THE INTERACTION OF METRICAL STRUCTURE, TONE, AND PHONATION TYPES IN QUIAVINÍ ZAPOTEC

by

Mario E. Chávez Peón

B.A. Hispanic Language and Literatures, UNAM, 2001

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Abstract

This thesis investigates the interaction between different prosodic patterns in Quiaviní Zapotec (Otomanguean), and accounts for them both at the phonetic and the phonological level. In it, I examine an array of complex patterns along multiple dimensions, including metrical structure, tone, and phonation types; as well as how these patterns interact with the fortis/lenis distinction, and syllable structure. Within the framework of Optimality Theory, my analysis sheds light on the phonetics-phonology interface and emphasizes the need for a theory with moraic structure.

This dissertation presents the first thorough phonetic documentation of the prosody of Quiaviní Zapotec. It makes a significant empirical contribution by providing descriptive generalizations of vowel and consonant length, a reanalysis of tone as contrastive in Quiaviní Zapotec, and a new approach to the study of the four-way phonation contrast in this language — modal /a/, breathy /a̤/, creaky /a̰/ and interrupted /aˀ/ vowels — (cf. Munro & Lopez, 1999).

In addition, this research makes significant contributions to phonological theory, with regards to both segmental and prosodic phenomena. Within an emergent feature approach, I revisit the fortis/lenis distinction, which crosscuts the obstruent-sonorant contrast in Quiaviní Zapotec. I analyze it as a composite of language-specific phonological and phonetic properties, encoded with the feature [+/-fortis]. Adding to the typology of syllable weight, fortis consonants are analyzed as moraic in coda position, but among them, only fortis sonorants may bear tone alongside vowels (i.e. *[-SON][TONE] 'No tones on obstruents').

Furthermore, I show specific timing patterns for the phonetic implementation of tonal and laryngeal features. Quiaviní Zapotec exhibits compatibility of contrasts; compromise of phonological features (e.g. tonal contrasts are cued during modal phonation, followed by breathiness or laryngealization); or complete incompatibility, which translates into phonemic gaps. This distribution is formalized in terms of markedness interaction and grounded constraints (e.g. 'If [+spread glottis], then Low tone', accounting for the absence of high tone with breathy vowels).

Overall, the thesis analyzes the minimal prosodic word in Quiaviní Zapotec (a bimoraic foot) as the domain where the full array of tonal and phonation type contrasts takes place, and illustrates particular mechanisms by which phonetic factors shape phonology.

Table of contents

List of tables

List of figures

List of abbreviations

'-' = affix boundary
'=' = clitic boundary
( ) = foot boundary
√ = root
1p = first person plural
1s = first person singular
2p = second person plural
2s = second person singular
3p = third person plural
3s = third person singular
C = consonant
dB = decibels
F1 = first formant
F2 = second formant
F3 = third formant
Ft = foot
Hz = hertz
IP = intonation Phrase
MA = manner of articulation
ms = milliseconds
N = nucleus
O = obstruent
obj = object
OT = Optimality Theory
PA = point of articulation
Pos = possessive
PPhrase = Prosodic Phrase
PWord = Prosodic Word
R = resonant (sonorant)
s = singular
S = stress
SPE = The Sound Pattern of English (Chomsky & Halle, 1968)
subj = subject
SVO = Subject-Verb-Object word order
TBU = tone-bearing unit
us = unstressed
V = full vowel
V = vocal
VOS = Verb-Object-Subject word order
VOT = Voice Onset Time
VSO = Verb-Subject-Object word order

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Dedication

To my daughter, Lía Inés

Preface (summary and committee members)

Name:	Mario E. Chávez-Peón
Degree:	Ph.D.
Title of Thesis:	The Interaction of Metrical Structure, Tone, and Phonation types in Quiaviní Zapotec
Committee:	Dr. Douglas G. Pulleyblank Co-Supervisor
	Dr Joseph P. Stemberger Co-Supervisor
	Dr. Bryan Gick Committee member
	Dr. Gunnar O. Hansson Committee member

