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ILLUSTRATION OF THE IPA

San Juan Piñas Mixtec

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San Juan Piñas Mixtec (endonym: Tò'ō Ndá'ví; henceforth SJPM) (ISO 639-3: vmc) is a previously undocumented Oto-Manguean language of the Mixtecan branch spoken in the municipality of Santiago Juxtlahuaca in Oaxaca, Mexico (shown in the map in Figure 1). According to a 2020 census conducted by the Mexican government (INEGI 2020), there are 717 inhabitants in the town of San Juan Piñas, almost all of whom speak SJPM as their native language. Additionally, speakers are found in diaspora communities in the western states of Baja California (Mexico), California, Oregon, Washington, and other places in Mexico and the United States. There are about half a million speakers of all Mixtec varieties in Mexico (INEGI 2020), and between 100,000 and 150,000 speakers of Mixtec in California (Kresge 2007). While elderly speakers in San Juan Piñas tend to be monolingual, younger speakers are bilingual in SJPM and Spanish. In diaspora communities in the United States, younger SJPM speakers shift to English and/or Spanish as their primary language(s) of communication.

The Mixtecan branch (which also includes Cuicatec and Triqui) is one of eight branches of the Oto-Manguean language stock. There are approximately 60 varieties of Mixtec within 18 mutually unintelligible dialect clusters (Josserand 1983) originally spoken in the states of Oaxaca, Guerrero, and Puebla. Josserand (1983) classifies Mixtec varieties into 12 dialectal areas. SJPM belongs to the Southern Baja region within this classification. Only one variety belonging to the Central Baja area has been previously illustrated phonetically, namely San Sebastián del Monte Mixtec (Cortés, Mantenuto & Steffman 2023).

There is a long tradition of phonological documentation of Mixtec languages spanning several decades since Pike's (1944, 1948) seminal work. More recently, there is work that addresses phonological and phonetic phenomena in Mixtec varieties (Gerfen 1999, 2001; Gerfen & Baker 2005; DiCanio, Amith, & Castillo García 2014; DiCanio et al. 2015; DiCanio, Benn & Castillo García 2018; DiCanio et al. 2020; Carroll 2015; Penner 2019; Eischens 2022, *inter alia*). However, Mixtec languages are highly diversified, and many varieties remain undocumented. Additionally, although several language varieties spoken in the

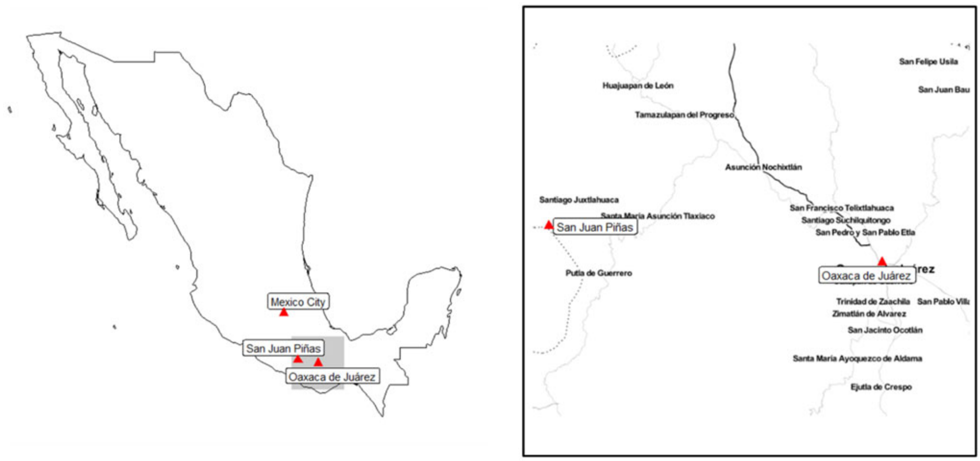

Figure 1. (Colour online) (Left) Map of Mexico and (Right) close-up map of region identifying landmarks of San Juan Piñas and Oaxaca de Juárez (capital). Map created with ggmap (Kahle & Wickham, 2013).

municipality of Santiago Juxtlahuaca share the same ISO code listed above, there are significant tonal and lexical differences between them.

Audio recordings in this illustration come from one of the authors, Claudia Juárez Chávez, who was born in San Juan Piñas, Oaxaca and has lived in the United States for the last 20 years. She speaks SJPM and Spanish fluently, using SJPM with community members and as part of her activities developing SJPM language resources for language revitalization and reclamation as well as teaching weekly language lessons. She speaks Spanish (L2) for most activities of daily living. The data analyzed throughout this paper were elicited during weekly elicitation sessions beginning January 2020. The examples include an orthographic representation, still under development, which reflect Claudia Juárez Chávez's spelling preferences. This representation shares certain aspects of the conventions developed by the *Ve'e Tu'un Savi* (Mixtec Language Academy), the Summer Institute of Linguistics (SIL) and Mexico's INALI (*Instituto Nacional de Lenguas Indígenas*) (Caballero, Juárez Chávez & Yuan 2024).

Recordings were conducted across multiple locations: prior to March 2020, all recordings were conducted at UC San Diego in a quiet room using a lavalier microphone and a Marantz PMD660 Portable Solid State Recorder at a 44.1k Hz sampling rate and 16-bit quantization. After March 2020, recordings were completed in a quiet room at the speaker's home using the same microphone and recording device. Additional recordings were collected across two elicitation sessions in a sound-attenuated booth using a standing Octava MK-319 condenser microphone and Focusrite Scarlett 2i2 pre-amp and digitizer at a 44.1k Hz sampling rate and 16-bit quantization. All forms used for quantification were produced in isolation (see supplemental materials for word list and audio files used for quantification).[1]

[1] Supplementary materials can be found at https://osf.io/crsvd/

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Consonants

	Bilabial	Labiodental	Alveolar	Postalveolar	Palatal	Velar	Glottal
Plosive	p		t ^{n}d			k ᵑg kʷ	
Affricate				t͡ʃ ^{n}d͡ʒ			
Nasal	m		n		ɲ		
Tap			ɾ				
Fricative		f v	s	ʃ ʒ			h
Lateral Approximant			l				

SJPM has 19 consonant phonemes in native and borrowed vocabulary. The consonant inventory of SJPM is provided above.

SJPM exhibits similar phonemic contrasts to those found in other, related Mixtec varieties (Josserand 1983). Across Mixtec varieties, few voicing contrasts are noted (Gerfen 1999; Marlett & Gittlen 1985; Sicoli 2005). SJPM also makes frequent use of plosive and fricative consonants.

As documented in other Mixtec languages, the minimal phonological word in SJPM is bimoraic (the minimal size of content words in the language). This bimoraic phonological unit, which can be monosyllabic ((C)VV) or disyllabic ((C)VCV)), corresponds to the canonical morphological root, referred to as a 'couplet' in Mixtecanist studies, following Pike (1948). We describe the properties of this root template below, but allude to the couplet throughout the paper, as the distribution of phonological patterns in the language is sensitive to this unit.

Phoneme	Transcription	SJPM	English Gloss	Spanish Gloss
p	/pa^{5}ɲo^{5}/	páñó	'shawl'	'chal'
t	/tĩ^{3}ĩ^{3}/	tīīn	'to grab'	'agarrar'
^{n}d	/^{n}di^{1}i^{3}/	ndìī	'dead'	'muerto'
k	/ki^{1}i^{5}/	kìí	'day'	'día'
kʷ	/kʷĩ^{3}ĩ^{3}/	kwīīn	'to buy'	'comprar'
^{n}g	/ʒa^{5}ᵑga^{5}/	yángá	difficult	'difícil'
m	/ma^{13}ˀɲo^{3}/	màā ' ñō	'middle'	'medio'
n	/na^{5}ˀno^{3}/	ná ' nō	'big.PL'	'grande.PL'

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ɲ	/ɲa^{3}ˀɲo^{3}/	ñā’ñō	‘half’	‘mitad’
f	/ka^{5}fe^{5}/	káfé	‘coffee, brown’	‘café’
v	/ve^{3}ˀe^{3}/	vē’ē	‘house’	‘casa’
s	/se^{1}ˀe^{3}/	sè’ē	‘offspring’	‘hijos’
ʃ	/ʃe^{1}ˀe^{3}/	xè’ē	‘ring’	‘anillo’
ʒ	/ʒe^{3}ˀe^{1}/	yē’è	‘patio’	‘patio’
h	/hã^{3}ã^{1}/	hāàn	‘yes’	‘sí’
t͡ʃ	/t͡ʃe^{5}ˀe^{5}/	ché’é	‘hard’	‘duro’
^{n}d͡ʒ	/^{n}d͡ʒe^{1}ˀe^{5}/	ndyè’é	‘peach’	durazno’
ɾ	/ɾa^{3}/	rā	‘and’	‘y’
l	/la^{3}lu^{3}/	lālū	‘navel’	‘ombligo’

Plosives and Affricates

Plosives contrast at bilabial, alveolar, velar and labialized velar places of articulation. The labial plosive /p/ occurs only in words borrowed from Spanish (e.g., /pa^{5}ɲo^{5}/ ‘shawl’, from Spanish *paño*). Alveolar and velar plosives may be voiceless or prenasalized.[2] The prenasalized velar /ᵑg/ is a marginal phoneme that has only been found in few words to date. The voicing of the stop release is variable in prenasalized stops and affricates; for example, /^{n}d/ may be produced phonetically as [^{n}d̥] or [^{n}d], though it is generally produced as voiced (Figure 2). Similarly, affricates contrast between voiceless and prenasalized. As with prenasalized stops, the prenasalized affricate /^{n}d͡ʒ/ may be realized with a voiced or voiceless affricate (Figure 2). In general, the speaker produces /^{n}d͡ʒ/ as voiceless. It is unclear what conditions this variation.

The phonological status of prenasalized obstruents is debated in the Mixtecanist literature. Specifically, there is debate about whether prenasalized obstruents should be analyzed (i) as underlyingly voiced with nasalization enhancing voicing or (ii) as allophones of nasal consonants (i.e., as orally released nasals) (Marlett 1992; Iverson & Salmons 1996; DiCanio et al. 2020). Arguments for the latter approach involve the timing of nasality and distribution of prenasalized consonants (Martlett, 1992; DiCanio et al. 2020). For example, in Yoloxóchitl Mixtec, prenasalized stops are restricted to words with oral vowels and alternate with nasals; when an oral vowel is affixed to a root with a nasal consonant (e.g., /n/ or /m/), the oral counterparts surface (e.g., [^{n}d], [^{m}b]) (DiCanio et al. 2020). In SJPM, prenasalized consonants are restricted in their distribution to roots and enclitics with oral vowels. However, there is no evidence that they alternate with nasals (i.e., /n/ or /ɲ/). Moreover, there is no prenasalized bilabial stop counterpart to /m/. For the purpose of this illustration, we use the commonly adopted system of transcription of prenasalization (/^{n}d/, /ᵑg/ and /^{n}d͡ʒ/).

To investigate voice onset time (VOT), 20 tokens each of [t, k, kʷ], 39 tokens of [^{n}d] and 36 tokens of [^{n}d͡ʒ] were analyzed in couplet-initial position. Words used for quantification of VOT of voiceless plosives were gathered from a larger corpus of data collected during the

[2] Some Mixtec languages have prenasalized stops at the bilabial and velar place of articulation (e.g., Yoloxóchitl Mixtec (DiCanio et al. 2020)). Prenasalized coronal stops are widespread across the language group (Josserand 1983).

