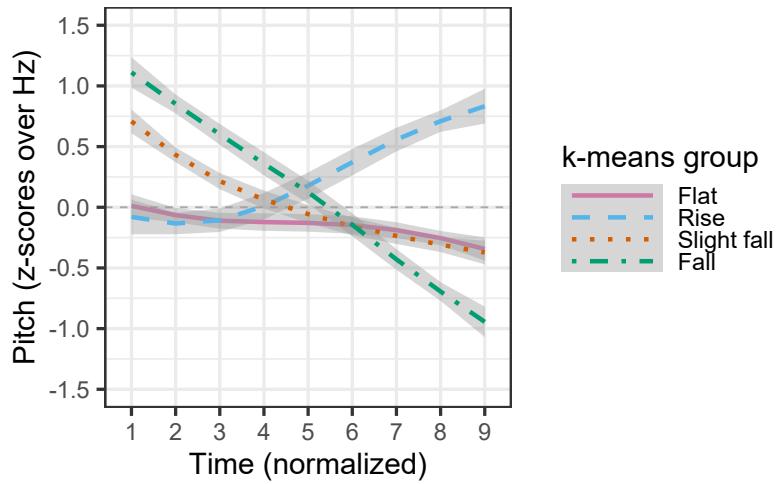


Figure 19: Tone shape categories identified by  $k$ -means clustering with  $k = 4$ .

If f0 shape were a distinguishing characteristic of tonal vowels, we should expect some of the shapes in Fig. 19 to be much more common for tonal vowels than for non-tonal vowels. This does not appear to be the case (Fig. 20). All four tone shapes occur on both tonal and non-tonal vowels alike. Still, flat and rising f0 shapes do seem somewhat more common for non-tonal vowels, and falling f0 shapes more common for tonal vowels. These patterns hold equally for short and long vowels, despite the phonetic evidence presented above that ‘non-tonal’ long vowels might actually be specified for a tonal target.

We assessed these patterns statistically by means of a multinomial mixed-effects analysis using the BRMS package in R (Bürkner 2018), which fits a Bayesian regression. This model included simple fixed effects for TONE and V LENGTH, and their interaction. It also included random intercepts for SPEAKER and ITEM. The only significant effect in this model is a tendency for tonal vowels to be realized more frequently with slight f0 falls, and less frequently with flat f0 (Table 7; significant effects are those whose 95% confidence interval excludes zero).

We interpret these results in the following way. Tonal vowels are specified for [H], and tone may fall somewhat after the attainment of that [H] target (e.g. Figs. 10, 11 and Bennett & Henderson 2013). All other variability in f0 shape is likely due to the influence of contextual factors which are distributed equally across tonal and non-tonal vowels (e.g. segmental context, phrasal position, etc.).<sup>13</sup> These patterns seem most consistent with a simple [H] target for tonal vowels,

<sup>13</sup>The slightly higher likelihood of rising pitch on non-tonal vowels may indicate greater susceptibility to influence

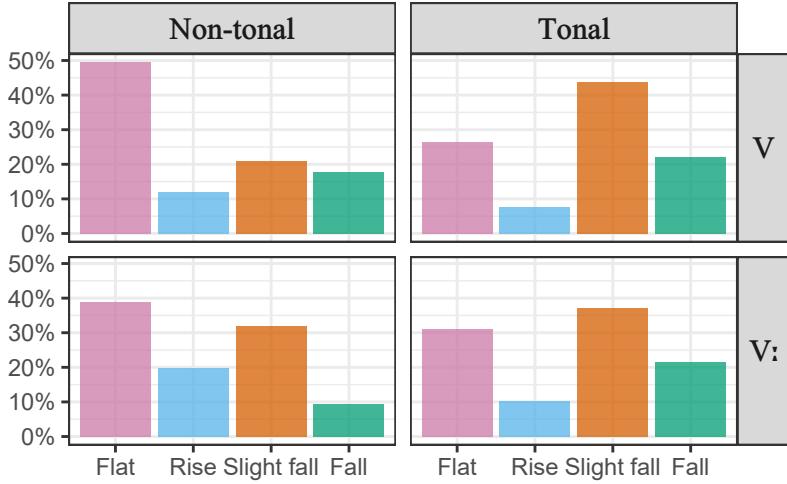


Figure 20: Proportion of different f0 shape categories across for different combinations of lexical tone and vowel length.

Table 7: All significant effects in multinomial mixed-effects model for f0 shape category. Reference level for TONE predictor is FLAT F0.

Predictor	$\beta$	SE( $\beta$ )	95% CI	
			lower bound	upper bound
Intercept	-1.53	0.36	0.84	2.25
TONE ( $\check{V}$ ; likelihood of slight fall)	1.52	0.57	0.44	2.67

which leaves room for the variability in f0 shape observed in Figs. 19, 20 (see Arvaniti 2016 for a similar approach to analyzing intonational variation).

If ‘non-tonal’ long vowels are really specified for tone in the surface phonetics (section 3.2), the simplest analysis would be to treat them as bearing a level [L] tone, possibly by default, and allow f0 shape to vary contextually in the same way that it does for the other accentual categories (section 3.2).

### 3.5 The magnitude of the tonal contrast

In section 3.1 we observed that vowels specified with an [H] tone are realized with higher f0 than toneless (or [L]-toned) vowels. However, the differences involved appear to be rather small, on the order of about  $\sim 10\text{Hz}$ . In this section we consider some explanations for this striking fact.