Chapter 1:

The thesis and the language

1.1 The thesis

This dissertation investigates the phonetics and phonology of San Lucas Quiaviní Zapotec (henceforth, Quiaviní Zapotec), an Otomanguean language spoken in southern Mexico, in the state of Oaxaca. Specifically, I examine the interaction of metrical structure, tone, and phonation types. This study proposes a unified account for these patterns, explaining their individual characteristics and how their interaction is constrained. Two topics are discussed in detail: the role of the mora as the link for different patterns in the phonology of this language and the mapping between phonology and phonetics in the expression of laryngeal features.

The goals of this dissertation are twofold. First, the description and analysis of these phenomena will improve our understanding of the phonology of Quiaviní Zapotec. Second, this research will explore the implications of tone-phonation interactions in phonological theory and contribute to the growing literature on this subject (Silverman, 1997a, 1997b; Herrera, 2000; Blankenship, 2002; DiCanio, 2008, among others), as well as the role of metrical structure in such interactions.

This chapter aims to provide a basic overview of Quiaviní Zapotec and its speakers as well as the basic features of Quiaviní Zapotec phonology and morpho-syntax.

Chapter 2 shows that vowel length in Quiaviní Zapotec is dependent on the type of syllable and on the type of coda consonant: stressed vowels are short before fortis consonants (both obstruents and sonorants), and long before lenis consonants or in open syllables; as such, the categorization of this vowel length pattern relies on the fortis/lenis contrast, which entails a complex set of phonetic properties encoded with the feature [+/-fortis] under an emergent feature approach (Mielke 2008 [2004]; Pulleyblank, 2006).

The third chapter describes and analyzes Quiaviní Zapotec metrical structure. The goal is to account for word stress in this language; thus, the domain of analysis is the prosodic word. According to Munro and Lopez (1999), the last syllable of uninflected words is stressed in Quiaviní Zapotec (referred to as the *key syllable* by the authors, p. 3), but no subsequent study has examined more details of the prosodic system of this language. I discuss prosodic issues like moraicity and minimality, as well as foot structure, building from monosyllables, up to morphologically complex disyllabic and longer words. The analysis of prominence provides a foundation for the other two central topics of this dissertation: tone and phonation types.

Chapters 4 and 5 examine the tonal system of Quiaviní Zapotec. Munro and Lopez (1999) argue that tone is predictable from phonation types in Quiaviní Zapotec. I put this claim to question in Chapter 4, analyzing instrumentally the voice quality of lexical items with low, rising and falling tones that appear to have modal voice. Results show that tone is contrastive within modal voice; consequently, a new categorization is presented for particular lexical items. These findings are then taken into account in the analysis of non-modal phonation (Chapter 6).

Chapter 5 establishes the association between moraicity and tonal patterns in Quiaviní Zapotec. This chapter relates the metrical structure proposed in Chapter 3 to the tone findings of Chapter 4, where tone is established as a contrastive feature in this language.

I analyze Quiaviní Zapotec non-modal phonation in Chapters 6 and 7. The goal of Chapter 6 is to provide descriptive generalizations governing breathy (/ a̤ /), creaky (/ a̰ /) and interrupted (/ aˀ /) vowels in Quiaviní Zapotec. I present a detailed description of each type of vowel and clarify their underlying representations along with their phonetic realizations. In light of the controversial distinction between creaky and interrupted vowels, acoustic comparisons are presented, supporting the contrast between two degrees of laryngealization in Quiaviní Zapotec.

The laryngeal complexity of Quiaviní Zapotec, a language with both contrastive tone and contrastive phonation, is accounted for in an integrated fashion in Chapter 7. I make a proposal for the laryngeal specifications in Quiaviní Zapotec and provide a comprehensive phonological representation for vowels, in terms of featural and prosodic information. Finally, the chapter examines the phonetic implementation of phonological features and seeks to test the hypothesis that the surface complexity of this language derives from a simpler phonological representation.