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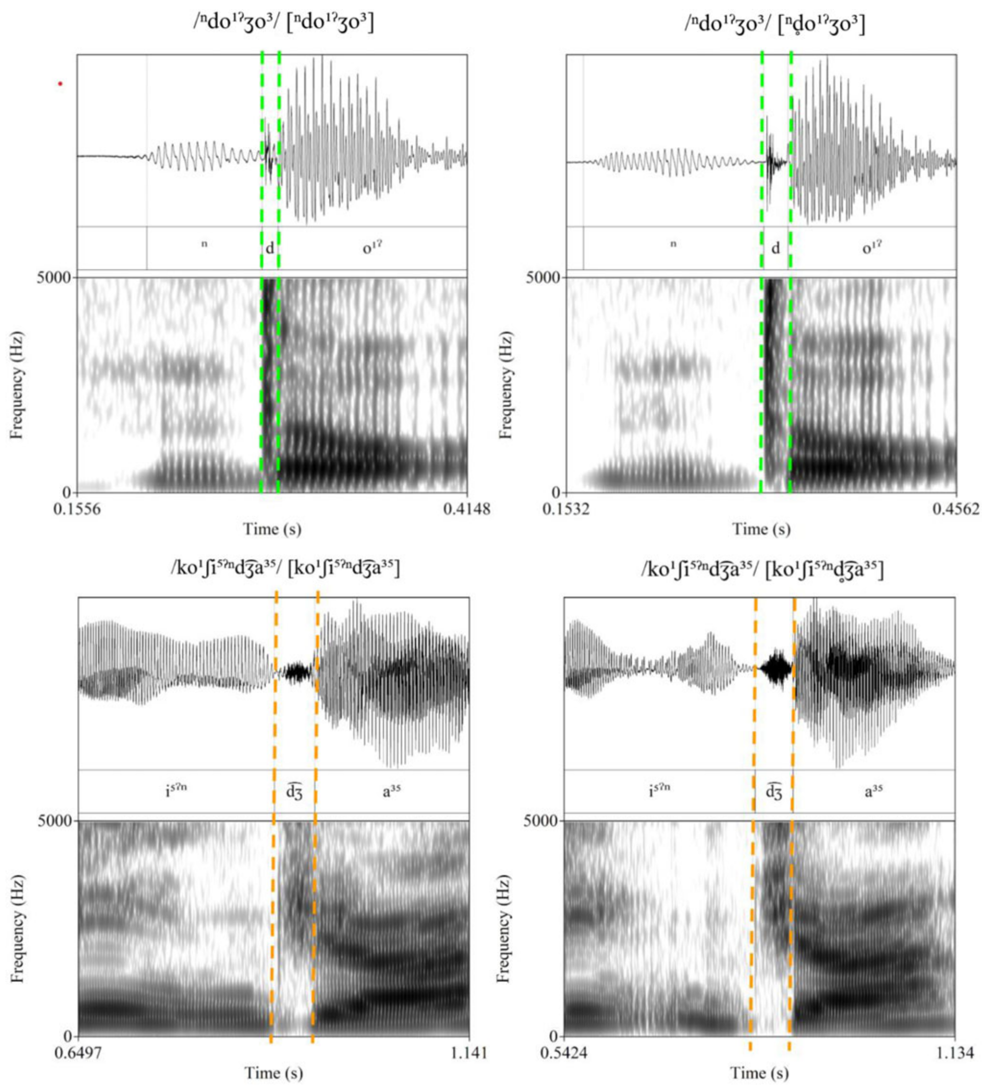

Figure 2. (Colour online) Waveforms and spectrograms illustrating variable voicing during release of /^{n}d/ and /^{n}d͡ʒ/. Top row shows the initial syllable, /^{n}do^{1ʔ}/ of /^{n}do^{1ʔ}ʒo^{3}/ 'spring', produced as [^{n}d] on the left and [^{n}d̥] on the right. Stop burst and VOT are segmented in green. Bottom row illustrates the sequence /i^{5ʔn}d͡ʒa^{35}/ in /ko^{1}ʃi^{5ʔ}ndʒa^{35}/ 'not stingy,' with /^{n}d͡ʒ/ produced as [^{n}d͡ʒ] on left and [^{n}d̥͡ʒ] on the right. Stop release and fricative portion of /^{n}d͡ʒ/ is segmented in orange.

elicitation period with the third author. Prenasalized segments were recorded in a sound-attenuated booth, as described in the introduction; these consist of 13 unique words for [^{n}d] and 12 for [^{n}dʒ], each repeated three times.

All tokens were spoken in isolation or with a noun classifier preceding (see supplemental materials for full word list). Plosives in medial position were not included as /k^{w}/ occurs infrequently in medial position. All voiceless plosives were more frequently followed by /i/ and /a/ as these vowels are very frequent in SJPM. Tokens used to calculate VOT for /k^{w}/ were never followed by /o/. Prenasalized plosives showed a different pattern: [d͡ʒ] was most frequently followed by [a], and never by [i], while [^{n}d] was most frequently followed by [i]

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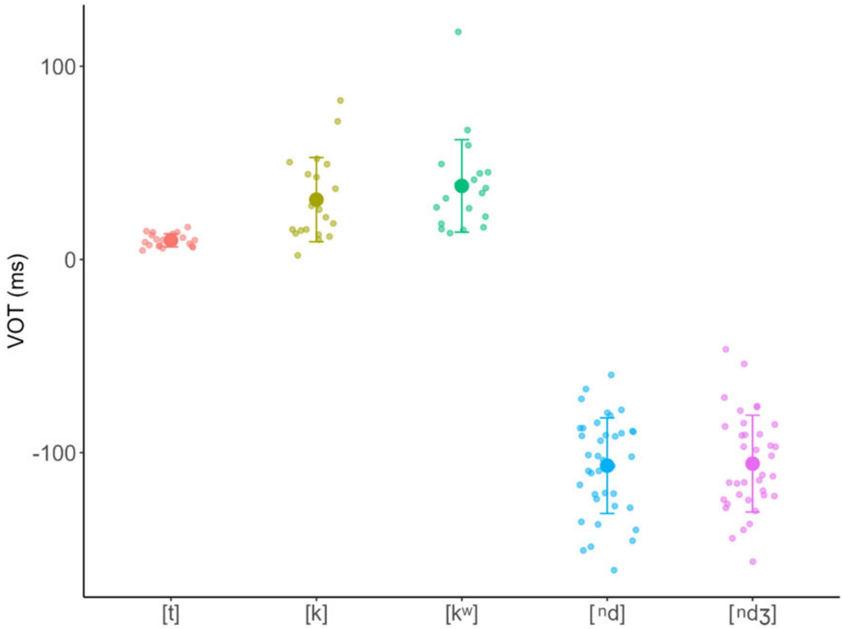

Figure 3. (Colour online) Positive and Negative VOT of voiceless stops [t, k, kʷ] and pre-nasalized consonants [ⁿd, ⁿd͡ʒ] in couplet-initial position. Large circles represent the mean VOT (in ms) for each stop and error bars represent one standard deviation. Values for individual tokens are represented by smaller circles.

and [o]. For voiceless plosives, VOT was annotated from the release of the stop burst to the onset of voicing in Praat (Boersma & Weenik 2020). Negative VOT was annotated from the onset of voicing (first positive peak in the waveform) to immediately before but not including the release burst. Mean VOT was found to be longest following [kʷ] with a duration of 38.06 ms (SD = 23.94 ms). The mean VOT for [k] and [t] were 30.98 ms (SD = 21.81 ms) and 9.91 ms (SD = 3.5 ms), respectively. Findings are illustrated in Figure 3. Negative VOT between [ⁿd] and [ⁿd͡ʒ] did not differ substantially with a mean of –106.7 ms (SD = 24.8 ms) and –105.7 ms (SD = 25.0 ms), respectively.

To analyze voicing during the closure of prenasalized stops, strength of excitation (SoE) was calculated in VoiceSauce (Shue et al., 2011). SoE is a measure of the strength of voicing at the point of glottic closure. Lower SoE values indicate weaker voicing (Murty & Yegnanarayana, 2008; Murty et al., 2009). SoE was found to rise at the onset of voicing, with a peak in SoE approximately halfway through prenasalization, followed by a drop in SoE, particularly during the last 25% of closure (Figure 4). While both consonants show a similar trajectory, it appears that voicing for [ⁿd͡ʒ] begins to weaken earlier than [ⁿd]. Additionally, just before stop release, SoE is markedly lower for [ⁿd͡ʒ] compared to [ⁿd]. That is, [ⁿd͡ʒ] appears more likely to be released as voiceless compared to [ⁿd] given its substantially weaker voicing as it reaches the stop release.

Voiceless plosives are optionally preaspirated when they occur in couplet-medial position (e.g., CV<u>C</u>V) and unaspirated elsewhere, a phenomenon also documented in other Mixtec varieties (e.g., Ayutla Mixtec (Pankratz & Pike 1967)).[3] This variation is

[3] In addition to Ayutla Mixtec, another Mixtec variety documented to have consonantal preaspiration in couplet-medial position is Acatlán Mixtec (Pike & Wistrand 1974). In Yoloxóchitl Mixtec, on the other hand, there is lengthening of couplet-medial consonants (DiCanio et al. 2020).

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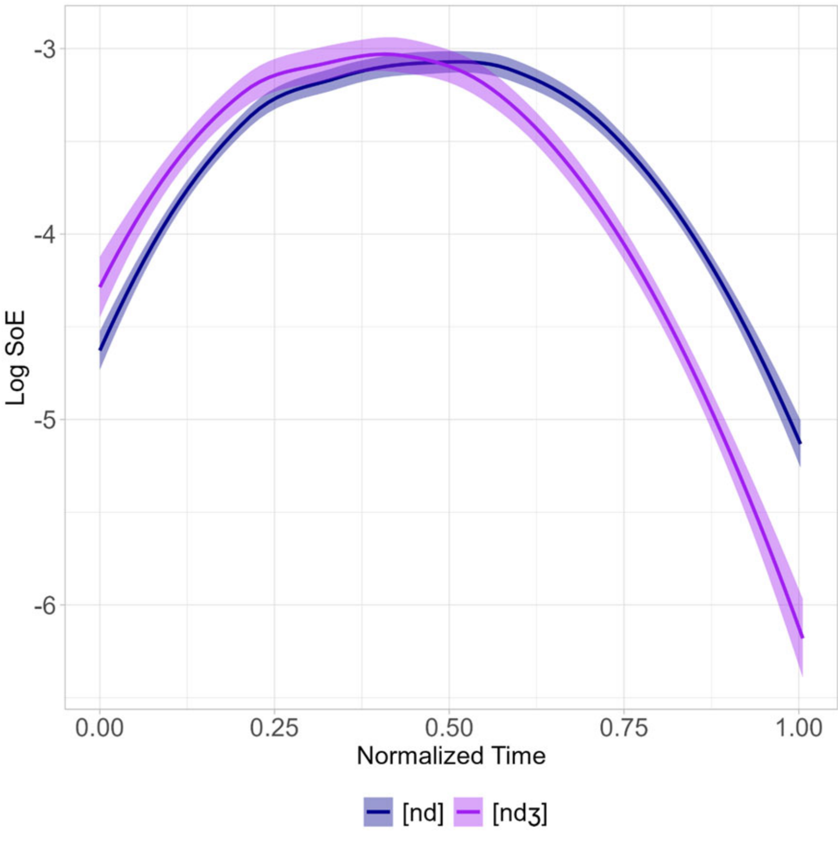

Figure 4. (Colour online) Log SoE over the duration of prenasalization for [ⁿd] (dark blue) and [ⁿd͡ʒ] (purple). Lighter colors (ribbons) represent 95% confidence intervals.

demonstrated in Figure 5. Figure 5 (left) demonstrates preaspiration of the couplet-medial consonant in [ka³ʰka³] 'to walk.' However, in Figure 5 (right) there is no preaspiration of /k/ in [ⁿda³-ko³o³] /ⁿda³-ko³o³/ 'to leave' since [k] is in couplet-initial position (e.g., CV-C̲VV, with CVV being the monosyllabic couplet). The voiceless postalveolar affricate /t͡ʃ/ also surfaces as [ʰt͡ʃ] in couplet-medial position.

Preaspiration was calculated from 20 couplet-medial tokens each of [ʰt, ʰk] and 17 of [ʰt͡ʃ]. Preaspiration was segmented following the vowel of the first mora from the onset of broadband noise in the spectrogram to the end of clear broadband aspiration noise. The right boundary also corresponded to the beginning of a period of silence, consistent with closure for the stop. Bilabial /p/ was excluded from the analysis of preaspiration as it does not occur frequently, and therefore, too few tokens were available for analysis. Likewise, /kʷ/ was excluded as it does not occur frequently in couplet-medial position. Similar to VOT measures, preaspiration was found to be longest preceding [ʰk], with an average duration of 79.99 ms (SD = 22.35 ms), followed by [ʰt] and [ʰt͡ʃ], which had similar preaspiration durations of 60.1 ms (SD = 24.17 ms) and 61.1 ms (SD = 16.51 ms), respectively. Results are illustrated in Figure 6.

