

Polar question formation in San Martín Peras Mixtec*

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Abstract: Polar questions in San Martín Peras Mixtec are distinguished from syntactically-identical declarative sentences by means of asymmetric pitch range expansion, utterance-final glottal closure, and the suspension of utterance-final tone sandhi. These intonational characteristics are unique to polar questions and are not present in *wh*-questions. When considered alongside other cross-linguistic uses of pitch range and laryngeal settings in prosody, these intonational patterns suggest that either pitch range modulation or boundary laryngealization — or both — should be modeled phonologically in at least some cases.

Keywords: Prosodic typology, intonation, Mixtec, questions

1 Introduction

Autosegmental-Metrical Theory (AM) posits that the structure of pitch phonology is identical across all languages (Ladd 2008). That is, both lexical tones and intonational tones are tonal units (i.e., Lows and Highs) that are anchored to specific points in a phonological string (i.e., a syllable or a prosodic boundary). This point is complicated by intonational changes that are not straightforwardly analyzable in terms of localized Lows and Highs. One example involves creaky voice, which is commonly used to mark phrase boundaries (Gordon & Ladefoged 2001). Another involves pitch range manipulations like those seen in many African languages. For example, in Bemba (Niger-Congo), polar questions involve expanding the f_0 range of tones (Kula & Hamann 2016), and in Moro (Niger-Congo), pitch range expansion occurs in the early part of polar questions, but pitch range compression occurs in the later part (Rose & Piccinini 2016). Ladd (2008) argues that such manipulations of pitch range are not phonological in nature but rather para-linguistic, since they are fundamentally different from tonal units like lexical or boundary tones. However, phonological analyses of pitch range expansion have been proposed using intonational tones (Kula & Hamann 2016; Sosa 1999), and the issue of whether or not pitch range modulation is phonological or para-linguistic remains an open question (DiCanio et al. 2018:5).

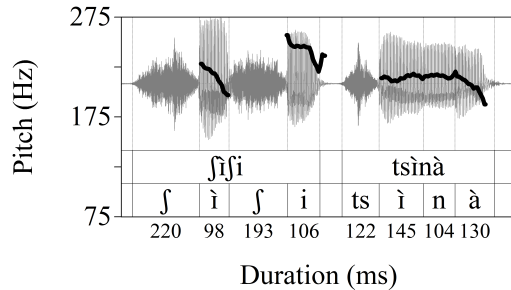
This paper addresses these issues through a study of question intonation in San Martín Peras Mixtec (SMPM, ISO 639-3: *jmx*). Polar questions in SMPM are syntactically identical to their declarative counterparts and differentiated solely by intonational changes. These changes are reliably used by SMPM speakers and listeners to distinguish between declaratives and questions, but they can be subtle to the untrained ear. For example, the only immediately obvious difference between the declarative in (1) and the polar question in (2) is seen on the final syllable, where the pitch in (1) starts a little lower and dips more steeply than the pitch in (2).¹

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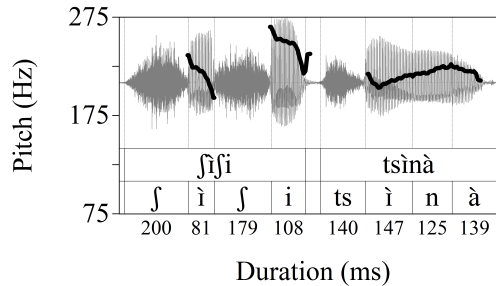
¹ Abbreviations in the glosses are as follows: 1, 2, 3 = first, second, third person, *COMPL* = completive, *CONT* = continuative, *NEG* = negation, *POT* = potential, *Q* = question, *SG* = singular.

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(1) *ʃiʃi tsinà.*
 COMPL-eat dog
 ‘The dog ate.’



(2) *ʃiʃi tsinà?*
 COMPL-eat dog
 ‘Did the dog eat?’



The syntactic identity between polar questions and declaratives is in contrast to wh-questions, which are formed by obligatorily pre-posing the wh-word to a pre-verbal position (Hedding 2019; Ostrove 2018). Maintaining the wh-word in situ is ungrammatical.

(3) *nǎǎ ʃiʃi tsinà?*
 what COMPL.eat dog
 ‘What did the dog eat?’

(4) **ʃiʃi tsinà nǎǎ?*
 COMPL.eat dog what
 Intended: ‘What did the dog eat?’

This investigation shows that polar questions in SMPM are discernible in the acoustic signal from their declarative and wh-question counterparts in at least three ways: First, polar questions involve asymmetric pitch range expansion, in which the pitch ceiling is raised while the pitch floor remains the same. Second, polar questions have glottal closure utterance-finally, whereas declaratives and wh-questions do not. Third, polar questions usually block the application of an utterance-final tone sandhi process in which rising tones flatten to a level, low pitch. I argue that these changes, when considered alongside similar intonational patterns in other languages, are not easily captured by a theory of intonation whose only units are tones aligned to specific points in an utterance. Instead, such approaches require augmentation to model the phonological status of these processes.