The first, somewhat banal possibility is that the small effect of [H] tone on f0 reflects a problem with the design of our study. Every target item was produced in each of our four experimental contexts ( $\{\text{focused, given}\} \times \{\text{medial, final}\}$ ). Each target item was therefore repeated at least several times by each speaker. As a consequence, even our ‘focused’ items were in a sense discourse-given—they had often been previously spoken by the participant during the recording session, as

---

from final H% boundary tones in the absence of a lexical tone, though this apparent difference is not supported by the statistical analysis in Table 7.

part of a different target sentence. The repetition of target items may have conditioned further phonetic reduction of f0 and/or duration across conditions, obscuring the phonetic effect of [H] tone on f0.<sup>14</sup>

Some evidence for this view comes from a comparison with the results of Bennett et al. (submitted), who present a phonetic analysis of wordlist data in Uspanteko. That study found an effect size of about 50Hz for lexical tone in Uspanteko, after controlling for the effect of utterance-final H% boundary tones on word-final syllables. An effect in the ~50Hz range is similar to the amount of f0 raising found for [H] tones in lexical pitch accent languages like Japanese, Goizueta Basque, and Serbo-Croatian (e.g. Beckman 1986, Pierrehumbert & Beckman 1988, Hualde et al. 2008, Zec & Zsiga 2010). Importantly, each target word in the wordlist was only produced once by each speaker, so repetition-related phonetic reduction could not have arisen in the same way.

We do not know whether the present study or the wordlist data in Bennett et al. (submitted) is more representative of the typical phonetic realization of lexical tone in regular Uspanteko speech.<sup>15</sup> But at least in our question-answer materials, it seems fair to say that tonal distinctions in Uspanteko are weakly implemented and phonetically marginal.

There are several other respects in which tone can be considered ‘marginal’ in Uspanteko. Lexical tone mostly occurs on nouns, and less frequently on other lexical categories, especially verbs (1). Additionally, tonal forms are often in free variation with non-tonal forms of the same word: for example, we have recorded numerous narratives in which people switch between productions like [í.ʃim]~[i.ʃim] ‘corn’ or [kú.ts<sup>?</sup>iχ]~[ku.ts<sup>?</sup>i(:?)χ] ‘flower’, with only a few seconds intervening between each rendition. (Such variation may reflect a high degree of bilingualism with K’iche’, a language that shares many cognate, non-tonal roots with Uspanteko.)

Perhaps most salient is the near absence of minimal pairs distinguished by tone. For example, we are aware of only three minimal pairs for tone on long vowels (7):

- (7)    a. [ʃa:b] ‘comb’ vs. [ʃá:b] ‘vomit’ (Figs. 3, 12, 13)
- b. [sí:p] ‘tick’ vs. [sí:p] ‘gift’
- c. [ɔrχ] ‘us (= 1P.ABS)’ vs. [ó:rχ] ‘avocado’

But even these minimal pairs are not in the vocabulary of all speakers. There is a good amount of lexical variation in Uspanteko, no doubt connected to widespread multilingualism in Mayan languages in the area. The notion of ‘gift’, for example, is lexicalized as [sí:p] (7b), but also as [si.'pá.nik], [si.pa.'nik], [si.'pa:n], [ko.'tʃab], and [ko:tʃ(χ)], with a good amount of inter-speaker variation (somewhat akin to English ‘gift’ vs. ‘present’). As a result, there are vanishingly few minimal pairs in Uspanteko in which tone is truly distinctive on long vowels. Compare this with Japanese, where fully 14% of the minimal pairs in the language are tonal minimal pairs (e.g. references in Kawahara 2015).

For short vowels, there are even fewer minimal pairs (e.g. Fig. 4). In fact, there are arguably *no* true minimal pairs for tone on short vowels. [H] tone on the penultimate syllable always involves

---

<sup>14</sup>Another potential issue with our materials is that we made no attempt to control for intonational events occurring at the edges of units smaller than the utterance, such as the INTONATIONAL PHRASE or PHONOLOGICAL PHRASE. We simply do not know enough about the intonational system of Uspanteko to know how to control for such confounds. The lack of such controls may have influenced f0 on some phrase-medial items in ways that we do not yet understand.

<sup>15</sup>We have also recorded a large quantity of more naturalistic speech in Uspanteko, but the transcription and phonetic analysis of those recordings is ongoing.

stress shift (section 1.1), which means that tonal words are also distinguished from non-tonal words by the *position* of accent, apart from the type of accent involved (tonal vs. non-tonal; Fig. 21). As a consequence, f0 on tonal short vowels can be quite similar to f0 on stressed, non-tonal short vowels without any risk of collapsing the prosodic distinction between these two classes of words.

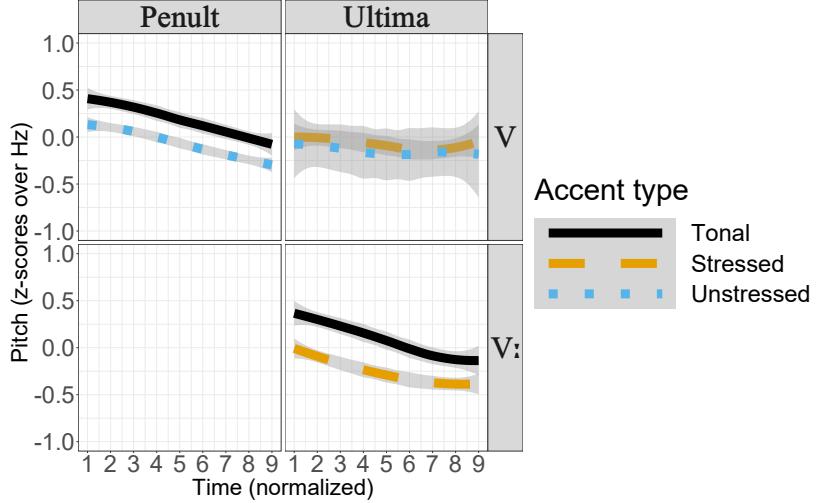


Figure 21: f0 trajectories (in z-scores over Hz) for all vowels, grouped by vowel length and position within the word.

Furthermore, tone is frequently introduced by overt morphology in Uspanteko (section 1.1, Table 1). In many cases, this too renders tone functionally redundant for the purpose of distinguishing word meanings (8).