In addition to optional preaspiration, velar stops /k/ and /kʷ/ also demonstrate lenition intervocalically, particularly during fast speech. As a result, they may surface as voiced

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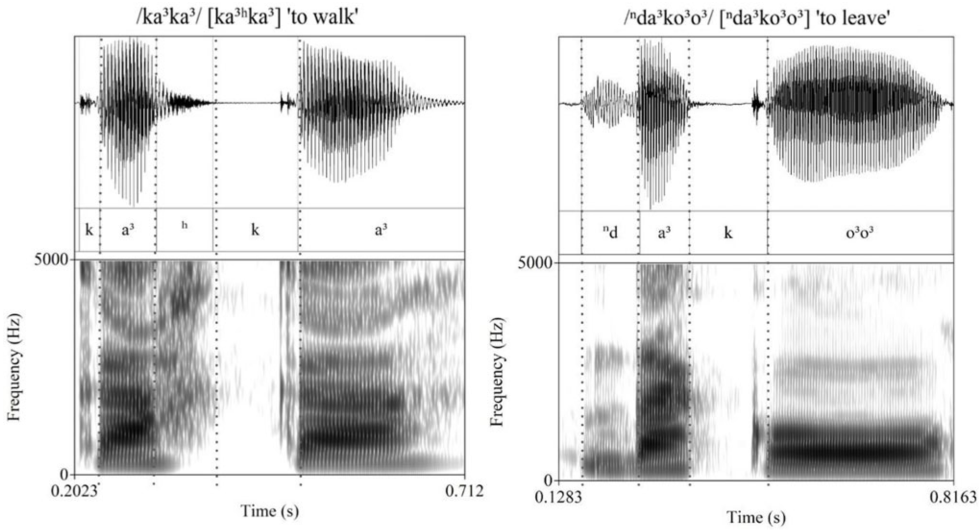

Figure 5. Left shows waveform and spectrogram of [ka^{3h}ka^{3}] 'to walk.' Aspiration on couplet-medial [^{h}k] is indicated with superscript h. Right shows spectrogram and waveform of [^{n}da^{3}ko^{3}o^{3}] 'to leave.' [k] is not preaspirated as it is in couplet-initial position, although it is word-medial. Light noise at the [k] closure onset is not audibly preaspiration but instead is attributed to echo.

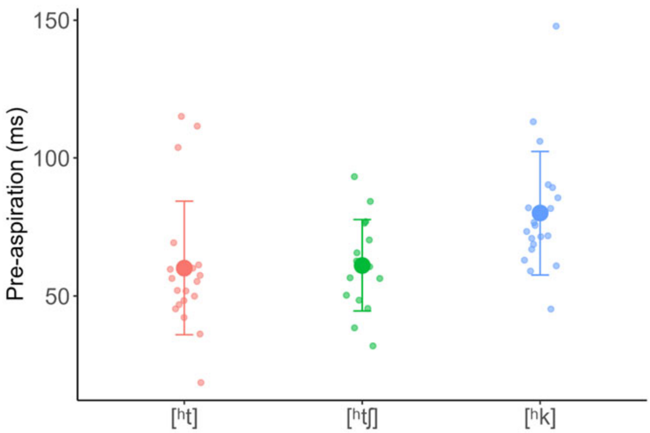

Figure 6. (Colour online) Preaspiration measures of voiceless stops and affricate [^{h}t, ^{h}t͡ʃ, ^{h}k]. Large circles represent the mean duration of preaspiration for each stop, and error bars represent one standard deviation. Values for individual tokens are represented by smaller circles.

velar stops [ɡ] and [ɡʷ] or voiced velar fricatives [ɣ] and [ɣʷ] as in examples (1)[4] and (2) below. Other Mixtec varieties have patterns of variable lenition of voiceless velar stops, including Acatlán Mixtec (Pike & Wistrand 1974), Silacayoapan Mixtec (North & Shields 1977), San Miguel el Grande Mixtec (Pike 1944), and Yoloxóchitl Mixtec (DiCanio et al. 2020),

[4] Each glossed example provides, from top to bottom: (i) an orthographic representation; (ii) a phonetic transcription in IPA; (iii) a phonemicized transcription (also in IPA) with morpheme breaks; (iv) glosses; and (v) English and Spanish free translations.

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among others. For more recent work examining prosodic factors and quantifying lenition, see DiCanio et al. 2022.

(1) kòó vìxìn rá rùkwīí.
[ko^{15} vi^{1}ʃĩ^{1} ɾa^{5} ɾu^{1}**g**^{w}i^{14}]
/ko^{15} vi^{1}ʃĩ^{1} ɾa^{5} ɾu^{1}k^{w}i^{15}/
NEG lukewarm CL.3SG.LIQ water
'The water is not lukewarm.' ('*El agua no está tibia.*')

(2) kwààkù kà ñá.
[k^{w}a^{15}ku^{1} **ɣ**a^{1}ɲa^{4}]
/k^{w}a^{15}ku^{1}=ka^{1}=ɲa^{5}/
NEG.IRR.laugh=again=3SG.F
'She will not laugh again.' ('*Ella no va a reír otra vez.*')

Nasals

Nasals /m, n, ɲ/ may occur in word-medial and word-initial positions; however, /m/ commonly occurs word-initially, while /ɲ/ more frequently occurs word-medially.

Tap

The alveolar tap, /ɾ/, has a very restricted distribution in SJPM as in other varieties of Mixtec (e.g., Ixpantepec Nieves Mixtec (Carroll 2015), Yoloxóchitl Mixtec (DiCanio et al. 2020)). It occurs primarily in function words, including noun classifiers (for the 3rd person singular masculine classifier /ɾa/, the liquid noun classifier /ɾa^{5}/, and the conjunction /ɾa^{3}/). The alveolar tap has an allophone, the alveolar trill [r], which occurs in word-initial position. This allophonic variation is illustrated in example (3), which shows the realization of the third person singular masculine noun class marker /ɾa/: the alveolar tap allophone [ɾ] surfaces in post-vocalic position (e.g., in contexts where the /ɾa/ morpheme is a pronominal enclitic) (3a), while the alveolar trill allophone surfaces word-initially (e.g., when the /ɾa/ morpheme is realized as a classifier preceding a noun in a noun phrase) (3b).[5]

(3) a. lēsō rā
[le^{3}so^{3} **ɾ**a^{3}]
/le^{3}so^{3}=**ɾ**a^{3}/
rabbit=CL.3SG.M
'his rabbit' ('*su conejo (de él)*')

b. rà chàā
[**r**a^{1} t͡ʃa^{1}a^{3}]
/**ɾ**a^{1} t͡ʃa^{1}a^{3}/
CL.3SG.M man
'the man' ('*el hombre*')

[5] This morpheme has variable tone realization (L or M) depending on the tonal context when used as an enclitic, but surfaces consistently with a L tone as a classifier (Caballero, Juárez Chávez & Yuan 2024; Duarte Borquez 2022; Duarte Borquez & Juárez Chávez 2022).

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Fricatives

Fricatives are also commonly attested in SJPM. Fricatives contrast at the labio-dental, alveolar, and postalveolar places of articulation. Although /f/ and /h/ are listed in the consonant chart, their distribution is very limited. To date, /f/ has only been found to occur in one loanword, /ka^{5}fe^5/ 'coffee, brown'. Likewise, /h/ has only been found in the SJPM word for *yes* /hã^{3}ã^1/. Despite being rarely attested in the language, they are included in this illustration in the consonant inventory to account for all consonants that occur in SJPM.

To illustrate fricative characteristics, mean power spectral slices were calculated from 20 tokens each of [v, s, ʃ, ʒ]. The two infrequent fricatives, /f/ and /h/, were excluded as there were not enough tokens. Mean spectral slices are illustrated in Figure 7. Fricatives were annotated from beginning to end of clear frication noise, and power spectra were calculated in Praat (Boersma & Weenik 2020). The sibilant fricatives ([s, ʃ, ʒ]) demonstrate peak spectral energy patterns that we would expect based on place of articulation. For [s], the peak occurs around 7.5 kHz, higher than both [ʃ] and [ʒ], which demonstrate greater energy at approximately 5 kHz (though this value may be slightly higher for [ʒ] based on visualization). This is consistent with a more anterior place of articulation for [s] compared to [ʃ] and [ʒ]. Spectral energy for [v] is overall low relative to other fricatives, which is expected given that it is a non-sibilant fricative. Other than the low frequency energy, no clear peak is seen; instead, the spectrum is relatively flat as expected for labial consonants. Both [v] and [ʒ] demonstrate relatively high amplitude in lower frequency energy, likely due to voicing.

The voiced fricative, /ʒ/, undergoes lenition during fast speech, often in the word-medial position. This appears to be gradient, where the consonant can be produced as the fricatives [ʒ] or [ʝ] or approximant [j] (4a and 4b).

(4) (a) kīnì yù

[ki^{3}ni^1**ʒ**u^1] ~ [ki^{3}ni^1**ʝ**u^1]

/ki^{3}ni^1=ʒu^1/

pig=1SG

'my pig' ('*mi puerco*')

(b) sīyō

[si^3**j**o^3]

/si^{3}ʒo^3/

'mold' *('moho')*

Additionally, voiced fricatives /v/ and /ʒ/ are produced with considerable pre-voicing, which is demonstrated in Figure (8) using strength of excitation (SoE; Murty & Yegnanarayana 2008) as a measure of voicing. Higher SoE indicates greater strength of voicing. SoE was measured in VoiceSauce (Shue et al., 2011) over the duration of the fricative, from the onset of voicing to the onset of clear vowel formants. SoE was measured from 20 tokens of [ʒ] and [v] in the word-initial position. An additional 20 tokens of [l] were analyzed for comparison to an approximant, which is known to be heavily voiced. Results indicate that [ʒ] has rising SoE at the onset, followed by a dip in SoE during the middle 50% of production, and finally, a rise in SoE as the speaker transitions to the vowel. This suggests strong voicing at the onset, followed by weaker voicing during the middle portion of the consonant, a pattern consistent with pre-voicing.

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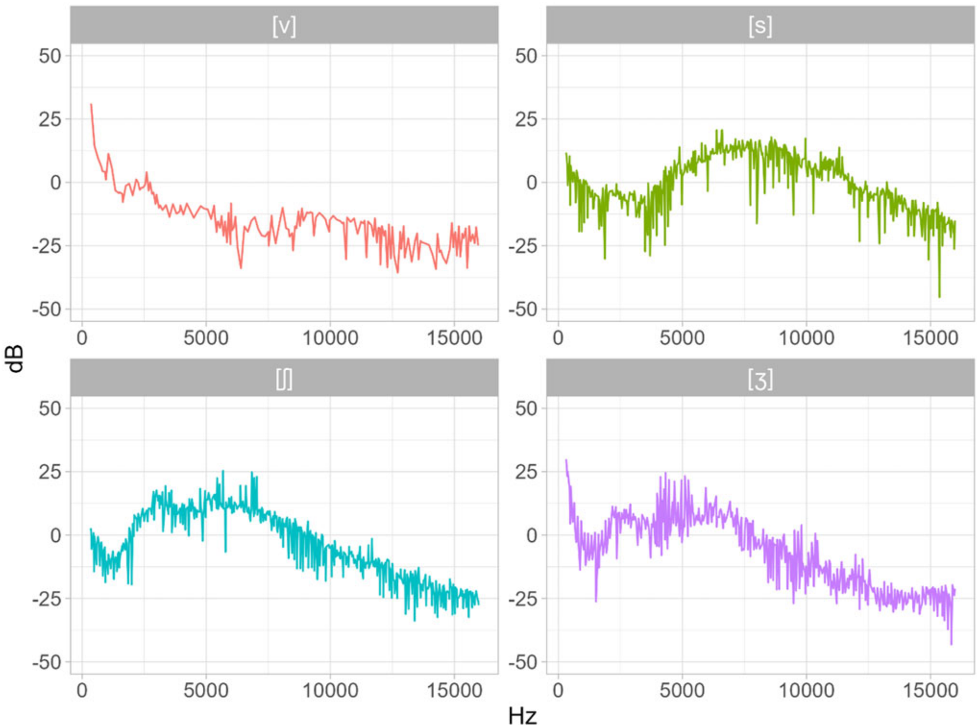

Figure 7. (Colour online) Mean spectral slices of [v, s, ʃ, ʒ] averaged from 20 tokens each.

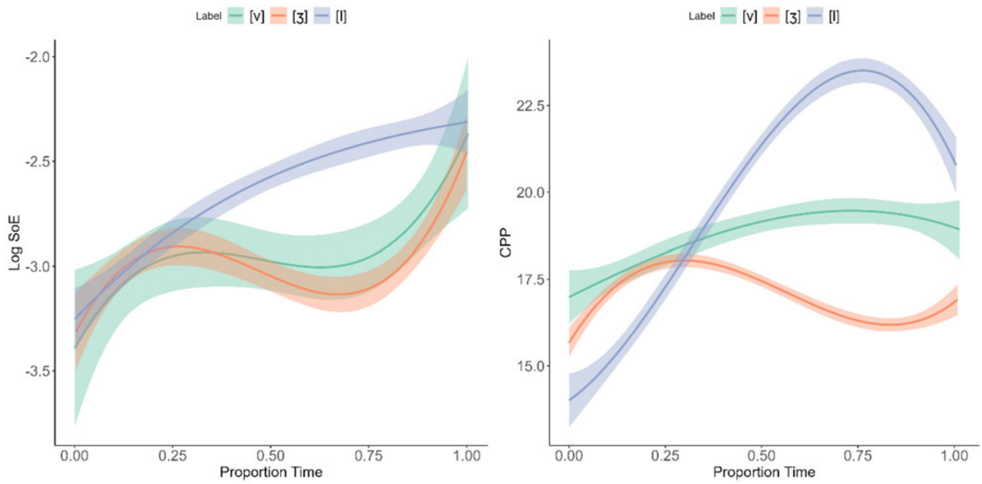

Figure 8. (Colour online) (Left) Log SoE over proportion time for [v, ʒ, l], consonants represented in color. (Right) Cepstral peak prominence over proportion time for [v, ʒ, l], consonants represented in color. Lighter colors (ribbons) represent 95% confidence intervals.