2 Background

2.1 Language

SMPM is an Otomanguean language and is referred to in the language proper as [tù^ʔũ sà^hvĩ] or [tù^ʔũ n^ʔtá^ʔβi]. It is spoken by about 10,000 people in and around the municipality of San Martín Peras in western Oaxaca, Mexico (Instituto Nacional de Estadística y Geografía 2010). Additionally, there are an estimated 350,000 indigenous Oaxacans living in California (Rabadán & Salgado 2018), many of whom speak one of the multitude of indigenous Oaxacan languages. Speakers of the San Martín Peras variety are concentrated principally in the towns of Watsonville, Oxnard, and Santa María (Natalia Gracida Cruz, p.c.). The language has default VSO word order, though arguments regularly front to a pre-verbal position through various processes related to information structure (Mendoza 2020; Ostrove 2018). It has a bi-moraic minimal word template, as seen across Mixtec languages (Penner 2019). It has five phonemic tones: three level tones (á = High, a = Mid, à = Low)

and two contour tones (ǎ = Low-to-High rise, â = High-to-Low fall). The tone-bearing-unit (TBU) is the mora, and a single mora may host any of the five phonemic tones (Peters 2017). Additionally, vowel laryngealization and nasalization are contrastive. Tone carries a large functional load and is involved in the expression of aspect and negation. For example, the following four examples differ only in the tone of the first syllable of the verb:

- | | |
|--|---|
| <p>(5) ⁿdá^hʃí saà.
fly.CONT bird
'The bird flies.'</p> | <p>(6) ⁿda^hʃí saà.
fly.POT bird
'The bird will fly.'</p> |
| <p>(7) ⁿdà^hʃí saà.
fly.COMPL bird
'The bird flew.'</p> | <p>(8) ⁿdǎ^hʃí saà.
NEG.fly.POT bird
'The bird won't fly.'</p> |

2.2 The syntax of questions

Though the main method of forming polar questions involves only supra-segmental changes, there is one way in which polar questions may differ linearly from declarative sentences, and that is in the presence of the sentence-initial particle [á], as seen in (9) below.

- (9) á ʃíʃí kolo?
Q CONT.eat turkey
'Is the turkey eating?'

However, this particle is restricted to formal speech registers, such as when talking with a teacher (Jason Ostrove, p.c.), and some speakers almost never or never use it. Because of its restriction to formal registers and its lack of frequent use by many speakers, I do not discuss it further in this paper. However, it may be important to note that impressionistic observation of a handful of tokens suggests that the intonational characteristics of polar questions described throughout this paper (pitch range expansion and utterance-final glottal closure) also appear to be present in polar questions containing this question particle. This state of affairs is also seen in other languages, such as K'ichee', where intonational patterns are the same irrespective of the presence or absence of a question particle (Baird 2019).

Aside from the presence of the question particle in formal speech, polar questions do not differ from their declarative counterparts in any immediately obvious way. Though I do not show the examples here for reasons of space, no word order or agreement differences have been found between polar questions and declarative sentences across a wide range of sentence types tested. These contexts have included pre-verbal pronoun doubling (see Ostrove 2018 for a thorough overview), verb-adverb word order differences, clausal embedding, focus fronting of various types, and topicalization.

2.3 Previous research on Mixtecan intonation

SMPM is an Otomanguean language, and the intonation of Otomanguean languages is highly understudied (DiCanio & Bennett 2021). This lack of research extends to the Mixtecan branch of the language family. Mixtecan languages tend to be tonally robust, with an average of nine tonal

contrasts per syllable (DiCanio & Bennett 2021:2). The studies that have been conducted on intonation in Mixtecan languages have yielded disparate results. For example, DiCanio and Hatcher (2018) show that Itunyoso Triqui does not use f0 to encode information structure or prosodic boundaries, and Macaulay (1996:126) states that there are no syntactic or intonational differences between declarative sentences and polar questions in Chalcatongo Mixtec. Pike (1944:136) comes to the same conclusion for San Miguel El Grande Mixtec. However, DiCanio, Benn, and García (2018) have demonstrated that f0 changes are correlated with boundaries and information structure in Yoloxóchitl Mixtec, and Hedding (2019) has demonstrated pitch variation related to information structure in SMPM as well. This limited number of studies, then, has shown a wide range of variation in the use of pitch intonation in Mixtecan languages. Such variation in the interaction between tone and intonation has the potential to shed light on the range of ways in which languages use pitch and other related phonetic cues to convey different linguistic functions. In this light, the present investigation also makes a typological contribution by describing in detail the intonation of questions in a Mixtecan language.

2.4 Methods

The source of the data in this paper is an informal production task carried out separately with two speakers of SMPM who live and work in Watsonville, CA. The task was carried out over Zoom due to restrictions on in-person meetings during the COVID-19 pandemic. Audio was recorded on zencastr.com (48 KHz, 16-bit) with a Cooler Master MH630 headset microphone.

The speakers were asked to translate a set of sentences from Spanish to SMPM. Speaker 1 translated 229 sentences, and speaker 2 translated 53. Because of the small number of tokens from Speaker 2, Speaker 1’s productions are used throughout the paper, and Speaker 2’s productions were used for qualitative but not quantitative confirmation that the observed patterns appear to generalize across speakers. The sentences were all mono-clausal and varied between declaratives, polar questions, and wh-questions. The sentences all used the optionally-transitive verb ‘to eat’ and were evenly divided between SMPM’s three aspects, each of which are marked with a different level tone on the first syllable of the verb. Continuative aspect is marked with a High tone (10), completive is marked with a Low tone (11), and potential aspect is marked with a Mid tone (12).²

(10)	ʃiʃi	(11)	ʃiʃi	(12)	kuʃi
	CONT.eat		COMPL.eat		pot.eat
	‘eating’		‘ate’		‘will eat’

Varying aspectual tone allowed for direct comparison between aspectual H, M, and L in the same syntactic and phonological position. In addition, the subject of the verb was varied systematically. Because SMPM is a VSO language, varying the subject allowed for the manipulation of tone of the final and penultimate syllable in the sentences. This permitted investigation of any utterance-edge effects on pitch, as well as whether pitch differences were localized to a single word or syllable. A representative triplet of a declarative, polar question, and wh-question from the task are given below.