1.1.1 General methodology

The two sources of data for this study are first-hand data, collected in the town of San Lucas Quiaviní and in the Los Angeles area, from fluent native speakers of the language, and Munro and Lopez' (1999) dictionary of Quiaviní Zapotec.

My field research was conducted in Mexico in the summers of 2005, 2006, 2007 and 2008, as well as in Los Angeles in May and September 2009. Throughout these periods, I recorded individual elicitation sessions with different speakers. Recordings were made with a Marantz 660 solid-state recorder and a lapel Countryman microphone (phantom power), and digital files were stored on the computer and burned onto CDs. Acoustic analysis included the use of Praat for Mac (version 5.1.07; Boersma & Weenink, 2009) and statistical programs. In the following chapters, I explain in detail the specific methods, structure of the tasks, and stimuli for the phonetic experiments.

The dictionary of Munro and Lopez (1999) is a seminal and groundbreaking study of Quiaviní Zapotec, and has been an essential source at all stages of my research. Many generalizations, minimal pairs, elicitation plans, etc, were facilitated by this study. The Quiaviní Zapotec second-language course *Cali Chiu*? (Munro, Lillehaugen, & Lopez, 2008) has also been a constant reference guide.

1.2 The language

This section provides a genetic and geographical background of Quiaviní Zapotec, as well as discussion of the previous work on the language, followed by an overview of the phonological and morpho-syntactic properties of Quiaviní Zapotec. In these latter sections, a large proportion of the basic information described here, as well as much of the terminology I adopt, was first observed, documented and proposed in the Quiaviní Zapotec dictionary (Munro & Lopez, 1999). However, my proposal regarding the phonology of Quiaviní Zapotec presents a considerable reanalysis that is developed in detail in later chapters of this study. Quiaviní Zapotec data come from my own fieldwork unless otherwise indicated.

1.2.1 Genetic and geographic background

Quiaviní Zapotec is spoken in southern Mexico, in the state of Oaxaca. It belongs to the Zapotec language family, which is part of the Otomanguean stock. Zapotec languages are divided into three subgroups (Kaufman, 1994): Northern, Central, and Southern Zapotec. Central Zapotec includes the variants of the Valley, where Quiaviní Zapotec is spoken, and the Isthmus.

The exact number of Zapotec languages is under debate; mutual intelligibility declines rapidly within relatively short distances. The SIL Ethnologue (Grimes, 2005) currently lists 58 Zapotec languages, but other scholars believe there are only 15 (T. Kaufman, personal communication, October 2007).

Quiaviní Zapotec is spoken in the town of San Lucas Quiaviní, in the Central Valley of Oaxaca state. The town has a population of close to 2000 people, most of whom speak Zapotec as their first language; nevertheless, Spanish is encroaching on the Zapotec community because of the matrix culture, media, schooling, jobs, etc. In addition, many families have re-located to the United States, into the greater Los Angeles area (probably around 2000 people). As a result the language is considered threatened by both Spanish and English.

1.2.2 Previous work

Munro and Lopez' (1999) dictionary of Quiaviní Zapotec constitutes the first comprehensive study of this language. Since then, more studies have investigated morpho-syntactic aspects of the language, including two M.A. theses (Méndez, 2000; Lillehaugen, 2003), three Ph.D. dissertations (Galant, 1998; Lee, 2006 [1999]; Lillehaugen, 2006), research articles (Munro, 1996, 2003, 2006, among others) and a second-language course (Munro et al., 2008).

An ongoing project on *First Language Acquisition in San Lucas Quiaviní Zapotec* directed by Dr. Joseph Stemberger at UBC has focused on phonological development in this language (Stemberger & Lee, 2007; Chávez-Peón, Stemberger, & Lee, *in press*). I have carried out continuous fieldwork since 2005 with children and adults, analyzing phonological (Chávez-Peón, 2006, 2008a, 2008b) and morphosyntactic (Chávez-Peón & Mudzingwa, 2008) aspects of this language.