Cepstral peak prominence (CPP) was also calculated to quantify frication noise. An increase in frication noise would be expected to increase the noise floor (regression line) in the cepstrum and, therefore, reduce the prominence of the cepstral peak relative to the regression line, resulting in overall lower CPP. Thus, a *decrease* in CPP indicates *more* noise in

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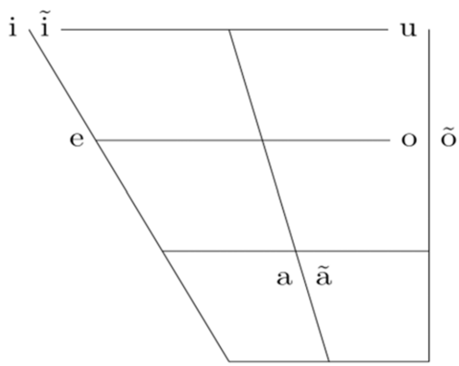
the signal (greater frication noise). Rising CPP was seen at the onset of [ʒ]; CPP peaks during the first half of [ʒ], followed by a drop in CPP that coincides with the drop in SoE. This suggests that frication noise is minimal during the pre-voicing of [ʒ] and increases during the final 50% of the consonant as strength of voicing decreases. Like SoE, this pattern is consistent with pre-voicing.

A different pattern was seen for [v]. Although [v] does show a decrease in SoE during the final 50% of the consonant compared to the first half, it maintains an overall greater strength of voicing than [ʒ]. Additionally, [v] demonstrates a steady rise in CPP over the course of the consonant, rather than a drop, indicating little frication noise throughout the duration of the consonant. Although [v] is produced with little frication noise, it falls short of SoE and CPP values similar to an approximant (i.e., [l], shown for comparison). Given that [v] is a non-sibilant fricative, the CPP results are in line with expectations of relatively quiet frication noise during production.

Vowels



SJPM has five oral vowels (/i, e, a, o, u/) and three phonemically nasal vowels (/ĩ, ã, õ/).[6] Phonemically nasal vowels can occur in the second syllable of a disyllabic word (the final syllable of the couplet) or on both vowels of CVˀV and CVV words, consistent with what has been documented for other varieties of Mixtec (Gerfen, 1999). In other words, phonemically nasal vowels in SJPM do not occur in the first syllable of disyllabic (CVCV) couplets.

Phoneme	Transcription	SJPM	English Gloss	Spanish Gloss
i	/si⁵ˀi⁵/	sí’í	‘woman’	‘mujer’
e	/se¹ˀe³/	sè’ē	‘offspring’	‘hijos’
a	/sa⁵ˀa³/	sá’ā	‘to make/to do’	‘hacer’
o	/so¹ˀo³/	sò’ō	‘ear’	‘oreja’
u	/su¹tu¹/	sùtù	‘priest’	‘sacerdote’

[6] For typographical ease, /e/ is used throughout the manuscript to represent the mid front unrounded vowel, though it is often perceived as [ɛ]. Likewise, /a/ is used in place of /ɐ/ for the mid-open central vowel.

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Phoneme	Transcription	SJPM	English Gloss	Spanish Gloss
i	/vi¹ʃi¹/	vìxì	'sweet'	'dulce'
ĩ	/vi¹ʃĩ³/	vìxīn	'cold'	'frío'
a	/tu¹kʷa¹a⁵/	tùkwàá	'orange'	'naranja'
ã	/kʷã⁵ã⁵/	kwáán	'yellow'	'amarillo'
o	/so³ko¹/	sōkò	'shoulder'	'hombro'
õ	/so¹kõ⁵/	sòkón	'neck'	'cuello'

Roots of open class words in SJPM are canonically bimoraic. These bimoraic roots show a surface contrast between short vowels in disyllabic ((C)VCV) roots and long vowels in monosyllabic ((C)VV) roots, as attested across Mixtec languages (Di Canio & Bennett 2021) (see Phonotactics, below). Long vowels also surface in bisyllabic ((C)VCVV) roots. In these root forms, long vowels are restricted to occur in the final syllable of the word, e.g., /tu¹kʷa¹a⁵/ 'orange.' Monomoraic roots containing a single vowel (i.e., CV forms) do not form minimal pairs with any bimoraic ((C)V(ˀ)V) forms, and typically correspond to functional morphemes and closed-class words.

Acoustic analysis to measure formant values of oral vowels was conducted. Nasal vowels were excluded due to nasality interfering with formant tracking. Oral vowel formants were measured from the final syllable of 167 bimoraic tokens, consisting of 44 [i] vowels, 27 [e], 47 [a], 27 [o] and 22 [u]. The number of vowels per vowel category was not balanced as they were pulled from the database; therefore, they represent the relative frequency in SJPM, demonstrating that /i/ and /a/ occur relatively frequently compared to /e/, /o/, and /u/. With the exception of /i/, vowels were typically preceded by alveolar, postalveolar, or velar consonants; /i/ was also frequently preceded by /v/. Vowels

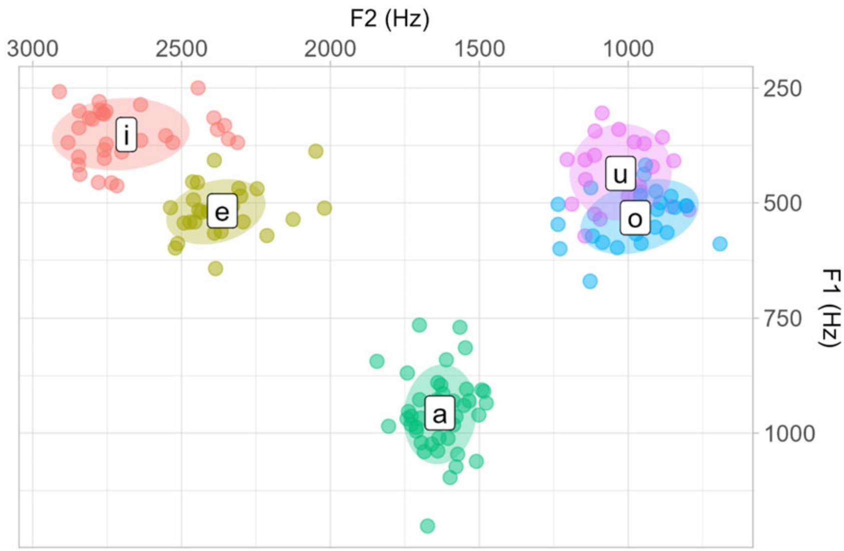

Figure 9. (Colour online) Plot of F1 and F2 values (Hz) of oral vowels with 1 standard deviation ellipses. Vowel labels are centered on the mean F1 and F2 values, and points represent individual tokens. Vowels are represented by color.

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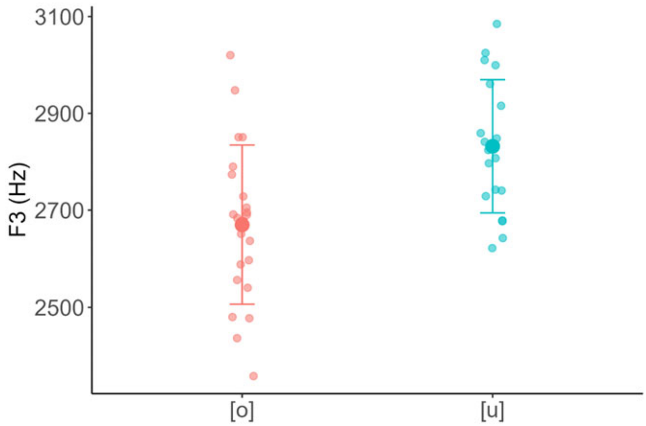

Figure 10. (Colour online) F3 values (Hz) of [o] and [u]. Large circles represent mean F3 for each vowel, and error bars represent one standard deviation. Values for individual tokens are represented by smaller circles.

were manually segmented in Praat (Boersma & Weenink 2020) from beginning to end of clear formants. Mean F1 and F2 were calculated in VoiceSauce (Shue e al. 2011) using the Snack algorithm (Sjölander 2004). Formant values from the middle one-third of the vowel were used to calculate mean F1 and F2 to reduce the effect of formant transitions in varying phonetic environments. Vowels with F1 and F2 values greater than 2 standard deviations away from the mean were excluded, as these were taken to be outliers. In addition, 8 tokens for /i/ were excluded as they were found to have mistracked F2 values (i.e., below 1000 Hz). Figure 9 demonstrates the acoustic vowel space. There is notably wide intra-speaker variation in vowel production and considerable overlap in F1 and F2 of [o] and [u]. The overlap in the back vowels may be due to less rounding on [u], which would result in overall higher formants compared to a more rounded [u]. To further investigate acoustic differences of [o] and [u], we compared F3 values of the two vowels (Figure 10). F3 was found to be lower for [o] (mean = 2670.51, sd = 163.93) compared to [u] (mean = 2831.91, sd = 137.68), suggesting less rounding for [u] compared to [o].

In addition to phonemically nasal vowels, the first person singular enclitic /=e¹/ surfaces as allophonically nasalized [ẽ¹] when the root-final vowel is nasal (5–6). Additional conditions for allophonically nasal vowels are described below.

(5) kō’ō — kō’ēè
[ko³ˀo³] — [ko³ˀe³¹]
/ko³ˀo³/ — /ko³ˀo³=e¹/
drink — drink=1SG
‘to drink’ (‘*beber*’) — ‘I will drink.’ *(Voy a tomar.’)*

(6) kò’òn — kò’èn
[kõ¹ˀõ¹] — [kõ¹ˀẽ¹]/
/kõ¹ˀõ¹/ — kõ¹ˀõ¹=e¹/
go — go=1SG
‘to go’ (‘*ir*’) — ‘I will go.’ (‘*Voy a ir.*’)

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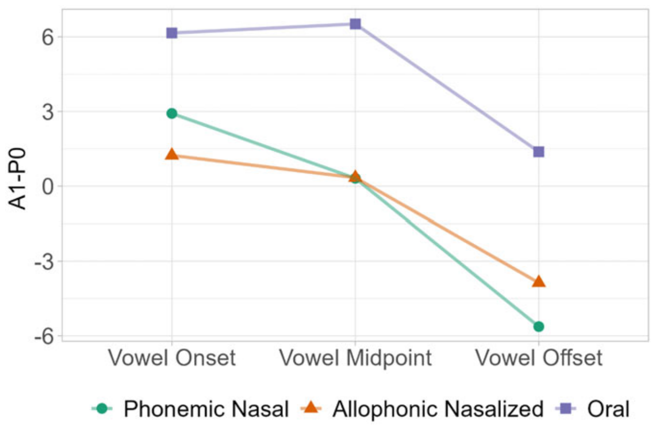

Figure 11. (Colour online) Mean A1-P0 (dB) values for phonemic nasal (green circles), allophonic nasalized (orange triangles), and oral vowels (purple squares) at the vowel onset, vowel midpoint, and vowel offset. Vowel onset corresponds approximately to the 3% time point of the total vowel duration, vowel midpoint corresponds to the 50% time point, and vowel offset corresponds approximately to 97% timepoint.

Phonemically nasal vowels in SJPM are restricted to the root-final position. In CVCV roots, phonemically nasal vowels can only occur if the second consonant is voiceless, and in (C) Vˀ V or (C) VV roots, both vowels must be nasal if the final vowel is nasal. However, in oral (C) Vˀ V or (C) VV forms that are inflected with a nasal enclitic, it is unclear if nasality spreads to the root. A thorough investigation of the distribution of nasality in SJPM remains to be undertaken.