² A more accurate description is that potential aspect involves the *absence* of grammatical tone, with the underlying tone of the verb’s first vowel surfacing instead. The two descriptions are functionally equivalent here, since the underlying tone of the first vowel of ‘eat’ is Mid.

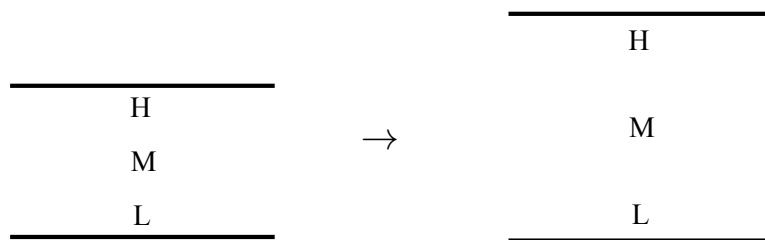
- (13) *fífi kolo.*
CONT.eat turkey
‘The turkey is eating.’
- (14) *fífi kolo?*
CONT.eat turkey
‘Is the turkey eating?’
- (15) *nǎǎ́ fífi kolo?*
what CONT.eat turkey
‘What is the turkey eating?’

For each utterance, the tone of the aspectual tone-bearing vowel, the penultimate vowel, and final vowel were spliced out of the audio signal using Praat (Boersma & Weenink 2020). The final vowel of the verb is not shown separately in this paper because it has a Mid tone in all cases, so it was not useful in determining the relationship between different tones on the same syllable. Praat scripts extracted various acoustic measures which were illustrated in R (R Core Team 2013) using the ‘ggplot2’ package (Wickham 2016). The measures were plotted using smoothed loess regression lines, which use a weighted least-squares method to fit a smoothed regression line to a series of observed values. Gray bands around the lines indicate 95% confidence intervals around the estimate of the position of the line at each step.

3 Pitch register

The main use of pitch intonation in polar questions in SMPM is the expansion of pitch range. Specifically, polar questions differ from declaratives and wh-questions in that they involve an asymmetrically expanded pitch range, where the pitch ceiling is raised but the pitch floor remains the same. The result of this type of expansion is that the pitch of High tones is raised significantly, and the pitch of Mid tones is raised, but to a somewhat lesser extent. Finally, the pitch of Low tones remains roughly the same, perhaps raising very slightly. This is schematized in (16), where the top and bottom black lines represent the pitch ceiling and pitch floor, respectively.

- (16) Asymmetric pitch range expansion:



3.1 High tone

High tones are realized with a higher pitch in polar questions than in declarative sentences or wh-questions. This pitch raising can be clearly seen in Figure 1, where the pitch of High tones in polar questions (PQ) is higher than that of High tones in declaratives (Decl) and wh-questions (WhQ) on both the aspectual tone-bearing vowel and the penultimate vowel. Aspectual High tones are ~20Hz higher in polar questions than declaratives or wh-questions, and penultimate High tones are ~25-30Hz higher than High tones in declaratives, and ~20Hz higher than High tones in wh-questions. However, for penultimate High tones, the confidence intervals are wider, likely due to the smaller number of tokens.

The pitch of High tones also appears to be higher utterance-finally in polar questions than it is in declaratives (~25Hz). However, the pitch of wh-words is intermediate between polar questions

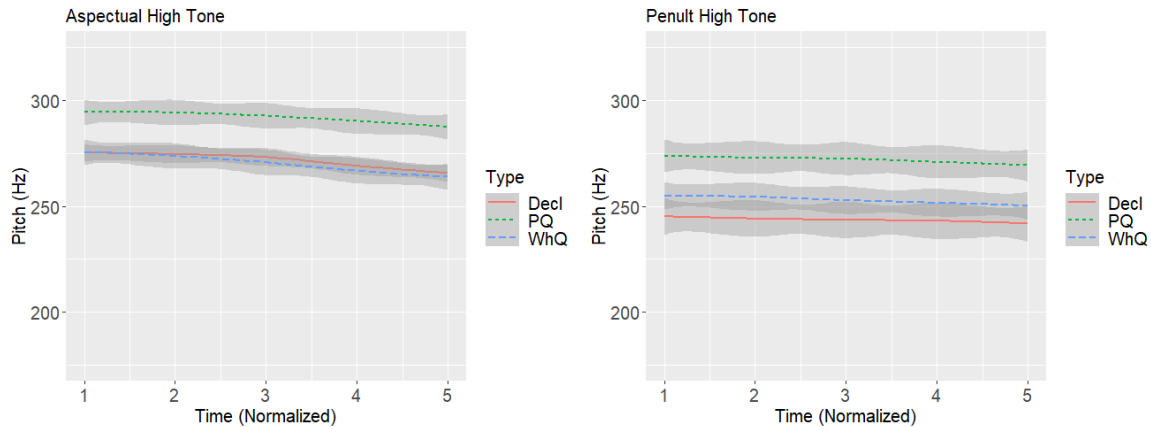


Figure 1: Pitch (Hz) of aspectual High tone (N=69; 26 PQ, 24 Decl, 19 WhQ) and penultimate High tone (N=37; 13 PQ, 12 Decl, 12 WhQ).