A number of closely related languages spoken in the region surrounding San Lucas have been also documented: San Juan Guelavía Zapotec (Jones & Knudson, 1977), Santa Ana del Valle Zapotec (Broadwell, 1991; Esposito, 2003; Rojas, 2010), San Pablo Güilá Zapotec (López Cruz, 1997; Arellanes, 2009), and Mitla Zapotec (Briggs, 1961; Stubblefield & Stubblefield, 1991).

1.2.3 Phonology

This section provides an overview of Quiaviní Zapotec phonology. The purpose is to present the segmental inventory and the topics that are analyzed in detail in subsequent chapters. In addition, two sections are background for the rest of the dissertation: Quiaviní Zapotec phonotactics and general morphosyntactic characteristics. These sections are mainly based on Munro and Lopez (1999).

Quiaviní Zapotec has a complex phonetic and phonological system, which includes a pervasive contrast between fortis and lenis consonants, phonemic distinctions among four phonation types (voice qualities), tone and stress patterns and a complex syllable structure. First, following Munro and Lopez (1999), I present the phonemic inventory.

Consonants

The inventory of consonants in Quiaviní Zapotec is presented in Table 1 (Munro & Lopez, 1999), with standard orthography (where different) in parentheses.

Table 1. Quiaviní Zapotec Consonant inventory

		Bilabial	Lab-dent	Dental/ Alveolar	Prepalatal	Retroflex	Palatal	Velar
Plosive	fortis	p		t				k (c/qu)
	lenis	b		d				g
Nasal	fortis	mˑ (mm)		nˑ (nn)				ŋˑ (nng)
	lenis	m		n				ŋ (ng)
Trill				r (rr)				
Tap				ɾ (r)				
Fricatives	fortis		f	s	ʃ (x)	ʂ (x:)		x (j)
	lenis			z	ʒ (zh)	ʐ (zh:)		
Lateral	fortis			lˑ (ll)				
	lenis			l				
Affricate	fortis			ts			ʧ (ch)	
Glides							j (y)	w

Similar to other Zapotec languages, Quiaviní Zapotec has a fortis/lenis contrast in its consonant pairs, rather than a strict voiced/voiceless opposition. Fortis obstruents are voiceless, never fricated (in the case of stops), and relatively long. Lenis obstruents are often (but not always) voiced, variably fricated, and relatively short. For sonorants, the main difference between fortis and lenis is duration, with fortis being longer. Chapter 2 provides more details on the fortis/lenis issue.

There is no consensus on how to represent the fortis/lenis contrast. Among obstruents, voicing is normally a salient difference, thus, most studies rely on voicing to represent the fortis/lenis contrast; voiceless symbols are used for fortis consonants (e.g. / p t k … /) versus voiced for lenis consonants (e.g. / b d g … /). This convention is adopted in this study. Sonorants embody a greater challenge with respect to the representation of the fortis/lenis distinction, since they basically rely on duration. For this study, in order to maintain the harmonization of phonetic and phonological representation, I represent fortis sonorants with the semi-long IPA symbol (e.g. / nˑ /), and lenis sonorants as plain ones (e.g. /n/).

Vowels

Quiaviní Zapotec has the following six monophthongal vowels: / i, ɨ, u, e, o, a /, distributed as shown in Table 2. (Diphthongs are presented in the phonotactics section below.)

Table 2. Quiaviní Zapotec vowels

	front	central	back
high	i	ɨ (ë)	u
mid	e		o
low		a	

Some variation in Quiaviní Zapotec vowels include tense-lax allophones [i ~ ɪ, e ~ ɛ, ɨ ~ ʌ] and to a lesser degree [u ~ ʊ, o ~ ɔ] (Stemberger, Chávez-Peón, & Lee, 2007).

The high central unrounded vowel, / ɨ /, appears less frequently than other vowels; some speakers use it only rarely, replacing it with [e] in most contexts. The low vowel seems to be used as the default in epenthetic contexts.