SJPM also has evidence of allophonic nasality, similar to other documented varieties of Mixtec (Gerfen 1999). Vowels demonstrate perseverative nasality when following nasal consonants. To demonstrate this, the difference between the amplitude of the first formant and the first nasal pole (A1-P0) was calculated automatically in Praat for vowels in CVCV words where the second vowel was phonemically oral (CVCV), nasal (CVCṼ), or followed a nasal consonant (CVNV) (Styler & Scarborough 2017). A lower value of A1-P0 indicates *increased* nasality (Styler 2017). Vowels in this analysis were taken from words produced in isolation found in the database. Vowels were excluded from analysis if they were flagged as likely errors by the script. Oral vowels were the same as those used to calculate vowel formants in Figure 9. In total, 15 allophonic nasal vowels, 24 phonemic nasal, and 96 oral vowels were included in the final analysis. These results are shown in Figure 11.

Phonemic nasal and allophonic nasalized vowels demonstrated lower A1-P0 values (mean of 0.31 dB and 0.34 dB, respectively) compared to oral vowels, suggesting vowels following nasal consonants are similar in degree of nasality to phonemically nasal vowels. Additionally, the trajectory of both types of nasal vowels is similar: both decrease in A1-P0 from the vowel onset to the midpoint. Oral vowels had relatively high A1-P0 (mean = 6.63 dB), as expected. All vowels (phonemic nasal, allophonic nasal, and oral) demonstrate reduced A1-P0 at vowel offset compared to onset. This is believed to be due to the speaker's use of breathy voicing at the end of each token. Since words were spoken in isolation, it's unclear if this is phrase-final breath (e.g., similar to that used in Spanish, Duarte Borquez et al. 2024) or if the speaker's use of breathy voice is related to some other phenomenon. Nevertheless, breathy voice results in lower amplitude of A1, thus lowering the overall value of A1-P0. Therefore, we do not take the lower A1-P0 at the end of oral vowels to indicate that oral vowels are becoming more nasal.

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Glottalization

SJPM has contrastive glottalization, as shown in (7). Surface glottalization patterns are similar to those documented in other varieties of Mixtec, which have been variously analyzed phonologically as a glottal stop phoneme (Pike 1948; Hunter & Pike 1969; Pike & Cowan 1967; Pankratz & Pike 1967), vowel glottalization (Josserand 1983; Gerfen 1999), or a prosodic property of root morphemes (Marlett 1992; Macaulay & Salmons 1995).

(7)	a. nìí	/ni^{1}i^{5}/	'blood' *('sangre')*
	b. nì'í	/ni^{1ʔ}i^{5}/	'hard' *('duro')*
	c. ùvì	/u^{1}vi^{1}/	'two' *('dos')*
	d. ù'vì	/u^{1ʔ}vi^{1}/	'painful' *('doloroso')*

Only root couplets may exhibit glottalization, while function morphemes (affixes, clitics, particles), which are monomoraic, are never glottalized. Furthermore, glottalization in roots is restricted to occur in couplet-medial position. In preconsonantal position, glottalization is exclusively attested in root morphemes that have a voiced medial consonant, a pattern also attested in other varieties of Mixtec (e.g., Ixpantepec Nieves Mixtec (Carroll 2015)). In this illustration, we adopt Macaulay & Salmons' (1995) and Gerfen's (1999) analysis that glottalization occurs as a feature of root templates rather than a consonantal segment, and we assume this glottalization feature is associated with the couplet-initial vowel. This analysis is motivated by the restricted distribution of glottalization in the language: if glottalization were to be analyzed as a consonantal segment, it would be the only possible coda and the only segment yielding consonant clusters. Additionally, in monomorphemic monosyllabic root couplets with glottalization, both vowels must have the same vowel quality and nasality,[7] as also attested in other documented Mixtec language varieties (e.g., San Sebastián del Monte Mixtec (Cortés et al. 2023); see also Gerfen (1999)). However, when inflected, the second vowel of the couplet may change.[8] This is unlike (C)VCV couplets, which may have different vowels in each mora in the uninflected forms.

Phonetically, glottalization may be implemented as a full glottal stop with no voicing and a period of silence ('tenate' in Figure 12), creakiness over a portion of the couplet-initial vowel ('to check by touch' in Figure 12), or "light" glottalization with full voicing and a drop of F0 and intensity during the period of glottalization ('lion' in Figure 12). Regardless of strength of voicing, pitch and intensity decrease during glottalization (Figure 12). This variation is consistent with the variation in the voicing of glottals cross-linguistically as well as in other Mixtec varieties (e.g., Coatzospan Mixtec (Gerfen & Baker 2005), San Sebastián del Monte Mixtec (Cortés et al. 2023); see also Garellek et al. 2023)). To our current knowledge, this variation is not predictable. Regardless of the phonetic implementation of the glottalization, it is produced in phase with the first mora, discussed further below.

In our analysis, we assume that gestures for vowel articulation and glottalization are overlapping rather than sequential, with glottalization generally phased with the second half of the first mora. To illustrate the phasing of glottalization, we calculated strength of excitation (SoE) in V^{ʔ}C and V^{ʔ}V contexts. SoE was calculated over the entire vowel in 35 words in V^{ʔ}C context and over both vowels in 45 words in V^{ʔ}V context.

[7] There are only three exceptions to this generalization in the developing SJPM corpus, namely the monomorphemic stems *ki^{1ʔ}a^{5}* 'chili plant,' *ri^{1ʔ}a^{5}* 'salsa' (i.e., in /ka^{1}ʃi^{1} ri^{1ʔ}a^{5}/, 'to grind the salsa'), and *ʃã^{5ʔ}õ^{1}* 'fifteen'.

[8] Specifically, vocalic enclitics may replace or fuse with the final root vowel.

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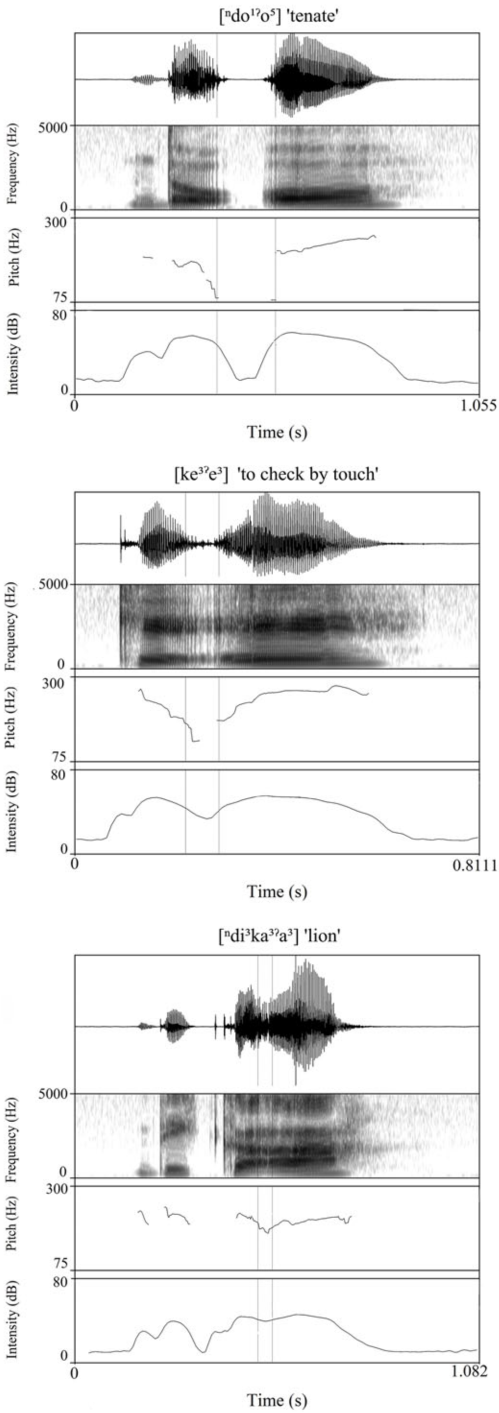

Figure 12. Waveforms, spectrograms, pitch tracks, and intensity tracks illustrating variation of glottalization. Glottalized portion is indicated by vertical boundaries.

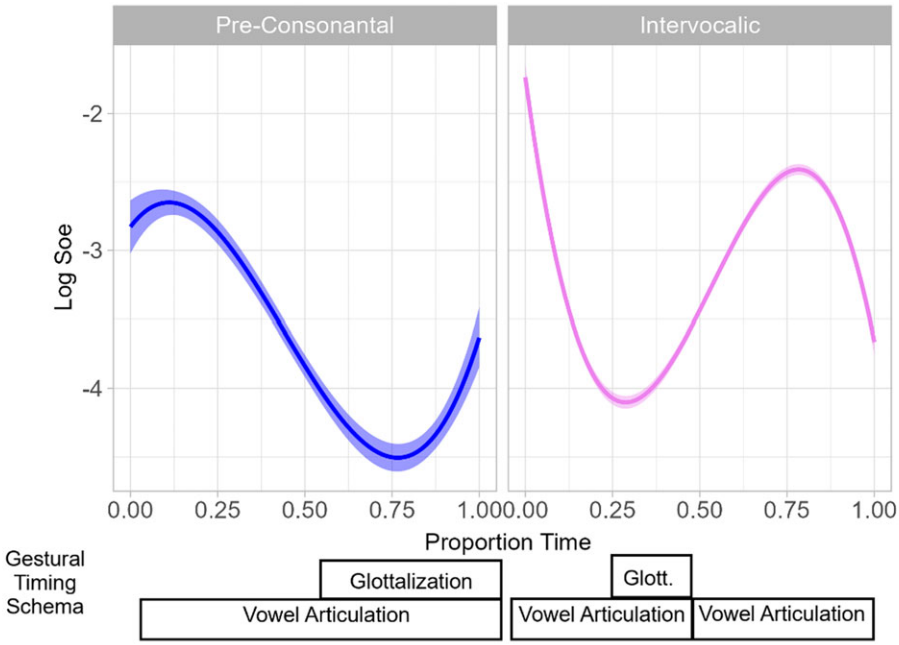

Figure 13. (Colour online) Log SoE in pre-consonantal, Vˀ C (left), and intervocalic, VˀV (right), sequences. Gestural timing schema below the x-axis indicates ideal gestural timing between vowel articulation and glottalization. Lighter colors (ribbons) represent 95% confidence intervals.

For VˀC words (Figure 13, left), SoE is strongest at the onset of the vowel and lowest during the second half of the vowel, indicating that glottalization is strongest during the second half of the vowel. There is a slight rise at the end of the vowel immediately before the onset of the consonant. There are two possible reasons for this. First, as in many languages, the phasing of glottalization may be variable (Borroff 2007). Although we generally see glottalization phased with the second half of the vowel, it's likely the case that the speaker's phonetic implementation of glottalization is variable. Second, the strength of glottalization weakens toward the end of the gesture, and in the VˀC context, it always occurs where C is a voiced consonant. As a result of this, if glottalization weakens before the onset of the consonant, SoE will increase, and an increase in voicing will be perceived. Additionally, due to both of these factors, listeners may perceive what appears to be a copy vowel but is, in fact, a continuation of the vowel gesture (as in [u¹ˀvi¹] "painful"). When the glottalization gesture extends beyond the vowel into the following consonant, no intrusive vowel is perceived.

In VˀV words, SoE is strongest at the onset of the first mora and drops precipitously during the first quarter of the VˀV sequence followed by an increase in voicing strength during the second half, indicating the glottalization is associated with the first mora. These results are illustrated in Figure 13. A gestural timing schema is included in Figure 13 to illustrate the idealized phasing of vowel articulation and glottalization; though, as previously discussed, phonetic implementation and phasing of glottalization may be variable.

Tone

SJPM has a complex system of lexical tone, with three level tones, H (V⁵), M (V³), and L (V¹). Following Caballero, Duarte Borquez, Juárez Chávez & Yuan (to appear), we analyze these three level tones to be tone feature primitives of SJPM.

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Tone	Transcription	SJPM	English Gloss	Spanish Gloss
High (H)	/ĩ^{5}ĩ^5/	íín	'hail'	'granizo'
Mid (M)	/ĩ^{3}ĩ^3/	īīn	'one'	'uno'
Low (L)	/ĩ^{1}ĩ^1/	ììn	'nine'	'nueve'

To illustrate f0 trajectories of level tones, f0 was calculated over the entire duration of couplet-final vowels in VoiceSauce using the STRAIGHT algorithm (Shue et al. 2011; Kawahara et al. 1998). F0 values include 10 tokens each of high, mid, and low tones from recordings collected during elicitation sessions from 2020–2023. An additional set of 8 low tone, 10 mid tone, and 12 high tone words were recorded in a sound-attenuated booth; each was repeated three times with the exception of "middle" and "navel," which were repeated twice. As shown in Figure 14, the three level tones of SJPM are distinguished by pitch height (for H and M tones), and by pitch height and trajectory (for L tones), since the L tone has a downward pitch trajectory. We note there is considerable intra-speaker variability in just these few tokens, resulting in overlap of f0 of some tokens of H and M tones.