and declaratives, which is similar to the results seen for penultimate High tones in Figure 1. Because of this, it appears that High tones in some positions are somewhat higher in wh-questions than in declaratives (~5-15Hz), but clearly higher in polar questions than in the other two sentence types (~20-30Hz). The final point of note is that utterance-final Highs dip toward the end of the vowel for all sentence types, but more drastically so for polar questions than for declaratives or wh-words. As will be discussed more in Section 4.1, the steep drop for polar questions is likely due to the fact that polar questions are marked with utterance-final glottal closure, which has a lowering effect on High tones.

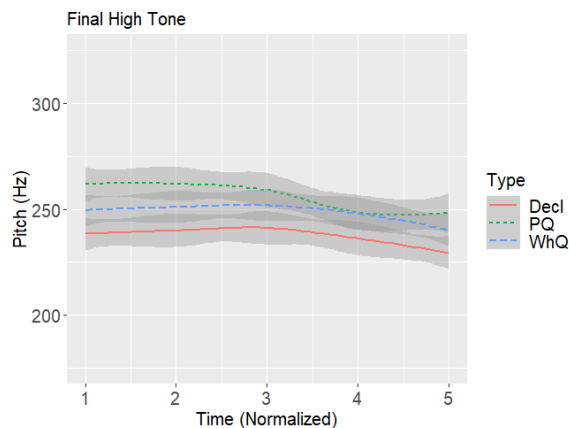


Figure 2: Pitch (Hz) of utterance-final High tone (N=52; 18 PQ, 17 Decl, 17 WhQ).

3.2 Mid tone

Like High tone, Mid tones are realized with a clearly higher pitch in polar questions than they are in declaratives or wh-questions. This pitch raising is first seen on the aspectual tone-bearing vowel, where Mid tones are ~15Hz higher in polar questions than in declaratives, and ~20Hz higher in

polar questions than in wh-questions. For the vowel of the penultimate syllable in the utterance, Mid tones are $\sim 20\text{Hz}$ higher in polar questions than in declaratives, and $\sim 15\text{Hz}$ higher in polar questions than in wh-questions. On the aspectual tone-bearing vowel, the pitch of Mid tones in declaratives is actually modestly higher than in wh-questions ($\sim 5\text{-}10\text{Hz}$). This is the opposite of what was observed for penultimate and final High tones, where the pitch for wh-questions was a small amount higher than the pitch of declaratives. In other words, the small difference between Mid tones in wh-questions and declaratives on the aspectual tone-bearing vowel is not consistent and therefore possibly spurious.

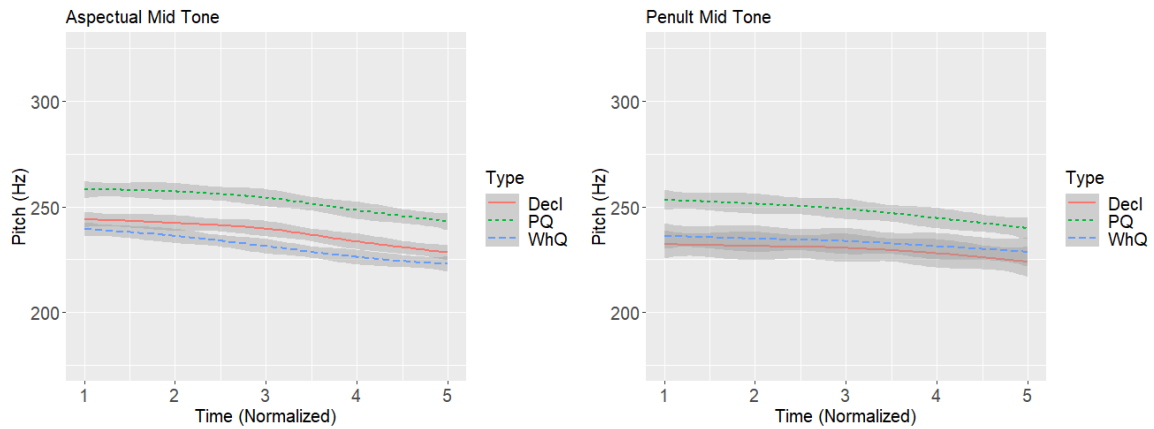


Figure 3: Pitch (Hz) of aspectual Mid tone (N=85; 27 PQ, 27 Decl, 31 WhQ) and utterance-penultimate Mid tone (N=52; 17 PQ, 19 Decl, 16 WhQ).

Figure 4 shows that utterance-final Mid tones appear to be raised compared to their declarative and wh-question counterparts ($\sim 15\text{-}20\text{Hz}$), but that there is more variation, as seen in the greater width of the confidence intervals. Additionally, the difference is only at the very beginning of the vowel, since pitch for utterance-final Mid tones drops more rapidly in polar questions, once again likely due to the utterance-final glottal closure described in Section 4.1.