- (8) a. [iχ-'<sup>h</sup>ba] ‘his/her head’ ~ ['ín-<sup>h</sup>ba] ‘my head’  
     b. [k<sup>?</sup>aχ] ‘wheat’ ~ [in-'<sup>h</sup>k<sup>?</sup>áχ] ‘my wheat’

These facts are potentially relevant for understanding the relatively small f0 differences associated with contrastive [H] tone in our study. It has been argued that the functional importance of a phonological contrast can affect its phonetic realization: contrasts which are more important for distinguishing words and morphemes tend to be more robustly implemented in speech production (see e.g. Berinstein 1979, Lindblom 1986, Baese-Berk & Goldrick 2009, Nakai et al. 2012, Goldrick et al. 2013, Renwick 2014, Nadeu & Renwick 2016, Nelson & Wedel 2017, Hall et al. 2018, Bennett et al. 2018b and references there). The weak f0 distinctions associated with tone in our results may therefore reflect, in part, the low functional relevance of tonal contrasts in the language. This is especially true for short vowels, which have a particularly low functional load for tone, and which show phonetic neutralization of f0 constraints in most conditions in our study (Fig. 17).

Two other phonetic observations are worth mentioning. First, speakers seem to vary in how robustly they implement tonal contrasts. Fig. 22 shows speaker-level mean f0 values, grouped by tonal specification and vowel length. This plot is an oversimplification of the facts, as it collapses over many other factors which condition f0 variation in our results. But it seems clear that some speakers express the f0 contrasts associated with tone more strongly than others. This raises the possibility that the magnitude of the tonal contrast in our study may have been affected by

the specific population of speakers who participated, if they happen to be speakers who produce tonal contrasts in a phonetically attenuated way. (We suspect that speakers who produce weaker tonal contrasts may be more K'iche'-dominant than speakers who produce the tonal contrast more robustly. Can Pixabaj (2007:49) also mentions possible age-grading in the robustness of tonal contrasts. We have not yet explored these possibilities in any systematic way.)

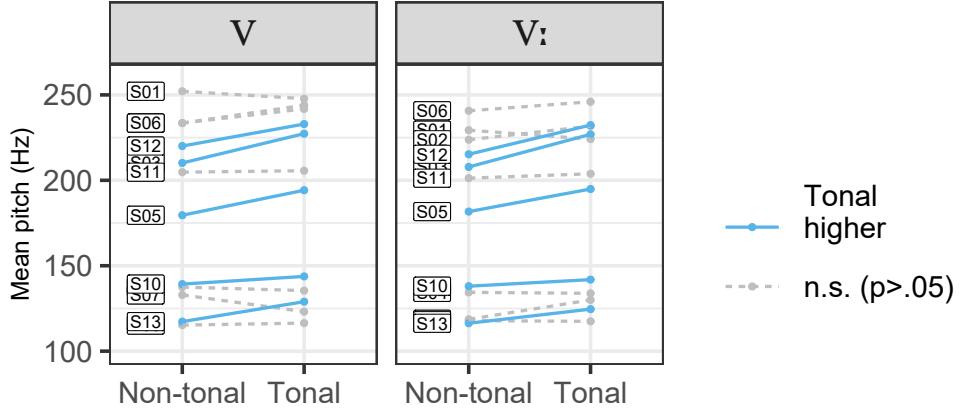


Figure 22: Individual variation in the implementation of f0 for tonal contrasts. Statistical significance assessed with one-sided Welch *t*-test for unequal variances.

A second phonetic observation is that tonal contrasts in Uspanteko may not be exclusively expressed by f0 distinctions. Bennett et al. (submitted) find that tonal short vowels are longer than non-tonal short vowels in their wordlist data. In the current study, the correlation between tone and vowel duration holds for long vowels as well as short vowels. Fig. 23 shows the distribution of vowel duration by accent type and phonemic vowel length in our data.

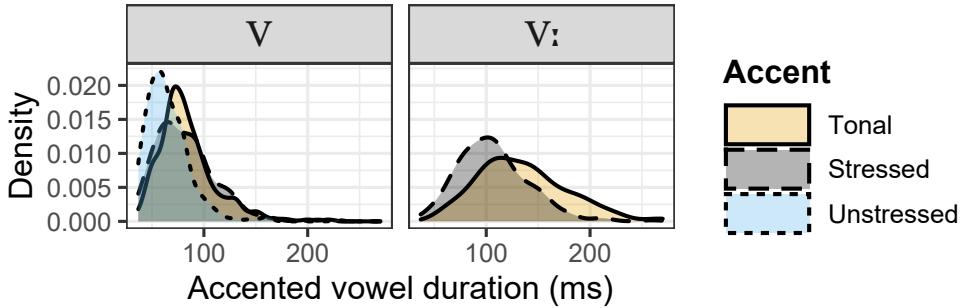


Figure 23: Vowel duration, grouped by phonemic length and accent type.

Despite visual appearances, a statistical analysis of vowel duration suggests that both short and long vowels have greater duration when bearing [H] tone, once other factors are controlled for. We fit a linear mixed effects model over vowel duration with the LME4 package in R. This model included simple fixed effects for TONE, V LENGTH, STRESS, and V QUALITY. We also included a two-way TONE  $\times$  V LENGTH interaction, and random intercepts for SPEAKER and ITEM. Step-down model criticism using the log-likelihood test with a threshold of  $\alpha = 0.05$  dropped the TONE  $\times$  V LENGTH interaction from the final model (Table 8; *p*-values were estimated using

the LMERTEST package). The final model has low collinearity between predictors ( $\kappa = 5.53$ ). Overall, vowels bearing [H] tone are about 10ms longer than toneless vowels. This lengthening does not neutralize the phonetic distinction between phonemic long and short vowels, but it does appear to serve as a correlate of tonal contrast.

Table 8: Final linear mixed-effects model for vowel duration in ms.

Predictor	$\beta$ (in ms)	SE( $\beta$ )	t	p <
Intercept	99	5.5	17.88	.001
V LENGTH (V:)	35	4.0	8.88	.001
STRESS ('V)	28	3.0	9.42	.001
TONE (́V)	10	2.6	3.81	.001
V QUALITY ([i])	-0.5	3.4	0.14	n.s.
V QUALITY ([u])	-10	7.5	1.39	n.s.
V QUALITY ([e])	-41	7.9	5.44	.001
V QUALITY ([o])	-36	3.8	9.58	.001

This provides an interesting counterpoint to lexical pitch accent languages like Goizueta Basque and Japanese: in these languages, f0 robustly distinguishes tonal vowels, but duration is not a cue to lexical tone (e.g. Beckman 1986, Hualde et al. 2008; Finfoft 1965, Kelly 2015 report similar results for Norwegian tonal accent, though see also Finfoft 1970). The multidimensionality of tonal contrast in Uspanteko may thus help explain why f0 distinctions are so marginal in the current study: they are redundantly cued by duration, and possibly other phonetic properties as well. (Impressionistically, tonal short vowels in Uspanteko also differ from non-tonal vowels in voice quality—they seem to be produced with ‘pressed’ or ‘tense’ voice. Phonetic investigation of this issue is underway.)