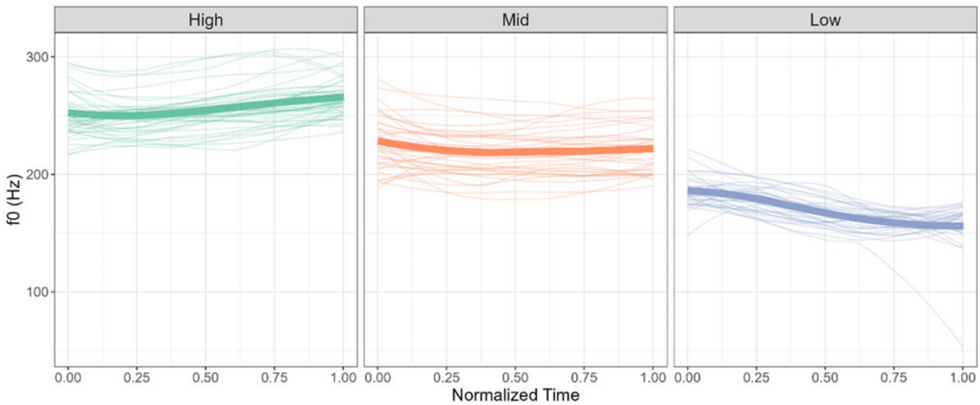

Figure 14. (Colour online) f0 track (Hz) of High, Mid, and Low lexical tones. Thin lines represent individual tokens, thick lines represent the mean across all tokens.

The three level tones of SJPM may combine to form contours. All logical possible combinations of level tones are attested in bimoraic stems, whether monosyllabic or disyllabic, where each mora has a single tone associated with it. Table 1 shows examples of these bitonal melodies in disyllabic and monosyllabic bimoraic stems.

We show the acoustic realization of two-tone melodies in monosyllabic bimoraic stems in Figure 15. Data for this figure were taken from three repetitions each of the words in Table 2; tokens were produced in isolation in a sound-attenuated booth.

Crowding of tones on single morae is permitted in SJPM: bimoraic stems sponsor up to four tones, whether monosyllabic (8a) or disyllabic (8b), while monomoraic function morphemes (like the negative proclitic *ko*^{15}), sponsor up to two tones (8c).

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Table 1. Bitonal melodies in monosyllabic and disyllabic bimoraic stems

Tone	Transcription	SJPM	English Gloss	Spanish Gloss
L.M	/ki^{1}si^{3}/	kìsī	‘pot’	‘olla’
	/ʃa^{1}a^{3}/	xàā	‘chin’	‘barbilla’
L.H	/vi^{1}ko^{5}/	vìkó	‘cloud’	‘nube’
	/ʒa^{1}a^{5}/	yàá	‘ash’	‘ceniza’
H.L	/k^{w}a^{5}ʒu^{1}/	kuáyù	‘horse’	‘caballo’
	/pã^{5}ã^{1}/	páàn	‘bread’	‘pan’
H.M	/va^{5}li^{3}/	válī	‘children’	‘niños’
	/ka^{5}a^{3}/	káā	‘deictic form’	‘allá’
M.L	/ʒu^{3}vi^{1}/	yūvì	‘stream’	‘arroyo’
	/t͡ʃa^{3}a^{1}/	chāà	‘tomorrow’	‘mañana’
M.H	/to^{3}tõ^{5}/	tōtón	‘firewood’	‘leña’
	/ta^{3}a^{5}/	tāá	‘honorific, male’	‘señor’

(8) a. ìíìí
[i^{15}i^{15}]
/i^{15}i^{15}/
NEG.delicate
‘not delicate’(‘*no delicado*’)

b. kìíníì
[ki^{15}ni^{51}]
/ki^{15}ni^{5}=i^{1}/
NEG.shoot=1SG
‘I will not shoot.’(‘*No voy a disparar.*’)

c. kòó ndīkō
[ko^{15} ndi^{3}ko^{3}]
/**ko^{15}** ^{n}di^{3}ko^{3}/
NEG.PST.grind
‘did not grind’ (‘*no molió*’)

SJPM licenses two lexical rising contour tones in single morae, namely LM (/V^{13}/) (9a) and LH (/V^{15}/) (9b–c). Falling contour tones (ML /V^{31}/ and HL /V^{51}/) are attested only in grammatically derived tonal melodies and are also licensed in single morae, as shown in (10a–b).

(9) a **LM**.M tìīnā /ti^{13}na^{3}/ ‘dog’ (‘*perro*’)
b. **LH**.M chìíkī /tʃi^{15}ki^{3}/ ‘prickly pear’ (‘*tuna*’)
c. M.**LH** nāñàá /na^{3}ɲa^{15}/ ‘chayote squash’ (‘*chayote*’)

(10) a. LH.**ML** yòósūè [ʒo^{15}s^{w}e^{31}] /ʒo^{15}so^{3}=e^{1}/ ‘my metate’ (‘*mi metate*’)
b. L.**HL** xìníì [ʃi^{1}ni^{51}] /ʃi^{1}ni^{5}=i^{1}/ ‘my head’ (‘*mi cabeza*’)

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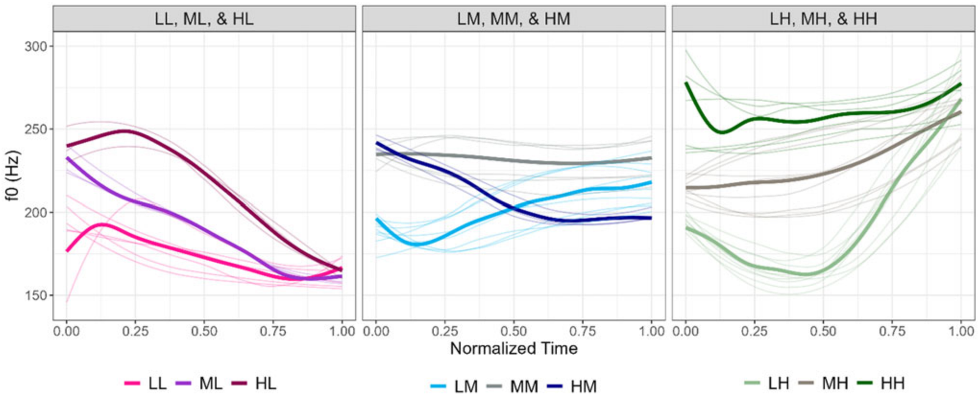

Figure 15. (Colour online) f0 trajectories (Hz) for bitonal melodies in monosyllabic bimoraic stems.

Table 2. Bitonal melodies on monosyllabic bimoraic words used for acoustic analysis in Figure 15 across three vowel categories: /i/ (blue/bottom), /o/ (purple/middle), and /a/ (black/top) (color online). Note that N/A indicates no token was found with the vowel and tone pattern pairing.

Tone	HH	MM	LL	HM	HL	ML	MH	LH	LM
Word	^{n}d͡ʒa^{5}a^{5} ʒo^{5}o^{5} ĩ^{5}ĩ^{5}	ʒa^{3}a^{3} ^{n}d͡ʒo^{3}o^{3} ĩ^{3}ĩ^{3}	ʒa^{1}a^{1} N/A ĩ^{1}ĩ^{1}	ka^{5}a^{3} N/A N/A	pã^{5}ã^{1} N/A N/A	t͡ʃã^{3}ã^{1} N/A N/A	ta^{3}a^{5} N/A k^{w}i^{3} i^{5}	ʒa^{1}a^{5} ʒo^{1}o^{5} ĩ^{1}ĩ^{5}	ʃa^{1}a^{3} t͡ʃo^{1}o^{3} ^{n}di^{1} i^{3}
Gloss	'black' '1pl.incl' 'hail'	'white' 'hummingbird' 'one'	'slow' N/A 'nine'	'deictic form' N/A N/A	'bread' N/A N/A	'tomorrow' N/A N/A	'hon., male' N/A 'watery'	'ash' 'moon' 'salt'	'chin' 'passion fruit' 'corpse'

SJPM also exhibits downstep and upstep that leads to surface tone levels differing from their phonemic ones. Downstep involves the realization of tones with lower pitch than other tones of the same phonological category (Clements 1979; Gussenhoven 2004; Hyman 2017), while upstep involves an upward shift of the tonal register that may be followed by a downward shift (Snider 1988, 1990). In SJPM, there is downstep of M tone to level [2] and H tone to level [4] as well as upstep of H tones to level [6] (Duarte Borquez 2022, Duarte Borquez, Juárez Chávez & Caballero to appear). These register effects are analyzed in Duarte Borquez (2022), and Duarte Borquez, Juárez Chávez & Caballero (to appear) as resulting from different association patterns of floating L tones sponsored by some roots. Level [6] tone for the upstepped tone is cross-linguistically unusual and not commonly used in IPA-based tonal descriptions, but a sixth 'super-high' tonal level is nonetheless attested in the description of other tonal languages (e.g., Quiotepec Chinantec (Castellanos Cruz 2014), White Hmong (Garellek & Esposito 2023); see also discussion in Zhu (2012)). While downstep is widely attested cross-linguistically and has been reported in several Mixtec varieties (see Daly & Hyman 2007 for an overview), to the best of our knowledge, upstep is only documented in three other varieties of Mixtec, namely Acatlán Mixtec (Pike & Wistrand 1974), Peñoles Mixtec (Daly & Hyman, 2007), and San Jerónimo de Xayacatlán Mixtec (Rueda Chaves, 2019).

Downstep is exemplified in (11) with the M-toned enclitic =*va*^{3} 'emph', which surfaces with a lower pitch when attaching to roots bearing a floating L tone (11a-b). A lowered pitch is not attested when the same enclitic attaches to other roots (11c-d).

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(11)	a. /M.M^L/	[M.M]	ītā	[i³ta³]	'flower' ('flor')
	b. /M.M^L=M/	[M.M=↓**M**]	ītā vā	[i³ta³=**va**²]	'flower!' (*'flor!'*)
	c. /M.M=M/	[M.M]	lēsō	[le³so³]	'rabbit' ('conejo')
	d. /M.M=M/	[M.M=M]	lēsō vā	[le³so³=va³]	'rabbit!' (*'conejo!'*)

To further illustrate the f0 of upstepped and downstepped tones, f0 was calculated in VoiceSauce (Shue et al., 2011) using the vowels in examples 11–12. Compare f0 tracks of "flower!" (Figure 16, top), which has downstep on the final mora, to "rabbit!" (Figure 16, bottom), which does not.

As seen in Figure 16, the f0 patterns of mid-tone roots in isolation in these examples exhibit a difference between the root with a posited low tone ([i³ta³] 'flower', in the top left), where a downtrend in the second vowel is attested, and the root with no floating low tone ([le³so³] 'rabbit', in the bottom left), where no downtrend is attested. We note that this downtrend could be attributed to the presence of the floating low tone or microprosody (or a combined effect of both), but we leave this question for future research. We note, however, that the downtrend attested in [i³ta³] 'flower' is not as clear and perceptually salient as the register drop attested in a following mora, if present, as exemplified in the final vowel in [i³ta³va²] 'flower!' in the top right panel.

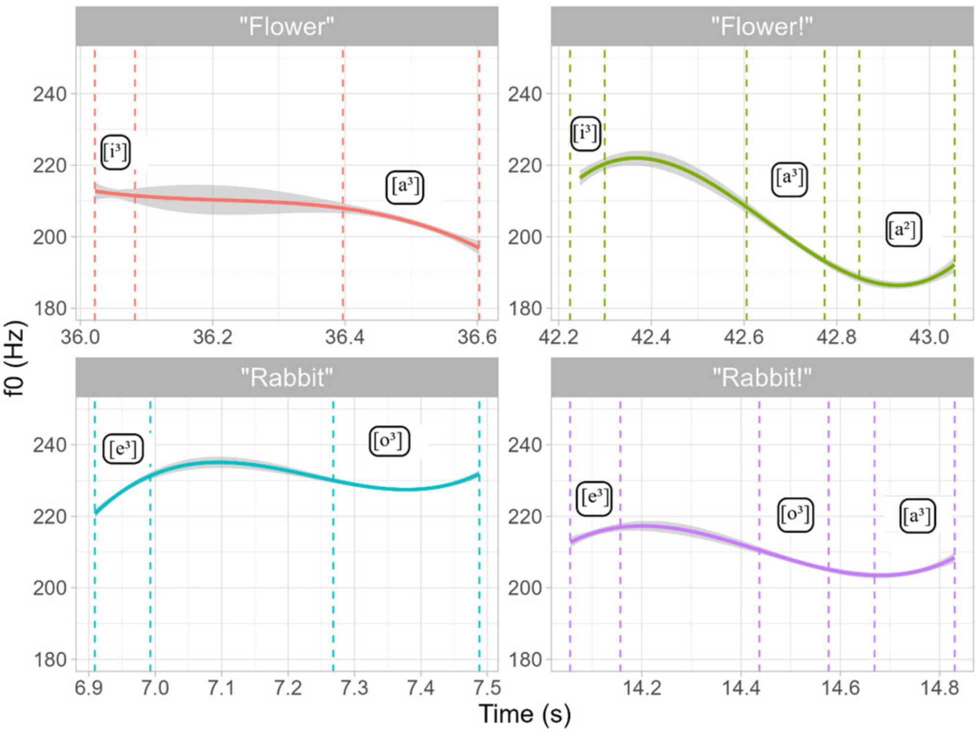

Figure 16. (Colour online) f0 tracks (Hz) of [i³ta³] 'flower' (top left), [i³ta³va²] 'flower!' (top right), [le³so³] 'rabbit' (bottom left) and [le³so³va³] 'rabbit!' (bottom right) (f0 between vowels is interpolated for visualization purposes and does not represent real f0). Note that all tones are phonemically mid level tones /3/, but downstep mid [2] is phonetically implemented with a lower f0 in 'flower!'; compare with 'rabbit!,' with phonetically all level [3] tones.