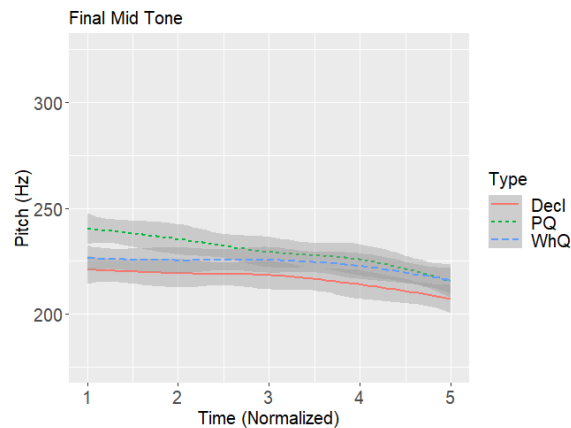


Figure 4: Pitch (Hz) of utterance-final Mid tone (N=52; 17 PQ, 18 Decl, 17 WhQ).

3.3 Low tone

The pitch of Low tones in polar questions is not so clearly distinct from that of Low tones in declaratives and wh-questions. This can be seen in Figure 5, where the pitch of aspectual Low tone in polar questions appears to diverge somewhat from the pitch of its declarative and wh-question counterparts, but only very slightly (~ 5 -10Hz), and only during the first half of the vowel. A similarly small difference is also seen for penultimate Low tones, which are ~ 10 Hz higher than in declaratives or polar questions.

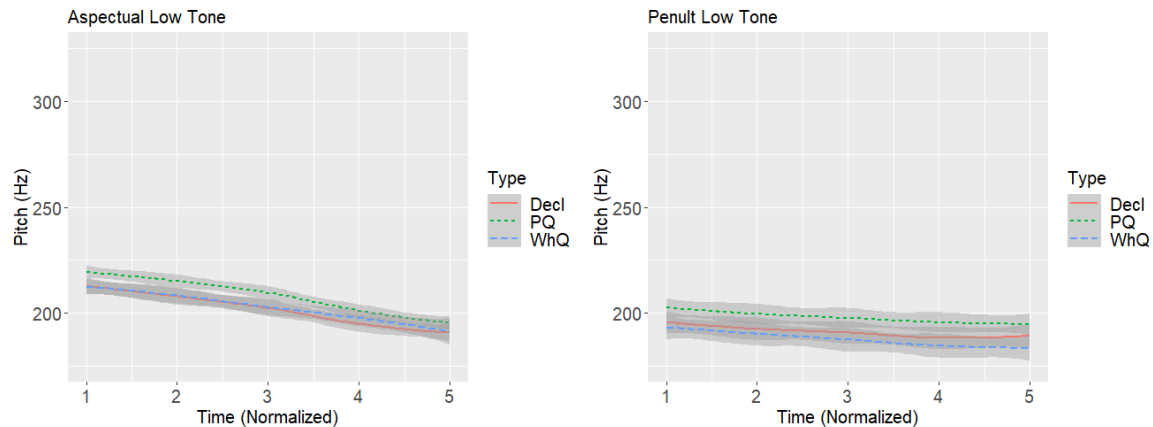


Figure 5: Pitch (Hz) of aspectual Low tone (N=71; 24 PQ, 25 Decl, 22 WhQ) and of penultimate Low tone (N=61; 21 PQ, 21 Decl, 19 WhQ).

Figure 6 (next page) shows that utterance-final Low tones differ from previous examples in that, though the pitch of Lows in all three sentence types overlaps in the first portion of the vowel, the pitch of Lows in polar questions stays flat, while that of declaratives and wh-questions falls throughout the duration of the vowel. Though I do not provide examples until Section 4.1, this may be due to a differential effect of utterance-final glottal closure on Low tones, where the pitch of about noun utterance-final Low tones rose heading into the glottal closure instead of lowering. Conversely, the right utterance boundary of declaratives and wh-questions was usually somewhat breathy, rather than creaky or constricted. This may have resulted in pitch-lowering, though the effect of breathiness on pitch is not entirely consistent cross-linguistically (for examples of this inconsistency in tonogenesis, see Kingston (2011)).

3.4 Review

In general, the pitch level of High, Mid, and Low tones is fairly consistent between declaratives and wh-questions. However, in polar questions, High and Mid tones are realized with a clearly higher pitch than in declaratives and wh-questions. Low tones do not appear to differ greatly by sentence type, though they do trend modestly higher in polar questions. Ultimately, more empirical work is needed to determine whether or not Low tones are consistently higher in polar questions. However, no matter the conclusion, the fact that Highs and Mids raise considerably while Lows remain relatively immobile is indicative of asymmetric pitch range expansion. That is, the pitch ceiling is raised in polar questions, causing the significant raising of Highs and Mids, with only a small amount (or potentially no) raising of Lows.

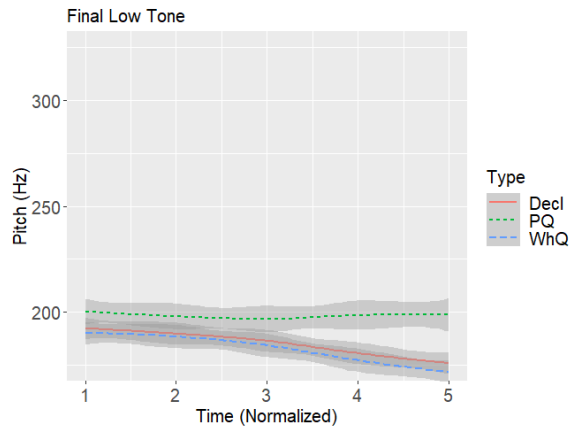


Figure 6: Pitch (Hz) of utterance-final Low tone (N=79; 27 PQ, 25 Decl, 27 WhQ).