To summarize, the amount of f0 raising associated with [H] tone in our study is smaller than might have been expected on the basis of phonetic patterns in other lexical pitch accent languages, or the wordlist data reported in Bennett et al. (submitted). We have speculated here on a number of practical and linguistic factors which may have jointly led to the compression of f0 distinctions in our data. We leave further exploration of these issues for future work.

## 4 Discussion

While there is no doubt that Uspanteko is a language with lexical tone, pinning down the phonological and phonetic properties of the tone system has proven a thorny task. Much of the difficulty involved stems from the extensive variability—phonetic, phonological, lexical, and sociolinguistic—that characterizes the tone system, and its interaction with intonation.

We have argued here that the tone system of Uspanteko is best understood as a privative [H]~Ø contrast on short vowels, and either a privative [H]~Ø contrast or binary [H]~[L] contrast on long vowels. Our evidence has been primarily phonetic, rather than phonological, and our arguments depend on the assumption that structured variability in the phonetic signal can provide a window on abstract phonological specifications. This approach follows a long line of research on intonation in the ‘Autosegmental-Metrical’ tradition, from which we draw our inspiration (e.g.

Pierrehumbert & Beckman 1988, Ladd 2008a, and other work cited above). At a minimum, we hope that this work has helped clarify the practical issues that arise in the study of restricted tone systems, particularly those in which tone has a low functional load, and in which intonation runs roughshod over tones assigned at the word level.

## References

- Adell, Eric James. 2019. *The phonetics, phonology, and morphology of Chajul Ixil (Mayan)*. Austin, TX: University of Texas, Austin dissertation.
- Aissen, Judith. 1992. Topic and focus in Mayan. *Language* 68(1). 43–80.
- Aissen, Judith. 2017. Information structure in Mayan. In Judith Aissen, Nora England & Roberto Zavala Maldonado (eds.), *The Mayan languages*, 293–324. New York: Routledge. doi:10.4324/9781315192345.
- Aissen, Judith, Nora England & Roberto Zavala Maldonado (eds.). 2017. *The Mayan languages*. New York: Routledge. doi:10.4324/9781315192345.
- Arvaniti, Amalia. 2016. Analytical decisions in intonation research and the role of representations: Lessons from Romani. *Laboratory Phonology* 7(1). 1–43.
- Baayen, R. Harald. 2008. *Analyzing linguistic data: A practical introduction to statistics using R*. Cambridge, UK: Cambridge University Press.
- Baese-Berk, Melissa & Matthew Goldrick. 2009. Mechanisms of interaction in speech production. *Language and cognitive processes* 24(4). 527–554. doi:10.1080/01690960802299378.
- Baird, Brandon. 2014a. *An acoustic analysis of contrastive focus marking in Spanish-K'ichee' (Mayan) bilingual intonation*. Austin, TX: University of Texas, Austin dissertation.
- Baird, Brandon. 2014b. Acoustic correlates of stress in K'ichee': a preliminary analysis. In Lauren Eby Clemens, Robert Henderson & Pedro Mateo Pedro (eds.), *Proceedings of Formal Approaches to Mayan Linguistics (FAMLi) II*, 21–34. Cambridge, MA: MIT Working Papers in Linguistics.
- Baird, Brandon. 2018. Syntactic and prosodic contrastive focus marking in K'ichee'. *International Journal of American Linguistics* 84(3). 295–325.
- Bardiaux, Alice & Piet Mertens. 2014. Normalisation des contours intonatifs et étude de la variation régionale en français. *Cahiers de Linguistique Française* 31. 273–284.
- Bates, Douglas, Martin Maechler & Ben Bolker. 2019. *lme4: Linear mixed-effects models using S4 classes*. Version 1.1.21, retrieved from <http://CRAN.R-project.org/package=lme4>.
- Beckman, Mary. 1986. *Stress and non-stress accent*. Dordrecht: Foris.
- Bennett, Ryan. 2016. Mayan phonology. *Language and Linguistics Compass* 10(10). 469–514. doi:10.1111/lnc3.12148.
- Bennett, Ryan. 2019. La tensión vocálica en el kaqchikel de Sololá, Guatemala: un estudio preliminar. In Esther Herrera Zendejas & Verónica Reyes Taboada (eds.), *Fonología segmental: procesos e interacciones*, 13–46. Mexico City: Colégio de México. <http://libros.colmex.mx/ficha/?b=2848>.
- Bennett, Ryan, Jessica Coon & Robert Henderson. 2016. Introduction to Mayan linguistics. *Language and Linguistics Compass* 10(10). 1–14. doi:10.1111/lnc3.12159.
- Bennett, Ryan & Robert Henderson. 2013. Accent in Uspanteko. *Natural Language & Linguistic Theory* 31(3). 589–645. doi:10.1007/S11049-013-9196-6.
- Bennett, Ryan, Robert Henderson & Megan Harvey. 2019. The interaction of tone and intonation in