Phonation and tone

Munro and Lopez (1999) recognize modal, breathy, creaky and checked vowels in Quiaviní Zapotec; Gordon and Ladefoged (2001) describe the phonetic properties of the first three.

(1) Quiaviní Zapotec phonation types

a. Modal / a /
b. Breathy / a̤ /
c. Creaky / a̰ /
d. Checked / aˀ / [1]

In the orthography, “Diacritic symbols indicate phonation type: *Vh* represents a breathy vowel (*ah, eh, ëh, ih, oh, uh*), and *V’* a checked (interrupted) vowel (*a’, e’, ë’, i’, o’, u’*). A creaky vowel is indicated with a grave accent (*à, è, ì, ò, ù*), except for the vowel *ë*, for which creakiness is indicated with a circumflex accent (*ê*). Vowels without one of these diacritics have plain (modal) phonation” (Munro & Lopez, 1999, p. 4). In addition, these scholars claim that syllable nuclei “may contain up to three individual vowels, each with its own phonation” (p. 3). (See vowel patterns in Table 3.)

Munro and Lopez (1999) recognize Quiaviní Zapotec as a tone language; however, the authors state that “tone melodies on Quiaviní Zapotec vowel complexes [syllable nuclei] are derived from the number and phonation type of the vowels in the complex and its phonological environment rather than representing primary contrasts” (Munro & Lopez, 1999, p. 3).

According to Munro and Lopez (1999), the chart below presents the major vowel patterns (syllable nuclei) in Quiaviní Zapotec. These vowels are represented with the vowel *a* (and with *ia* for patterns that occur only with diphthongs). Each vowel pattern includes one example, its derived tone, and its combination form.[2]

[1] The glottal stop is analyzed as a property of the vowel rather than as an independent consonant. I discuss this issue in detail in Chapter 6.

[2] According to Munro et al (2008, Unida 1, p. 32) “many Valley Zapotec words shorten to simpler COMBINATION FORMS when endings are added to them, or when they occur with other words following them.”

Table 3. Munro and Lopez (1999, p. 4) Quiaviní Zapotec vowel patterns

	Pattern	Combination	Examples	Tone
1	*aa*	*aa* (same)	*rdaa* ‘gets bitter’	high
2	*iia*	*ia*	*badiia* ‘roadrunner’	high
3	*a’*	*a'* (same)	*tyo'p* ‘two’	high
4	*ah*	*ah* (same)	*zah* ‘grease’	low
5	*ahah*	*ah*	*bihih* ‘air’	low
6	*àa*	*àa* (same)	*bòo* ‘charcoal’	low
7	*a'a*	*a'a* (same)	*gyi'izh* ‘city person’	rising
8	*a'aa*	*a'a*	*chi'iinnzh* ‘bedbug’	rising
9	*àaa*	*a'a*	*nnàaan* ‘mother’	rising
10	*àaa'*	*a'a*	*rsìii’lly* ‘morning’	rising
11	*a'ah*	*a'* (final), *a'ah* (same; non-final)	*zhi'ih* ‘nose’	falling
12	*a'ahah*	*a'ah*	*gahll* gui'ihihzh ‘sickness’	falling
13	<u>*a'aah*</u>	*a'ah*	*be'euh* ‘turtle’	falling
14	<u>*a'aha*</u>	*a'ah*	*re'ehiny* ‘blood’	falling
15	*aa'ah*	*aa'* (final)*, a'ah* (same; non-final)	*baa'ah* ‘earlier today’	falling
16	<u>*a'aa'*</u>	*aa'*	*bi'ii'by* ‘pipe (plant)’	falling
17	*aa'*	*aa'* (same)	*bax:aa't* ‘toad’	falling
18	<u>*a'àa*</u>	*àa*	*zhi'ìilly* ‘sheep’	falling
19	*ààa'*	*àa'*	*bèèe'll* ‘snake’	falling
20	<u>*a'àa'*</u>	*àa'*	*zhi'ìi'zh* ‘pineapple’	falling
21	*àa'ah*	*àa'*	*bàa’ah* ‘eyeball’	falling
22	<u>*ààa'ah*</u>	*àa'*	*rcwààa'ah* ‘throws’	falling
23	*àa'*	*àa'* (same)	*bèe’ll* ‘sister’	falling
24	*àa'a+n*	*àa'a* (same)	*zhìi'iny* ‘son’	falling
25	<u>*aàa'ah*</u>	*aàa'*	*rloòo'oh* ‘floods’	falling
26	*aàa'*	*aàa'* (same)	*zhiìi'lly* ‘cotton’	falling
27	<u>*aahah*</u>	*aah*	*iihahz* ‘year’	falling
28	<u>*iiah*</u>	*aah*	*cu'liiahd* ‘altar boy’	falling
29	*aah*	*aah* (same)	*baahlly* ‘flame’	falling
30	<u>*àah*</u>	*àah* (same)	*rzùahz* ‘gets drunk’	falling
31	<u>*ahaha*</u>	*aha*	*curehehizh* ‘cabbage’	falling
32	<u>*aaha'*</u>	*aha'*	*barcwiaha'cw* ‘bwitch’	falling
33	<u>*aha'*</u>	*aha'* (same)	*nsehe's* ‘fast’	falling