4 Edge effects

This section outlines two ways in which polar questions differ from declaratives and wh-questions at the right utterance boundary. First, polar questions are shown to contain utterance-final glottal closure. Second, Low-to-High rising tones are usually flattened utterance-finally in declaratives and wh-questions, but they usually surface faithfully in polar questions.

4.1 Final glottal closure

Aside from pitch range expansion, another consistent characteristic that sets polar questions apart from their declarative and wh-question counterparts is that they are ended with a sort of abrupt glottal closure.³ The presence of this glottal closure is salient to speakers. For example, in describing the difference between declaratives and polar questions, Speaker 1 noted that there was a difference utterance-finally, mimicking the end of a polar question by producing a velar stop. They have elsewhere described polar questions as ending by doing something “in your throat”.

These descriptions are borne out by the data. First, impressionistic investigation of individual tokens shows consistent glottal closure utterance-finally in polar questions. This is sometimes accompanied by a short period of creak or laryngealization. For example, the waveforms in Figure 7 show a difference between utterance-final vowels in declaratives and polar question for both speakers. In the top waveforms, the vowel ends gradually, with some breathy voicing. However, in the bottom waveforms, the vowel ends with widely and irregularly spaced glottal pulses, characteristic of creaky voice.

³ Interestingly, this feature of questions is shared with some varieties of rural Mexican Spanish (Hirotto Uchihara, p.c.). It is unclear whether this feature was borrowed, and if so, in what direction.

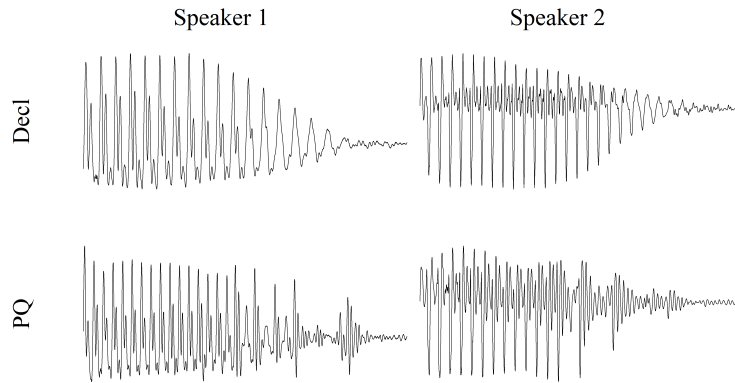


Figure 7: Waveforms of the final vowel of [léló] ('skunk') in utterance-final position in a declarative and polar question for Speaker 1 and Speaker 2.

Second, polar questions have a steeper fall in amplitude at the end of the final vowel than declaratives and wh-questions do, which is consistent with the presence of abrupt glottal closure. This can be seen below in Figure 8, which shows normalized intensity across utterance-final vowels. Intensity was normalized for each token by dividing the dB value at each step by that token's maximum dB value.

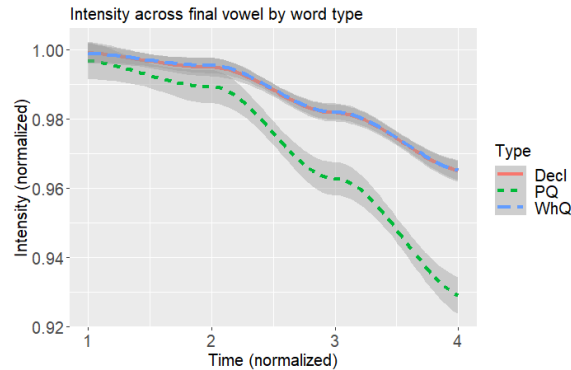
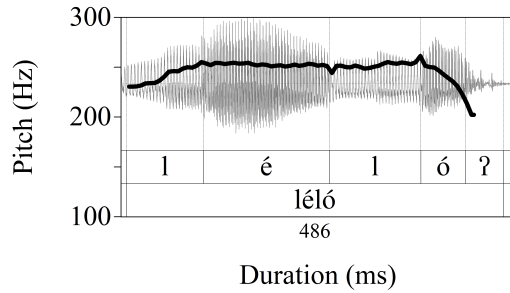


Figure 8: Normalized intensity (dB) contours of utterance-final vowels by sentence type (N=216; 72 Decl, 72 PQ, 72 WhQ).

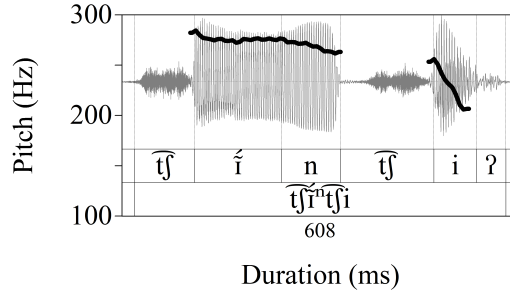
Third, the pitch drops seen for final High and Mid tones in polar questions are also consistent with the presence of glottal closure utterance-finally, since glottalization is often associated with a fall in f_0 (Keating, Garellek, & Kreiman 2015). Representative examples of this pitch lowering for final High and Mid tones are given in (17) and (18).