- Uspanteko. In Sasha Calhoun, Paola Escudero, Marija Tabain & Paul Warren (eds.), *Proceedings of the 19th International Congress of Phonetic Sciences, Melbourne, Australia 2019*, 452–456. Canberra, Australia: Australasian Speech Science and Technology Association Inc. [https://assta.org/proceedings/ICPhS2019/papers/ICPhS\\_501.pdf](https://assta.org/proceedings/ICPhS2019/papers/ICPhS_501.pdf).
- Bennett, Ryan, Robert Henderson & Megan Harvey. submitted. Uspanteko. *Journal of the International Phonetic Association*.
- Bennett, Ryan, Máire Ní Chiosáin, Jaye Padgett & Grant McGuire. 2018a. An ultrasound study of Connemara Irish palatalization and velarization. *Journal of the International Phonetic Association* 48(3). 261–304. doi:10.1017/S0025100317000494.
- Bennett, Ryan, Kevin Tang & Juan Ajsivinac Sian. 2018b. Statistical and acoustic effects on the perception of stop consonants in Kaqchikel (Mayan). *Laboratory Phonology* 9(1). 9. doi: 10.5334/labphon.100.
- Berinstein, Ava E. 1979. *A cross-linguistic study on the perception and production of stress*. University of California Los Angeles MA thesis. Available online at <http://escholarship.org/uc/item/0t0699hc>.
- Berinstein, Ava E. 1991. The role of intonation in K'ekchi Mayan discourse. In Cynthia McLemore (ed.), *Texas linguistic forum* 32, 1–19. Austin, TX: Department of Linguistics and the Center for Cognitive Science, The University of Texas at Austin.
- Boersma, Paul & David Weenink. 2016. Praat: doing phonetics by computer (version 6.0.23). Computer program. Retrieved from <http://www.praat.org/>.
- Borise, Lena. to appear. Tone and intonation in the languages of the Caucasus. In Maria Polinsky (ed.), *Handbook of the languages of the Caucasus*, Oxford, UK: Oxford University Press.
- Brody, Jill. 1984. Some problems with the concept of basic word order. *Linguistics* 22(5). 711–736. doi:10.1515/ling.1984.22.5.711.
- Bürkner, Paul-Christian. 2018. Advanced Bayesian multilevel modeling with the R package brms. *The R Journal* 10(1). 395–411. doi:10.32614/RJ-2018-017.
- Campbell, Lyle. 1977. *Quichean linguistic prehistory*, vol. 81 University of California Publications in Linguistics. Berkeley, CA: University of California Press.
- Can Pixabaj, Telma. 2007. *Gramática descriptiva Uspanteka*. Antigua, Guatemala: Oxlajuuj Keej Maya' Ajtz'iib' (OKMA).
- Can Pixabaj, Telma & Nora England. 2011. Nominal topic and focus in K'ichee'. In Rodrigo Gutiérrez-Bravo, Line Mikkelsen & Eric Potsdam (eds.), *Representing language: essays in honor of Judith Aissen*, 15–30. Santa Cruz, CA: Linguistics Research Center. Available online at <https://escholarship.org/uc/item/0vf4s9tk#page-15>.
- Chomsky, Noam. 1964. *Current issues in linguistic theory*. The Hague: Mouton.
- Clopper, Cynthia & Judith Tonhauser. 2013. The prosody of focus in Paraguayan Guaraní. *International Journal of American Linguistics* 79(2). 219–251.
- Coon, Jessica. 2016. Mayan morphosyntax. *Language and Linguistics Compass* 10(10). 515–550. doi:10.1111/lnc3.12149.
- Dayley, Jon. 1985. *Tzutujil grammar*, vol. 107 University of California Publications in Linguistics. Berkeley, CA: University of California Press.
- De Looze, Céline & Stéphane Rauzy. 2009. Automatic detection and prediction of topic changes through automatic detection of register variations and pause duration. In *Proceedings of INTERSPEECH 2009*, 2919–2922. ISCA Archive. Available online at [http://www.isca-speech.org/archive/interspeech\\_2009/i09\\_2919.html](http://www.isca-speech.org/archive/interspeech_2009/i09_2919.html).

- DiCanio, Christian, Joshua Benn & Rey Castillo García. 2018. The phonetics of information structure in Yoloxóchitl Mixtec. *Journal of Phonetics* 68. 50–68.
- DiCanio, Christian & Ryan Bennett. To appear. Prosody in Mesoamerican languages. In Carlos Gussenhoven & Yiya Chen (eds.), *The Oxford handbook of language prosody*, Oxford, UK: Oxford University Press.
- Dilley, Laura. 2010. Pitch range variation in English tonal contrasts: continuous or categorical? *Phonetica* 67(1-2). 63–81.
- Dillon, Brian, Ewan Dunbar & William Idsardi. 2013. A single-stage approach to learning phonological categories: Insights from Inuktitut. *Cognitive Science* 37(2). 344–377.
- Dockum, Ricker. 2017. Computational modeling of tone in language documentation: citation tones vs. running speech in Chindwin Khamti. In Julia Nee, Margaret Cychosz, Dmetri Hayes, Tyler Lau & Emily Remireza (eds.), *Berkeley Linguistic Society (BLS) 43*, 43–73. Berkeley, CA: University of California, Berkeley Linguistics Society.
- Du Bois, John W. 1987. The discourse basis of ergativity. *Language* 64(4). 805–855.
- Elordieta, Gorka. 2007. A constraint-based analysis of the intonational realization of focus in Northern Bizkaian Basque. In Tomas Riad & Carlos Gussenhoven (eds.), *Tones and tunes: typological studies in word and sentence prosody*, vol. 1, 199–232. Berlin: Mouton De Gruyter.
- Elordieta, Gorka. 2008. Constraints on intonational prominence of focalized constituents. In Chungmin Lee, Matthew Gordon & Daniel Büring (eds.), *Topic and focus: Cross-linguistic perspectives on meaning and intonation*, 1–22. Dordrecht: Springer. doi:10.1007/978-1-4020-4796-1\_1.
- Elordieta, Gorka & José Hualde. 2014. Intonation in Basque. In Sun-Ah Jun (ed.), *Prosodic typology II: the phonology of intonation and phrasing*, 405–463. Oxford, UK: Oxford University Press.
- England, Nora. 1991. Changes in basic word order in Mayan languages. *International Journal of American Linguistics* 57(4). 446–486.
- England, Nora & Brandon Baird. 2017. Phonology and phonetics. In Judith Aissen, Nora England & Roberto Zavala Maldonado (eds.), *The Mayan languages*, 175–200. New York: Routledge. doi:10.4324/9781315192345.
- England, Nora & Laura Martin. 2003. Issues in the comparative argument structure analysis in Mayan narratives. In John W. Du Bois, Lorraine E. Kumpf & William J. Ashby (eds.), *Preferred argument structure: Grammar as architecture for function*, 131–157. Amsterdam: John Benjamins.
- Féry, Caroline. 2013. Focus as prosodic alignment. *Natural Language & Linguistic Theory* 31(3). 683–734.
- Féry, Caroline & Shinichiro Ishihara. 2009. How focus and givenness shape prosody. In Malte Zimmermann & Caroline Féry (eds.), *Information structure: Theoretical, typological, and experimental perspectives*, 36–63. Oxford, UK: Oxford University Press. doi:10.1093/acprof:oso/9780199570959.001.0001.
- Féry, Caroline & Shinichiro Ishihara (eds.). 2016. *The Oxford handbook of information structure*. Oxford, UK: Oxford University Press.
- Féry, Caroline & Frank Kügler. 2008. Pitch accent scaling on given, new and focused constituents in German. *Journal of Phonetics* 36(4). 680–703.
- Fintoft, Knut. 1965. Some remarks on word accents. *Phonetica* 13(4). 201–226.
- Fintoft, Knut. 1970. *Acoustical analysis and perception of tonemes in some Norwegian dialects*.