In Munro et al. (2008), these 33 vowel patterns are reduced to 20. The 13 vowel patterns that were not included in this work are underlined in the table above. In this dissertation, I refer most of the time to the original Zapotec dictionary vowel patterns (Munro & Lopez, 1999), but I also commonly cross-reference the simplification in Munro et al. (2008), and both analyses are considered in the concluding chapter.

Clearly, tone and phonation represent the most challenging issues in the phonology of Quiaviní Zapotec. Munro and Lopez' (1999) analysis is the first comprehensive account for these issues, with particular focus on the orthographic representation as part of the Quiaviní Zapotec dictionary. These authors, nonetheless, acknowledge that "our analysis of San Lucas Quiaviní Zapotec tone and phonation is ongoing" (Munro & Lopez, 1999, p. 5). Based on their previous work, this dissertation seeks to continue this analysis. In addition, the present work acknowledges and adopts many aspects of Munro and Lopez (1999), including the consonant and vowel inventory, the fortis/lenis distinction among both obstruents and sonorants, the tone melodies (high, low, rising, falling), the four-way phonation contrast, the stress and loanword description, and basically all the morphosyntactic analysis.

In what follows, I present a synopsis of my analysis of tone and phonation types in Quiaviní Zapotec, developed in subsequent chapters. I argue that tone is contrastive. The analysis is presented in detail in Chapter 3. Here, I illustrate the tone melodies with the following minimal and near-minimal sets.

(2)	a. High tone	/ ʒi / ˥ → [ʒíː]	'tomorrow'
	b. Low tone	/ ʒi / ˩ → [ʒìː]	'quite'
	c. Rising tone	/ ʒilj / ˩˥ → [ʒǐːlʲ] [3]	'saddle'
	d. Falling tone	/ ʒilj / ˥˩ → [ʒîːlʲ]	'sheep'
	e. High tone	/ nda / ˥ → [ndáː]	'bitter'
	f. Low tone	/ nda / ˩ → [ndàː]	'sensitive'
	g. Rising tone	/ dad / ˩˥ → [dǎːð]	'father'
	h. Falling tone	/ nda̰ / ˥˩ → [ndâ̰ː]	'hot'[4]

[3] Underlyingly, glides are represented as / j, w /, which basically correspond to a vocalic segment without a mora. On the surface, they may have different realizations, such as secondary articulation of a consonant (e.g. / ʒilj / ˩˥ → [ʒǐːlʲ] 'saddle'), as a palatal nasal (e.g. / ʒiʔnj / ˥˩ → [ʒíʔìɲ] 'son'), or as part of the onset (e.g. /njet/ ˥ → [njét] 'Anita').