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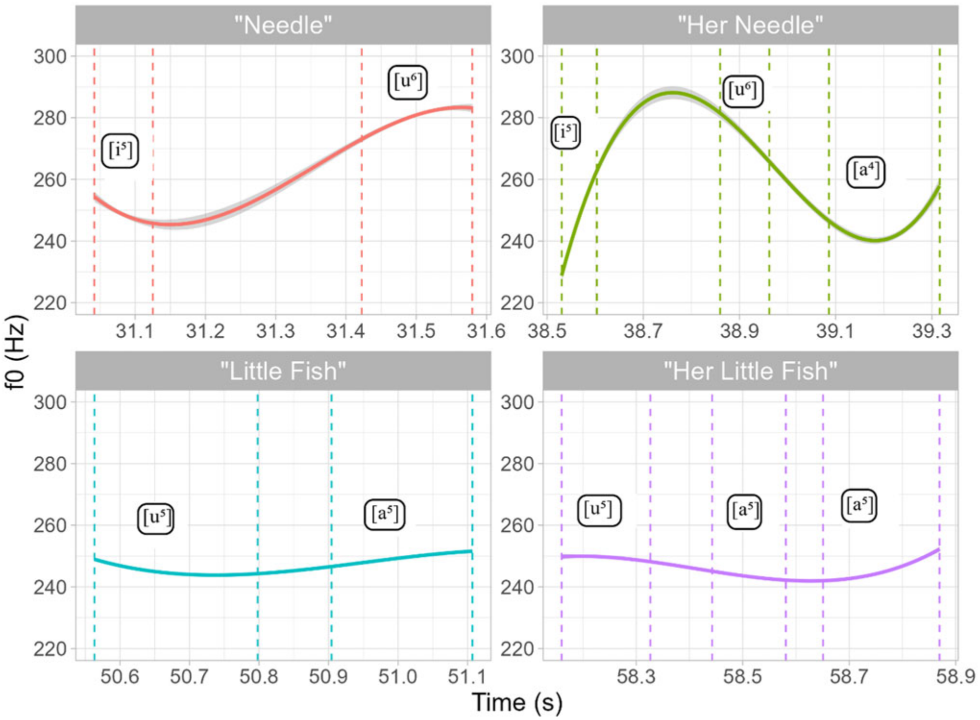

Figure 17. (Colour online) f0 tracks (Hz) of [ti^{5}ku↑^{6}] 'needle' (top left), [ti^{5}ku$^{↑6}$ɲa$^{↓4}$] 'her needle' (top right), [^{n}d͡ʒu^{5}ma^5] 'little fish' (bottom left), and [^{n}d͡ʒu^{5}ma^{5}ɲa^5] 'her little fish' (bottom right) (f0 between vowels is interpolated for visualization purposes and does not represent real f0). Note that all tones are phonemically high level tones /5/.

Upstep is attested in /H.H^L/ sequences, where the second H tone is realized with a higher pitch. The H-toned TBU that follows the upstepped tone becomes downstepped. In contrast, no register effects are attested in sequence of H tones in the absence of floating L tones. This is exemplified in (12), with stems attaching a H-toned enclitic, =*ɲa*^{5} '3sg.f'. Figure 17 (top) illustrates upstepped level [6] tone followed by downstepped level [4] tone (compare to Figure 17 (bottom), with all level [5] tones). As shown in Figure 17, high-toned roots with and without floating low tones are distinguished in isolation by the presence and absence of upstep, respectively, in the second mora.

(12)	a. /H.H^L/	[H.↑H]	tíkú	[ti^{5}ku↑^{6}]	'needle'	(*'aguja'*)
	b. /H.H^L=H/	[H.$^↑$H=$^↓$H]	tíkú ñá	[ti^5**ku**$^{↑6}$=**ɲa**$^{↓4}$]	'her needle'	(*'su aguja'*)
	c. /H.H/	[H.H]	ndyúmá	[^{n}d͡ʒu^{5}ma^5]	'little fish'	(*'pescadito'*)
	d. /H.H=H/	[H.H=H]	ndyúmá ñá	[^{n}d͡ʒu^{5}ma^5=ɲa^5]	'her little fish'	(*'su pescadito'*)

Phonotactics

Bimoraic root templates are the unit of analysis of tone patterns, several phonotactic constraints, and the domain for some phonological processes in SJPM, and as documented in other varieties of Mixtec (Gerfen 1999; Carroll 2015; Penner 2019). Attested monomorphemic word structures and their syllable structure are provided in Table 3 (a period indicates a syllable boundary).

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Table 3. Attested monomorphemic word structures and their syllable structure

Syllable Structure	Transcription	SJPM	English Gloss	Spanish Gloss
V	/a^5/	á	'polar question particle'	'partícula de pregunta de polaridad'
CV	/ti^5/	tí	'3sg animal class marker'	'marcador de clase animal 3sg'
VV	/i^{3}i^{15}/	ììí	'husband'	'esposo'
VˀV	/i^{5}ˀi^3/	í'ī	'uncooked' or 'unripe'	'crudo' o 'sin madurar'
CVV	/tĩ^{15}ĩ^3/	tìíín	'mouse'	'ratón'
CVˀV	/^{n}di^{3}ˀi^3/	ndī'ī	'all'	'todos'
V.CV	/i^5.tĩ^{15}/	ítìín	'left'	'izquierda'
Vˀ.CV	/i^{3}ˀ.ni^5/	ī'ní	'hot'	'caliente'
CV.CV	/kʷi^5.ti^5/	kwítí	'short'	'corto'
CVˀ.CV	/^{n}di^{3}ˀ.vi^5/	ndī'ví	'clear'	'claro'
CV.CV.CV	/si^1.^{n}di^1.ki^5/	sìndìkí	'cattle'	'ganado'
CV.CVˀ.CV	/ti^1.so^{3}ˀ.ma^1/	tìsō'mà	'scorpion'	'escorpión'
CV.CVV	/^{n}da^3.ko^{3}o^3/	ndākōō	'to leave'	'dejar'
CV.CVˀV	/^{n}di^3.ka^{3}ˀa^3/	ndīkā'ā	'lion'	'león'

The syllable structure of SJPM, as in other Mixtec varieties, is (C)V, an open syllable with an optional onset. Codas are disallowed. As mentioned above, monomorphemic open-class words are minimally bimoraic (analyzed here as root templates), either monosyllabic with a long vowel ((C)VV) or disyllabic with two short vowels ((C)VCV), though trimoraic monomorphemic words are not uncommon (as mentioned above, long vowels are restricted to occur in the final syllable of trimoraic words). In contrast, function words, affixes and clitics are canonically monomoraic. Bimoraic templatic roots may be contrastively glottalized as exemplified above, with glottalization associating with the first vowel of the couplet. The vowels in uninflected monosyllabic ((C)VV or (C)VˀV) roots must be identical.

Consonant cluster onsets may occur in certain contexts involving vowel deletion in synchronic patterns of reduction in fast speech. As a result, both a "long form," with a full vowel, and a "short form," with a consonant cluster in fast speech, are often attested. The only consonant clusters attested in SJPM involve a sibilant-plosive sequence, a pattern also attested in other Mixtec varieties (e.g., Chalcatongo Mixtec; Macaulay 1996). The resulting sibilant-plosive clusters in SJPM include [ʃt], [ʃkʷ], [ʃk], [st], [sk] and [s^{n}d]. Some of these clusters are exemplified in (13). In addition, SJPM has a few words with underlying clusters where no "long form" alternative exists as in (14).

(13) a. xìtá ~ xtá
[ʃi^{1}ta^5] ~ [ʃta^5]
/ʃi^{1}ta^5/
'tortilla'

b. kāsìkí ~ kāskí
[ka^{3}ski^5]
/ka^{3}si^{1}ki^5/
'nape of the neck' *('nuca')*

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c. sìndòkó ~ sndòkó
[s^{n}do^{1}ko^{5}]
/si^{1}ndo^{1}ko^{5}/
'chicatana' (a species of edible ant, *atta mexicana*)

(14) xtó'ō
[ʃto^{5ʔ}o^{3}]
/ʃto^{5ʔ}o^{3}/
'boss, owner' (*jefe, patroán)*

As shown in these examples, the deleted vowel in each instance bears a L tone, and the tone of the deleted vowel is also deleted in the reduced form. The resulting cluster may be located at the onset of the couplet, as in (13a) and (13c), where vowel deletion targets the vowel preceding the couplet (e.g., /si^{1}(^{n}do^{1}ko^{1})/ becomes [(s^{n}do^{1}ko^{1})]). Vowel deletion may also target the couplet-initial vowel as in (13b), where /ka^{3}(si^{1}ki^{5})/ becomes [(ka^{3}ski^{5})]. In this second environment, the resulting cluster is in the couplet-medial position.

Illustrative Passage

The story "The North Wind and the Sun" was introduced in Spanish and translated line by line, as this story does not come naturally to the L1 speaker of SJPM and aspects of the story are not present in traditional narratives in SJPM (namely, inanimate objects speaking). Two lines including repetitions were edited to remove repeated words, /ɾa^{3} ka^{5}t͡ʃi^{5} ɲa^{1} ^{n}d͡ʒa^{5} ku^{5}u^{3} ɲa^{3} ^{n}da^{3}ku^{5} ka^{3} no^{1}o^{5} ^{n}di^{3ʔ}i^{3} ^{n}da^{1}a^{1}/ '. . . who is the strongest . . .' and /ki^{1}ʃa^{5}a^{5} ɲa^{1} ti^{13}vi^{3}a^{1}/ '. . . begins to blow . . .'. The transcription presented here corresponds to the recorded text. The phonemic transcriptions do not reflect downstep, upstep and other tonal register effects. The narrow phonetic transcription encodes upstep and downstep.