- Oslo: Universitetsforlaget.
- Fox, James. 1978. *Proto-Mayan accent, morpheme structure conditions, and velar innovation*: University of Chicago dissertation.
- Goldrick, Matthew, Charlotte Vaughn & Amanda Murphy. 2013. The effects of lexical neighbors on stop consonant articulation. *Journal of the Acoustical Society of America* 134(2). EL172–EL177. doi:10.1121/1.4812821.
- Grimes, James. 1971. A reclassification of the Quichean and Kekchian (Mayan) languages. *International Journal of American Linguistics* 37(1). 15–19.
- Grimes, James. 1972. *The phonological history of the Quichean languages*. Carbondale, IL: University Museum, Southern Illinois University. Available online at [http://www.ailla.utexas.org/search/resource.html?r\\_id=6534](http://www.ailla.utexas.org/search/resource.html?r_id=6534).
- Gubian, Michele, Francisco Torreira & Lou Boves. 2015. Using functional data analysis for investigating multidimensional dynamic phonetic contrasts. *Journal of Phonetics* 49. 16–40.
- Gussenhoven, Carlos. 1983. Focus, mode and the nucleus. *Journal of linguistics* 19(2). 377–417.
- Gussenhoven, Carlos. 2004. *The phonology of tone and intonation*. Cambridge, UK: Cambridge University Press.
- Gussenhoven, Carlos & Renske Teeuw. 2008. A moraic and a syllabic H-tone in Yucatec Maya. In Esther Herrera Zendejas & Pedro Martín Butragueño (eds.), *Fonología instrumental: patrones fónicos y variación*, 49–71. Mexico, D.F.: El Colegio de México.
- Hall, Kathleen Currie, Elizabeth Hume, T. Florian Jaeger & Andrew Wedel. 2018. The role of predictability in shaping phonological patterns. *Linguistics Vanguard* 4(s2).
- Hartmann, Katharina. 2008. Focus and tone. *Acta Linguistica Hungarica* 55(3-4). 415–426.
- Hedding, Andrew. to appear. Asymmetric pitch raising under focus in San Martín Pellas Mixtec. In *Proceedings of the Workshop on Structure and Constituency in the Languages of the Americas (WSCLA)* 24, vol. 24 University of British Columbia Working Papers in Linguistics, Vancouver, Canada: University of British Columbia, Department of Linguistics.
- Henderson, Robert. 2012. Morphological alternations at the intonational phrase edge. *Natural Language & Linguistic Theory* 30(3). 741–787.
- Herrera Zendejas, Esther. 2014. *Mapa fónico de las lenguas mexicanas: formas sonoras 1 y 2*. Mexico, D.F.: El Colegio de México 2nd edn.
- Himmelmann, Nikolaus. 2006. Prosody in language documentation. In Jost Gippert, Nikolaus Himmelmann & Ulrike Mosel (eds.), *Essentials of language documentation*, 163–181. Berlin: Mouton de Gruyter.
- Himmelmann, Nikolaus & D. Robert Ladd. 2008. Prosodic description: An introduction for fieldworkers. *Language documentation and conservation* 2(2). 244–274. Available online at <http://nflrc.hawaii.edu/ldc/December2008/>.
- Hualde, José Ignacio, Oihana Lujanbio & Francisco Torreira. 2008. Lexical tone and stress in goizueta basque. *Journal of the International Phonetic Association* 38(1). 1–24.
- Hyman, Larry. 2006. Word-prosodic typology. *Phonology* 23(2). 225–257.
- Hyman, Larry. 2009. How (not) to do phonological typology: the case of pitch-accent. *Language Sciences* 31(2-3). 213–238.
- Hyman, Larry. 2014. How to study a tone language, with exemplification from Oku (Grassfields Bantu, Cameroon). *Language Documentation and Conservation* 8. 525–562. Available online at <https://scholarspace.manoa.hawaii.edu/handle/10125/24624>.
- Johnson, Keith. 2008. *Quantitative methods in linguistics*. Malden, MA: Blackwell.