One interesting point is that utterance-final Low tones do not behave uniformly with respect to pitch. In the majority of cases, the pitch of Low tones lowers heading into glottal closure. However, in about 1/3 of the examples, the pitch of the Low raises when approaching glottal closure. These two different effects can be seen on the final vowel of two productions of the word for 'pig' in (19) in the same context.

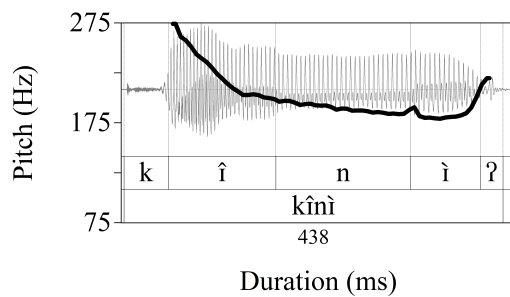
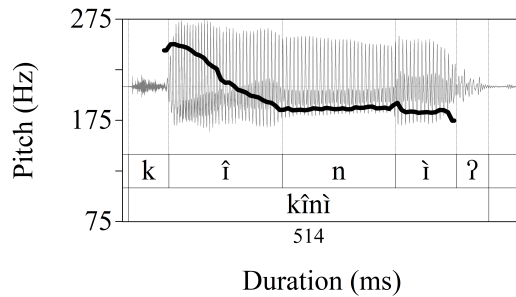
(17) *ʃiʃi lélo?*
 CONT.eat skunk
 ‘Is the skunk eating?’



(18) *ʃiʃi tʃiⁿtʃi?*
 CONT.eat cricket
 ‘Is the cricket eating?’



(19) *ʃiʃi kîni?*
 CONT.eat pig
 ‘Is the pig eating?’

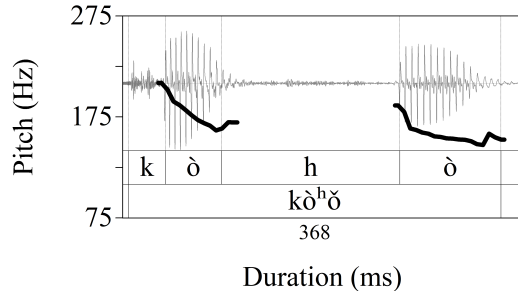


To summarize, there is evidence from speakers’ intuitions, aperiodic voicing in the acoustic signal, intensity contours, and effects on pitch that polar questions in SMPM contain some sort of utterance-final glottal closure or laryngealization. This phenomenon is interesting within the context of SMPM because laryngealization within words is best analyzed as a supra-segmental feature rather than a consonant proper (Eischens 2020), as in other Mixtec languages (Macaulay & Salmons 1995; Gerfen 2013). In this sense, laryngealization acts as a sort of supra-segmental boundary feature in a way similar to boundary tones. I explore this concept more in Section 5.

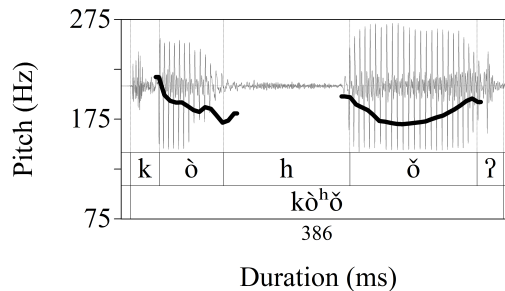
4.2 Sandhi at utterance edges

Another distinction between polar questions, declaratives, and *wh*-questions comes from the behavior of utterance-final rising tones. Words with a final Low-to-High contour tone, such as [k^hɔ] (‘snake’) are often realized with a level, low pitch utterance-finally in declarative sentences (20). However, in polar questions, utterance-final rises do not flatten nearly as often, and they are usually realized as a rising tone (21).

(20) ʃiʃi kò^hò.
 COMPL.eat snake
 ‘The snake is eating.’



(21) ʃiʃi kò^hǒ?
 COMPL.eat snake
 ‘Is the snake eating?’



It appears, then, that there is some conditioning factor that causes utterance-final rising tones to tend to surface with level, low pitch in declaratives and wh-questions. However, this conditioning factor appears to largely be absent or blocked in polar questions.

5 Discussion

I have shown that polar question formation in SMPM involves pitch range expansion, utterance-final glottalization, and the suspension of utterance-final tone sandhi. As noted earlier, Ladd (2008) argues that general pitch scaling effects are para-linguistic, or non-phonological because they do not change or obscure a tonal unit’s identity, nor does it add a new tonal category to the phonological string. Additionally, pitch range modulation cannot be straightforwardly analyzed using the tools of AM theory, namely tonal units aligned to a specific point on a phonological string. Instead, it causes (generally) global changes, and it is often the case that different tone levels are affected to different extents. These properties suggest that something distinct from the tonal string is responsible for this change.