[4] As we will see in Chapter 3, falling tone is mostly found with non-modal voice. In order to keep this contrastive set as similar as possible, the voice quality of the last example is creaky.

As the examples above illustrate, in the underlying representation (UR), tone is transcribed with the tone letters ˥ ˩ ˩˥ ˥˩, whereas in the surface form it is indicated with the accent symbols: [é è ê ě]. Both are equivalent IPA symbols to represent tone; nonetheless, the accent marks allow for a more precise phonetic transcription, necessary, for example, in diphthongs (e.g. / beu / ˥˩ → [béù] 'moon') and non-modal vowels (e.g. /n-gaʔ/ ˥˩ → [ŋgáˀà] 'green'). This convention is adopted throughout the dissertation. Vowel length is not lexically contrastive, but is prosodically relevant (Chapters 2 & 3), and is therefore only indicated in phonetic transcriptions of surface forms.

With respect to Quiaviní Zapotec phonation types, different acoustic analyses and phonetic experiments in the subsequent chapters support the four-way contrast in Quiaviní Zapotec proposed by Munro and Lopez (1999). However, I reanalyze some of the Munro and Lopez (1999) vowel patterns and advocate explaining some of the surface complexity as phonetic implementation of phonological features (Chapters 6 & 7). These contrasts are illustrated by the following contrastive sets.[5]

(3)	a.	Modal	/ be /	→ [beː]	'mesquite bean'
	b.	Breathy	/ be̤ /	→ [be̤ː]	'mold (growth)'
	c.	Creaky	/ ḛ /	→ [ḛː]	'notch made in a sheep's ear'
	d.	Interrupted	/ beˀ /	→ [beˀe]	'mushroom'
(4)	a.	Modal	/ lat /	→ [lat]	'(tin) can'
	b.	Breathy	/ la̤t /	→ [la̤t]	'place'
	c.	Creaky	/ la̰ts /	→ [la̰ts]	'flat area'
	d.	Interrupted	/ naˀ /	→ [naˀa]	'heavy'

Phonation types refer to the manner in which vocal folds vibrate. Quiaviní Zapotec includes *modal* voice, which consists of regular vibration of the vocal folds (the standard vibration type), *breathy* phonation (or murmur), where the folds are held partly apart while the vibration continues, *creaky* voice, where folds are held stiffly and vibration is partially inhibited, and *interrupted* vowels, represented as modal voice followed by a

[5] In order to reduce the amount of information and to focus on phonation types, I have left out tone from the transcriptions.

glottal closure. Both creaky and interrupted vowels are referred to as laryngealized vowels. Interrupted, which can also be referred to as glottalized voice, is controversial as a unified phonation type. However, there is solid evidence for analyzing the glottal feature as part of the vowel, and not as an independent segment in Quiaviní Zapotec (Chapter 6). Cross-linguistically, the literature on voice qualities supports glottalized voice as a possible laryngeal setting (Gordon & Ladefoged, 2001; Edmondson & Esling, 2006, among others). In my analysis of Quiaviní Zapotec, interrupted vowels / $a^{ʔ}$ / may be realized as either checked, [aʔ] (with high tone), or rearticulated, [$a^{ʔ}a$] (with low and falling tones). This terminology will be used throughout this work.

As anticipated, tone and phonation interact closely in Quiaviní Zapotec. Table 4 illustrates this interaction.

Table 4. Tone and phonation co-occurrence in Quiaviní Zapotec

	High	Low	Falling	Rising
Modal	√	√	√	√
Breathy	X	√	√	X
Creaky	√	√	√	X
Interrupted	√	√	√	X

Modal vowels may have all four tones. Within non-modal phonation, breathy vowels appear with low and falling tones, whereas laryngealized vowels, both creaky and interrupted, appear with high, low and falling tones. This distribution will be exemplified and analyzed in detail in Chapters 6 and 7.