- Jolliffe, Ian T. 2002. *Principal component analysis*. New York: Springer.
- Jun, Sun-Ah & Janet Fletcher. 2014. Methodology of studying intonation: From data collection to data analysis. In Sun-Ah Jun (ed.), *Prosodic typology II: the phonology of intonation and phrasing*, 493–519. Oxford, UK: Oxford University Press.
- Kaufman, Terrence. 1976. *Proyecto de alfabetos y ortografías para escribir las lenguas mayances*. Antigua, Guatemala: Proyecto Lingüístico Francisco Marroquín.
- Kawahara, Shigeto. 2015. The phonology of Japanese accent. In Haruo Kubozono (ed.), *The handbook of Japanese phonetics and phonology*, chap. 11, 4454–492. Berlin: Mouton de Gruyter.
- Keelan, Evanini, Catherine Lai & Klaus Zechner. 2011. The importance of optimal parameter setting for pitch extraction. In *Proceedings of meetings on acoustics*, vol. 11 1, Acoustical Society of America. Available online at <http://scitation.aip.org/content/asa/journal/poma/11/1/10.1121/1.3609833>.
- Kelly, Niamh Eileen. 2015. *An experimental approach to the production and perception of Norwegian tonal accent*. Austin, TX: University of Texas, Austin dissertation.
- Kügler, Frank & Caroline Féry. 2017. Postfocal downstep in German. *Language and speech* 60(2). 260–288.
- Kügler, Frank & Susanne Genzel. 2012. On the prosodic expression of pragmatic prominence: The case of pitch register lowering in Akan. *Language and speech* 55(3). 331–359.
- Kügler, Frank & Stavros Skopeteas. 2006. Interaction of lexical tone and information structure in Yucatec Maya. In *Proceedings of the Second International Symposium on Tonal Aspects of Languages (TAL-2)*, 380–388. Available online at [http://www.isca-speech.org/archive/tal\\_2006/tal6\\_077.html](http://www.isca-speech.org/archive/tal_2006/tal6_077.html).
- Kügler, Frank & Stavros Skopeteas. 2007. On the universality of prosodic reflexes of contrast: the case of Yucatec Maya. In *Proceedings of the XVIth International Congress of Phonetic Sciences*, vol. 2, 1025–1028. Saarbrücken, Germany: Universität des Saarlandes. Available online at <http://www.icphs2007.de/conference/Papers/1188/>.
- Kügler, Frank, Stavros Skopeteas & Elisabeth Verhoeven. 2007. Encoding information structure in Yucatec Maya: On the interplay of prosody and syntax. *Interdisciplinary studies on information structure* 8. 187–208. Available online at <http://opus.kobv.de/ubp/volltexte/2008/1946/>.
- Kuznetsova, Alexandra, Per Bruun Brockhoff & Sofie Pødenphant Jensen Rune Haubo Bojesen Christensen. 2019. *lmerTest: Tests in linear mixed effects models*. Version 3.1-1, retrieved from <http://CRAN.R-project.org/package=lmerTest>.
- Ladd, D. Robert. 2008a. *Intonational phonology*. Cambridge, UK: Cambridge University Press 2nd edn. doi:10.1017/cbo9780511808814.
- Ladd, D. Robert. 2008b. Review of Sun Ah-Jun (ed.) (2005). prosodic typology: the phonology of intonation and phrasing. Oxford: Oxford University Press. ix + 462. *Phonology* 25(2). 372–376.
- Larsen, Thomas. 1988. *Manifestations of ergativity in Quiché grammar*: University of California, Berkeley dissertation.
- Liberman, Mark & Janet Pierrehumbert. 1984. Intonational invariance under changes in pitch range and length. In Mark Aronoff & Richard Oehrle (eds.), *Language sound structure: studies in phonology presented to Morris Halle by his teacher and students*, 157–233. Cambridge, MA: MIT Press.
- Lindblom, Björn. 1986. Phonetic universals in vowel systems. In John Ohala & Jeri Jaeger (eds.), *Experimental phonology*, 13–44. Orlando: Academic Press.
- McAuliffe, Michael, Michaela Socolof, Sarah Mihuc, Michael Wagner & Morgan Sonderegger.

2017. Montreal Forced Aligner: trainable text-speech alignment using Kaldi. In *Proceedings of the 18th conference of the international speech communication association*, 498–502.
- Méndez, Miguel Angel Vicente. 2007. *Diccionario bilingüe uspaneko-español*. Antigua, Guatemala: Oxlajuuj Keej Maya' Ajtz'iib' (OKMA).
- Mielke, Jeff. 2012. A phonetically-based metric of sound similarity. *Lingua* 122. 145–163. doi: 10.1016/j.lingua.2011.04.006.
- Mixdorff, Hansjörg, Jennifer Cole & Stefanie Shattuck-Hufnagel. 2012. Prosodic similarity – evidence from an imitation study. In Qiuwu Ma, Hongwei Ding & Daniel Hirst (eds.), *Proceedings of the speech prosody 2012 conference*, 571–574. Shanghai, China: Speech Prosody. Available online at <https://www.isca-speech.org/archive/sp2012/>.
- Moritz, Steffen & Sebastian Gatscha. 2019. *imputeTS: time series missing value imputation in R*. Version 3.0, retrieved from <http://CRAN.R-project.org/package=imputeTS>.
- Myers, Scott. 1998. Surface underspecification of tone in Chichewa. *Phonology* 15(3). 367–391.
- Myers, Scott, Elisabeth Selkirk & Yelena Fainleib. 2018. Phonetic implementation of high-tone spans in luganda. *Laboratory Phonology* 9(1). 1–22. doi:<https://doi.org/10.5334/labphon.101>.
- Nadeu, Marianna & Margaret Renwick. 2016. Variation in the lexical distribution and implementation of phonetically similar phonemes in Catalan. *Journal of Phonetics* 58. 22–47.
- Nakai, Satsuki, Alice Turk, Kari Suomi, Sonia Granlund, Riikka Ylitalo & Sari Kunnari. 2012. Quantity constraints on the temporal implementation of phrasal prosody in Northern Finnish. *Journal of Phonetics* 40(6). 796–807.
- Nelson, Noah Richard & Andrew Wedel. 2017. The phonetic specificity of competition: Contrastive hyperarticulation of voice onset time in conversational English. *Journal of Phonetics* 64. 51–70. doi:10.1016/j.wocn.2017.01.008.
- Pierrehumbert, Janet & Mary Beckman. 1988. *Japanese tone structure*. Cambridge, MA: MIT Press.
- Pike, Kenneth. 1946. Phonemic pitch in Maya. *International Journal of American Linguistics* 12(2). 82–88.
- Pike, Kenneth. 1948. *Tone languages: a technique for determining the number and type of pitch contrasts in a language, with studies in tonemic substitution and fusion*. Ann Arbor, MI: University of Michigan Press.
- Polian, Gilles. 2013. *Gramática del Tseltal de Oxchuc*. Mexico, D.F.: Centro de Investigaciones y Estudios Superiores en Antropología Social.
- R Development Core Team. 2019. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing Vienna, Austria. Version 3.6.2, retrieved from <http://www.R-project.org/>.
- Remijsen, Bert, Farienne Martis & Ronald Severing. 2014. The marked accentuation pattern of Curaçao Papiamentu. In Sun-Ah Jun (ed.), *Prosodic typology II: the phonology of intonation and phrasing*, 302–323. Oxford, UK: Oxford University Press.
- Remijsen, Bert & Vincent van Heuven. 2005. Stress, tone and discourse prominence in the Curaçao dialect of Papiamentu. *Phonology* 22(2). 205–235.
- Renwick, Margaret. 2014. *The phonetics and phonology of contrast: The case of the Romanian vowel system*. Berlin: Walter de Gruyter. doi:10.1515/9783110362770.
- Riad, Tomas. 2006. Scandinavian accent typology. *Sprachtypologie und Universalienforschung (STUF)* 59(1). 36–55.
- Richards, Michael. 2003. *Atlas lingüístico de Guatemala*. Guatemala City: Instituto de Lingüística