Broad phonemic transcription

ɲa^{1} ta^{1}t͡ʃi^{5} ka^{5}t͡ʃi^{5} ɲa^{1} ʃĩ^{5ʔ}i^{3} ɲa^{1} ni^{1}ka^{3n}d͡ʒi^{3ʔ}i^{15} ‖ ka^{5}t͡ʃi^{5} ɲa^{1} ^{n}d͡ʒa^{5}ku^{5}u^{3} ʒo^{5} ^{n}da^{3}ku^{5} ka^{3} ‖

ka^{5}t͡ʃi^{5} ɲa^{1} ^{n}da^{1}tõ^{5ʔ}õ^{3} tã^{5ʔ}ã^{1} ɾa^{3} ʃi^{13}ni^{3}a^{1} ĩ^{3}ĩ^{3} ɾa^{1} t͡ʃa^{1}a^{3} ‖ ^{n}di^{5}ʃi^{3} ɾa^{3} t͡ʃa^{5}ma^{5}ɾa^{5} ‖

ka^{5}t͡ʃi^{5} ɲa^{1} vi^{3}t͡ʃĩ^{3} ɾa^{3} na^{3}ko^{3}to^{3n}do^{3}se^{5} ^{n}d͡ʒa^{5} ku^{5}u^{3}ʒo^{5} ^{n}da^{3}ku^{5} ka^{3} ‖ t͡ʃi^{1}tã^{5ʔ}ã^{3} tõ^{1ʔ}õ^{3} ɲa^{1} ‖

ɾa^{3} ka^{5}t͡ʃi^{5} ɲa^{1} ^{n}d͡ʒa^{5} ku^{5}u^{3} ɲa^{3} ^{n}da^{3}ku^{5} ka^{3} no^{1}o^{5} ^{n}di^{3ʔ}i^{3} ^{n}da^{1}a^{1} ‖ a^{3} ku^{3}vi^{3} sa^{5ʔ}a^{3} ɲa^{1} ‖

ta^{5}k^{w}ã^{1} ta^{3}va^{5} ɾa^{1} t͡ʃa^{1}a^{3} t͡ʃa^{5}ma^{5}ɾa^{5} ɾa^{1} ‖

ʃi^{3}na^{3} ɲa^{1} ta^{1}t͡ʃi^{5} ki^{1}ʃa^{5}a^{5} ɲa^{1} ti^{13}vi^{3}a^{1} nĩ^{1ʔ}ĩ^{3} no^{1}o^{5} ^{n}di^{3ʔ}i^{3} ^{n}da^{1} ‖

su^{3} ɾa^{1} t͡ʃa^{1}a^{3} ɾa^{3} t͡ʃi^{1}ka^{3}si^{3} va^{3} ra^{3} nõ^{1}õ^{5} t͡ʃa^{5}ma^{5}ɾa^{5} ɾa^{1} ‖

ɾa^{3} ta^{5n}di^{3ʔ}i^{3} ɾa^{3} ki^{1}ʃa^{5}a^{5} ɲa^{1} ni^{1}ka^{3n}d͡ʒi^{3ʔ}i^{15} ^{n}d͡ʒi^{5}i^{1}a^{5} ‖

ɾa^{3} ki^{1}ʃa^{5}a^{5} i^{3ʔ}nĩ^{5} ʃi^{5}ni^{5} ɾa ^{1}t͡ʃa^{1}a^{3} ta^{13}va^{5} ra^{1} t͡ʃa^{5}ma^{5}ɾa^{5} ɾa^{1} ‖

ɾa^{3} ɲa^{1} ni^{1}ka^{3n}d͡ʒi^{3ʔ}i^{15} ki^{5}a^{1} ^{n}da^{3}ku^{5} t͡ʃĩ^{3}ĩ^{3} sa^{1}ka^{3}na^{5ʔ}a^{3} ɲa^{1}

Narrow phonetic transcription

ɲa^{1} ta^{1h}t͡ʃi^{5} ka^{5}t͡ʃi^{6} ɲa^{1} ʃĩ^{5} ɲa^{1} ni^{1}ka^{3n}d͡ʒi^{3ʔ}i^{15} ‖ ka^{5}t͡ʃi^{6} ɲa^{1} ^{n}d͡ʒa^{5}ku^{5}u^{3} ʒo^{5} ^{n}da^{3h}ku^{5}ga^{3} ‖

ka^{5}t͡ʃi^{6} ɲa^{1} ^{n}da^{1}tõ^{5ʔ}õ^{3} tã^{5ʔ}ã^{1} ra^{3} ʃi^{13}ni^{3}a^{1} ĩ^{3}ĩ^{3} ra^{1} t͡ʃa^{1}a^{3} ‖ ^{n}di^{5}ʃi^{3} ɾa^{3} t͡ʃa^{5}ma^{5}ra^{6} ‖

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ka5ʰt͡ʃi6 ɲa1 vi3t͡ʃĩ3 ɾa3 na3ko3to3ndo3se5 nd͡ʒa5 ku5u3jo5 nda3ʰku5ga3 ‖ t͡ʃi1tã5ˀã3 tõ1ˀõ3 ɲa1 ‖
ra3 ka5ʰt͡ʃi6 ɲa1 nd͡ʒa5 ku5u3 ɲa3 nda3ku5ga3 no1o5 ndi3ˀi3 nda1a1 ‖ ra3 ku3vi3 sa5ˀa3 ɲa1 ‖
ta5kʷã1 ta3va5 ɾa1 t͡ʃa1a3 t͡ʃa5ma5ra6 ɾa1 ‖
ʃi3na3 ɲa1 ta1ʰt͡ʃi5 ki1ʃa5a5 ɲa1 ti13vi3a1 nĩ1ˀĩ3 no1o5 ndi3ˀi3 nda1 ‖
su3 ɾa1 t͡ʃa1a3 ɾa3 t͡ʃi1ka3si3 va3 ɾa3 nõ1õ5 t͡ʃa5ma5ra6 ɾa1 ‖
ra3 ta5ndi3ˀi3 ɾa3 ki1ʃa5a5 ɲa1 ni1ka3nd͡ʒi3ˀi15 nd͡ʒi5i1a5 ‖
ra3 ki1ʃa5a5 i3ˀnĩ5 ʃi5ni6 ra1 t͡ʃa1a3 ta13va5 ɾa1 t͡ʃa5ma5ɾa6 ɾa1 ‖
ra3 ɲa1 ni1ka3nd͡ʒi3ˀi155 ki5a1 nda3ʰku5 t͡ʃĩ3ĩ3 sa1ka3na5ˀa3 ɲa1

Orthographic representation
Ñà tàchí káchí ñà xí’īn ñà nìkāndyī’ìí káchí ñà: “¿ndyá kúū yó ndākú kā?” Káchí ñà ndàtó’ōn tá’àn rā xìīnià īīn rà chàā ndíxī rā chámárá. Káchí ñà: “vīchī rā nākōtōndōsé ndyá kúū yó ndākú kā.” Chìtá’ān tò’ōn ñà rā káchí ñà: “¿ndyá kúū ñā ndākú kā nòó ndī’ī ndà rā kūvī sá’ā ñà tákwàn tāvá rà chàā chámárá rà?” Xīnā ñà tàchí kìxáá ñà tìīvīà nì’īn nòó ndī’ī ndà sū rà chàā rā chìkāsī vā rā nòón chámárá rà. Rā tándī’ī rā kìxáá ñà nìkāndyī’ìí ndyíìá rā kìxáá ī’nín xíní rà chàā tàāvá rā chámárá rà. Rā ñà nìkāndyī’ìí kíà ndākú chīīn sàkāná’ā ñà.

Glossed phonemic transcription

ɲa1	ta1t͡ʃi5	ka5t͡ʃi5=ɲa1	ʃĩ5ˀĩ3=ɲa1	ni1ka3nd͡ʒi3ˀi15	ka5t͡ʃi5=ɲa1	nd͡ʒa5	ku5u3=ʒo5
3SG.N	wind	PRS.say=3SG.N	with=3SG.N	sun	PRS.say=3SG.N	who	PRS.COP=1PL.IN

nda3ku5=ka3
strong=COMP

‘El viento le pregunta al sol “¿quién de nosotros es más fuerte?”’

‘The wind asks the sun: “who is the strongest?”’

ka5t͡ʃi5=ɲa1	nda1tõ5ˀõ3	tã5ˀã1	ɾa3	ʃi13ni3=a1	ĩ3ĩ3	ɾa1	t͡ʃa1a3
PRS.say=SG.N	PST.chat	RECP	and	PST.see=3SG.N	one	3SG.M	man

ndi5ʃi3=ɾa3	t͡ʃa5ma5ɾa5
PRS.wear=3SG.M	jacket

‘(Estaban) platicando entre ellos y vieron a un hombre con una chamarra puesta.’

‘They were talking among themselves and they saw a man with a jacket.’

ka5t͡ʃi5=ɲa1	vi3t͡ʃĩ3	ɾa3	na3-ko3to3ndo3s=e5	nd͡ʒa5	ku5u3=ʒo5	nda3ku5=ka3
PRS.say=3SG.N	today	and	HORT-try=1PL.IN	who	PRS.COP=1PL.IN	strong=COMP

‘Y dijo: “hoy vamos a probar quién de nosotros es el más fuerte”’

‘And it said: “today we are going to see who is the strongest.”’

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t͡ʃi^{1}ta^{5}ˀã^{3}	tõ^{1}ˀõ^{3}=ɲa^{1}	ɾa^{3}	ka^{5}t͡ʃi^{5}=ɲa^{1}	^{n}d͡ʒa^{5}	ku^{5}u^{3}=ɲa^{3}	^{n}da^{3}ku^{5}=ka^{3}
PST.get.together	word=3SG.N	and	PRS.say=3SG.N	who	PRS.COP=3SG.N	strong=COMP
no^{1}o^{5}	^{n}di^{3}ˀi^{3}=^{n}da^{1}	ɾa^{3}	ku^{3}vi^{3}	sa^{5}ˀa^{3}=ɲa^{1}	ta^{5}kʷã^{1}	ta^{3}va^{5}=ɾa^{1}
on	all=more	and	IRR.be.able	IRR.do=3SG.N	so.that	IRR.remove=3SG.M
t͡ʃa^{1}a^{3}	t͡ʃa^{5}ma^{5}ɾa^{5}=ɾa^{1}					
man	jacket=3SG.M					

‘Se pusieron de acuerdo y dijo: “¿quién es el que es mucho más fuerte para hacer que el hombre se quite su chamarra?”’

‘They agreed and said: “who is the strongest to make the man take off his jacket?”’

ʃi^{3}na^{3}	ɲa^{1}	ta^{1}t͡ʃi^{5}	ki^{1}ʃa^{5}a^{5}=ɲa^{1}	ti^{13}vi^{3}=a^{1}	nĩ^{1}ˀĩ^{3}	no^{1}o^{5}	^{n}di^{3}ˀi^{3}=^{n}da^{1}
first	3SG.N	wind	PST.begin=3SG.N	PST.blow=3SG.N	strong	on	all=more

su^{3}	ɾa^{1}	t͡ʃa^{1}a^{3}	ɾa^{3}	t͡ʃi^{1}ka^{3}si^{3}=va^{3}=ɾa^{3}	nõ^{1}õ^{5}	t͡ʃa^{5}ma^{5}ɾa^{6}=ɾa^{1}
but	3SG.M	man	and	PST.close=EMPH=3SG.M	face	jacket=3SG.M

‘Primero empezoá el viento a soplar fuerte, muy fuerte, pero el hombre se abrochoá su chamarra.’

‘First the wind started to blow hard, really hard, but the man zipped his jacket.’

ɾa^{3}	ta^{5}^{n}di^{3}ˀi^{3}	ɾa^{3}	ki^{1}ʃa^{5}a^{5}=ɲa^{1}	ni^{1}ka^{3}^{n}d͡ʒi^{3}ˀi^{15}	^{n}d͡ʒi^{5}i^{1}=a^{5}
and	then	and	PST.begin=3SG.N	sun	sunny.bright=3SG.N

‘Y luego empezó el sol a estar caliente’

‘And then the sun started to be hot’

ɾa^{3}	ki^{1}ʃa^{5}a^{5}	i^{3}ˀnĩ^{5}	ʃi^{5}ni^{5}=ɾa^{1}	t͡ʃa^{1}a^{3}	ta^{13}va^{5}=ɾa^{1}
and	PST.begin	hot	PRS.feel=3SG.M	man	PST.take.off=3SG.M
t͡ʃa^{5}ma^{5}ɾa^{5}=ɾa^{1}					
jacket=3SG.M					

‘y el hombre empezó a tener calor, se quitoá su chamarra.’

‘and the man began to get hot, he took off his jacket.’

ɾa^{3}	ɲa^{1}	ni^{1}ka^{3}^{n}d͡ʒi^{3}ˀi^{15}	ki^{5}=a^{1}	^{n}da^{3}ku^{5}	t͡ʃĩ^{3}ĩ^{3}
and	3SG.N	sun	PRS.COP=3SG.N	strong	because

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sa¹ka³na⁵ˀa³=ɲa¹

PST.win=3SG.N

'Entonces el sol es el más fuerte porque ganoá.'

'And the sun is the strongest because it won.'

Free Spanish translation
El viento le pregunta al sol: "¿quién de nosotros es más fuerte?" Estaban platicando entre ellos y vieron a un hombre con una chamarra puesta. Y entonces uno de ellos dijo: "hoy vamos a probar quién de nosotros es el más fuerte". Se pusieron de acuerdo que decidirían viendo quién era el más fuerte para hacer que el hombre se quitara su chamarra. Primero empezó el viento a soplar fuerte, muy fuerte, pero el hombre se abrochó su chamarra. Y luego empezó el sol a estar caliente y brillar y el hombre empezó a tener calor y se quitó su chamarra. Entonces el sol es el más fuerte porque ganó.

Free English Translation
The wind asks the sun: "who is the strongest?". They were talking among themselves and they saw a man with a jacket. And one of them says: "today we are going to see who is the strongest." They agreed they would decide who the strongest was to make the man take off his jacket. First the wind started to blow hard, really hard, but the man zipped his jacket. And then the sun started to be hot and the man began to get hot and he took off his jacket. Therefore the sun is the strongest because it won.

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