However, there is evidence that pitch range expansion is able to interact with phonological grammar in at least some languages. For example, pitch range expansion in Bemba polar questions is accompanied by a suspension of downstep, which is an independent phonological process in the language (Kula & Hamann 2016:344–345). A similar suspension of downstep in tandem with pitch range expansion in polar questions has been documented in Moro (Chung, Piccinini, & Rose 2016:617). Insofar as it is pitch range expansion that triggers this suspension and not, say, some other property of polar questions, this point provides evidence that pitch range expansion in Bemba and Moro is part of the phonological grammar.⁴

This point raises the question of whether pitch range expansion or utterance-final glottal closure in SMPM can be demonstrated to be phonological. Here, it is helpful to consider the suspension of utterance-final tone sandhi. Recall that utterance-final Low-to-High rising tones undergo flattening at the right edge of declaratives and wh-questions. This process is rather categorical, flattening nearly every final rising tone at the end of an utterance. Additionally, it applies only to Low-to-High

⁴ Rialland (2007:5) provides a list of African languages in which pitch range expansion in polar questions is correlated with reduction or suspension of downdrift, but does not explicitly differentiate between downstep and downdrift. If what the article labels as downdrift is in fact downstep in at least some of these languages, this would strengthen the correlation between pitch range expansion and suspension of downstep.

contour tones linked to a single mora; Low-to-High melodies realized as a continuous contour on a bi-moraic long vowel do not undergo flattening. This categoricity and sensitivity to the phonological alignment of the tones involved suggest that utterance-final flattening is a phonological process. However, flattening is suspended in polar questions (21), meaning that some aspect of polar question formation blocks the application of tone sandhi. There are several distinct possibilities: It might be the case that pitch range expansion facilitates the non-flattened realization of the tone, it might be that utterance-final glottal closure is what blocks utterance-final flattening, or it could even be some combination of the two. For reasons of space, I do not tease apart these possibilities, but instead point out that at least one of these possibilities must be true in order to explain the suspension of utterance-final flattening. That is, either pitch range expansion in SMPM is a part of the grammar (as it might be argued to be in Bemba and Moro), or utterance-final glottal closure is a part of the grammar, or both.

If pitch range expansion is grammatical, then theories of intonational phonology must be augmented to include some representational mechanism to account for this. In fact, Ladd (2008:163–164) acknowledges this possibility, stating that the proposed cross-linguistic unity of pitch phonology would not necessarily be undermined by the inclusion of pitch range modification in the grammar. Instead, “all languages would still require *both* tonal specifications and descriptions of how pitch range can be modified”. That is, pitch phonology could still be essentially the same across languages, but pitch range modulation would need to be modeled in addition to strings of lexical and intonational tones.

If it is the case that utterance-final glottal closure is phonologically represented, then there are two possible analyses. The first possibility is that this final laryngealization is the phonological realization of a polar question morpheme docked to the right edge of the utterance. This use of a supra-segmental morpheme would certainly not be surprising, since tonal morphemes are used in SMPM to express aspect and negation. However, this seems unlikely, given that in SMPM and other Mixtec languages, such as Ixtayutla Mixtec (Penner 2019:253), morphemes that are smaller than a bi-moraic foot are characterized by the *absence* of laryngealization. For example, strong pronouns with laryngealization, like [jú²u] (‘1SG’), co-vary with weak pronouns without it, like the non-laryngealized pronominal enclitic [=i] (‘1SG’). In this light, it would be somewhat surprising for a grammatical morpheme to be made up entirely of laryngealization. Instead, I argue that utterance-final glottal closure is best represented as a boundary ?% feature, much like a boundary tone. The use of ?% as a prosodic marker is also consistent with the fact that laryngealization on lexical roots interacts intricately with prosodic structure in SMPM (Eischens 2020). Even though the use of a boundary ?% feature seems somewhat straightforward, it would still require a slight extension of AM Theory, since the units of AM theory are strictly tonal. However, given the widespread interactions between tone and laryngeal segments like [ʔ] and [h], the use of laryngeal features in intonational phonology is not necessarily implausible. In fact, the use of laryngeal settings to mark prosodic boundaries is already well attested. For example, creaky voice is often used to mark prosodic boundaries (Gordon & Ladefoged 2011), and Rialland (2007) notes that polar questions in many African languages have utterance-final breathiness. In this light, the inclusion of laryngeal features in the inventory of possible intonational units is certainly reasonable, but is nonetheless still a tentative proposal.

6 Conclusion

In this paper, I have shown that polar questions in SMPM are distinguished from declarative sentences by means of asymmetric pitch range expansion, utterance-final glottal closure, and the suspension of the flattening of utterance-final rising tones. These prosodic characteristics are unique to polar questions; similar patterns are not seen for wh-questions in the language. I have argued that because utterance-final tone sandhi is suspended in polar questions, some aspect of polar question formation must be grammatical. This aspect could be pitch range expansion, which interacts with phonological processes like downstep in other languages, or it could be utterance-final glottal closure, which resembles phrase-final creak in other languages. Alternatively, both of these could be phonological. In any of the three possible cases, theories of intonational phonology would need to be augmented to account for the facts. Either pitch range modulation would need to be formalized, laryngeal features would need to be added to the inventory of possible intonational units, or both.

This paper also presents a modest step forward in the study of the prosody of Otomanguan languages in general, and Mixtecan languages in particular. Along with Yoloxóchitl Mixtec (DiCanio et al. 2018), polar question formation in SMPM shows that languages with robust and complex tonal systems may still make use of intonation to convey various linguistic functions. However, given its use of pitch range modulation and utterance-final glottalization to do so, it suggests that the intonational patterns of tonally-rich languages are likely to differ significantly from the intonational patterns of non-tonal or tonally-sparse languages.

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