- y Educación de la Universidad Rafael Landívar.
- Roettger, Timo. 2017. *Tonal placement in Tashlhiyt: How an intonation system accommodates to adverse phonological environments*. Berlin: Language Science Press.
- Sapir, Shimon. 1989. The intrinsic pitch of vowels: Theoretical, physiological, and clinical considerations. *Journal of Voice* 3(1). 44–51. doi:10.1016/S0892-1997(89)80121-3.
- Shosted, Ryan, Marissa Barlaz & Di Wu. 2015. Modeling Iu Mien tone with eigen-pitch representations. In The Scottish Consortium for ICPHS 2015 (ed.), *Proceedings of the 18th International Congress of the Phonetic Sciences*, 1–5. Glasgow: University of Glasgow. Available online at <https://www.internationalphoneticassociation.org/icphs-proceedings/ICPhS2015/Papers/ICPHS0728.pdf>.
- Snider, Keith. 2014. On establishing underlying tonal contrast. *Language Documentation & Conservation* 8. 707–737.
- Sobrino Gómez, Carlos Martín. 2018. *El sistema fonológico protoyucatecano: reconstrucción y desarrollo*. Ciudad de México: El Colegio de México dissertation.
- Stoll, Otto. 1884. *Zur ethnographie der republik Guatemala*. Zürich: Orell Füssli.
- Stoll, Otto. 1887. *Die sprache der Ixil-Indianer: Ein Beitrag zur ethnologie und linguistik der Maya-völker. Nebst einem Anhang: Wortverzeichnisse aus dem nordwestlichen Guatemala*. Leipzig: FA Brockhaus.
- Stoll, Otto. 1888. *Die Maya-Sprachen der Pokom-Gruppe*. Wien: A. Hölder.
- Stoll, Otto. 1896. *Die sprache der K'e'kchi-Indianer. Nebst einem Anhang: Die Uspanteca*. Leipzig: K.F. Köhler's Antiquarium.
- Sugiyama, Yukiko. 2011. *The production and perception of Japanese pitch accent*. Newcastle upon Tyne, UK: Cambridge Scholars Publishing.
- Us Maldonado, Juan Antonio. no date(a). *Chololtzij: Diccionario Uspanteko*. San Miguel Uspantán: Comunidad Lingüística Uspanteka.
- Us Maldonado, Juan Antonio. no date(b). *Monografía Uspanteka: Aspectos culturales, lingüísticos y sociales de la Comunidad Lingüística Uspanteka*. San Miguel Uspantán: Comunidad Lingüística Uspanteka.
- Velleman, Leah. 2014a. On optional focus movement in K'ichee'. In Lauren Eby Clemens, Robert Henderson & Pedro Mateo Pedro (eds.), *Proceedings of Formal Approaches to Mayan Linguistics (FAMILi)* 2, 107–118. Cambridge, MA: MIT Working Papers in Linguistics.
- Velleman, Leah Bridges. 2014b. *Focus and movement in a variety of K'ichee'*. Austin, TX: University of Texas, Austin dissertation.
- Verhoeven, Elisabeth & Stavros Skopeteas. 2015. Licensing focus constructions in Yucatec Maya. *International Journal of American Linguistics* 81(1). 1–40.
- Wagner, Michael. to appear. Prosodic focus. In Daniel Gutzmann, Lisa Matthewson, Cécile Meier, Hotze Rullmann, Thomas Ede Zimmerman & Dina Voloshina (eds.), *The Wiley Blackwell companion to semantics*, Wiley Blackwell.
- Wickham, Hadley. 2009. *ggplot2: Elegant graphics for data analysis*. New York: Springer. <http://had.co.nz/ggplot2/book>.
- Xu, Yi. 1999. Effects of tone and focus on the formation and alignment of f0 contours. *Journal of phonetics* 27(1). 55–105.
- Xu, Yi & Xuejing Sun. 2002. Maximum speed of pitch change and how it may relate to speech. *The Journal of the Acoustical Society of America* 111(3). 1399–1413.
- Yu, Kristine. 2014. The experimental state of mind in elicitation: illustrations from tonal fieldwork.

- Language Documentation and Conservation* 8, 738–777.
- Zec, Draga. 1999. Footed tones and tonal feet: rhythmic constituency in a pitch-accent language. *Phonology* 16(2). 225–264.
- Zec, Draga & Elizabeth Zsiga. 2010. Interaction of tone and stress in Standard Serbian. In Wayles Browne, Adam Cooper, Alison Fisher, Esra Kesici & Nikola Predolac (eds.), *Formal approaches to Slavic linguistics (FASL)* 18, 536–555. Ann Arbor, MI: Michigan Slavic Publications.
- Zhang, Jingwei. 2019. A comparison of tone normalization methods for language variation research. In *Proceedings of the 32nd Pacific Asia Conference on Language, Information and Computation (PACLIC-32)*, Hong Kong: Association for Computational Linguistics. <https://www.aclweb.org/anthology/Y18-1095>.
- Zsiga, Elizabeth & Draga Zec. 2013. Contextual evidence for the representation of pitch accents in Standard Serbian. *Language and speech* 56(1). 69–104.