1.2.4 Phonotactics

The phonotactics of a language are concerned with restrictions on the permissible combinations of phonemes. They define permissible syllable structure, consonant clusters, and vowel sequences by means of phonotactic constraints. These conditions and constraints will be important in the following chapters, in defining characteristics of prominent syllables and tone-bearing segments, among other things. This section is based on the Quiaviní Zapotec dictionary (Munro & Lopez, 1999).

Languages of the world differ in their syllable phonotactics. Some languages are extremely restrictive and allow only CV sequences; others allow more complex structures both in the margins and nuclei. Across languages, segments are organized into well-formed sequences according to universal principles of segment sequencing. The organization of segments within the syllable (and possibly across syllables) is traditionally assumed to be driven by principles of sonority, a property that ranks segments along a hierarchy from most sonorous to least sonorous. A number of strong cross-linguistic tendencies on the distribution and sequencing of segments are explained with reference to the sonority hierarchy, where obstruents (subdivided into stops and fricatives) have the lowest sonority and vowels are the most sonorous.

(5) Sonority Hierarchy (SH): O(bstruent) < N(asal) < L(iquid) < G(lide) < V(owel)

Principles such as the Sonority Sequencing Principle, introduced as early as the 19th century by Sievers (1881), and later by Jespersen (1904), explains, for instance, the tendency, within a syllable, for more sonorous segments to stand closer to the syllable peak than less sonorous ones.

(6) Sonority Sequencing Principle (SSP)
Sonority increases towards the syllable peak and decreases towards the syllable margins

With respect to Quiaviní Zapotec, all consonants may appear in singleton onsets and singleton codas. As for consonant clusters, this language has a wide variety of sequences. Below, I present all licit clusters in onset position in terms of sonority (manner of articulation). As the purpose of these examples is to illustrate consonant sequences, a phonemic transcription is sufficient. Examples in this study are always presented with morphological boundaries; verbs are shown in the habitual form.

(7) CC *Rising sonority*

stop + fricative	/ bse / [6]	'José'	(< Sp. *José*) [7]
stop + nasal	*None*		
stop + liquid	/ bli̤a̤n /	'jackrabbit	
	/ glob /	'balloon'	(< Sp. *globo*)
stop + glide	/ gja̤x /	'tree'	
fricative + nasal	/ ʃnia /	'red'	
fricative + liquid	/ fɾuat /	'fruit'	(< Sp. *fruta*)
fricative + glide	/ baɾʃje̤k /	'mountain turkey'	
nasal + liquid	/ nɾḛinjdṵa̰t /	'soft and tender'	
nasal + glide	/ nja /	'clean'	
liquid + glide	/ ljḛʐ /	'misfortune'	

(8) CC Equal sonority

stop + stop	/ bdo̰ /	'baby'
fricative + fricative (+ glide)	/ fsjuan /	'coral snake'
nasal + nasal	/ mna̰ /	'woman'
liquid + liquid	/ ɾ-lo̰ /	'floods'
glide + glide	*None*	

(9) CC Reversed sonority

fricative + stop	/ ʃtḛ /	'of, about'	
nasal + stop	/ n-dṵa̰ʃ /	'powerful'	
nasal + fricative	/ n-sual /	'blue'	(Sp. *azul*)
liquid + stop	/ ɾ-gḛz /	'hugs'	
liquid + fricative	/ ɾsillj /	'early morning'	
liquid + nasal	/ ɾmudj /	'medicine'	(< Sp. *remedio*)
glide + stop (+ glide)	/ wbwi̤ʒ /	'sun'	
glide + fricative (+ glide)	/ wʒjar /	'spoon'	(< Sp. *cuchara*)
glide + nasal (+glide)	/ wnja̰ /	'traditional healer'	
glide + liquid	/ wli̤a̤z /	'daughter-in-law'	

[6] In sequences of lenis stop plus another segment, the initial consonant may be fricated, e.g. /bse/ → [bse ~ βse] 'José'; or /bdo̰/ → [bdo ~ βdo̰] 'baby' below (the latter creates a reversed sonority cluster).

[7] Following the convention of the Quiaviní Zapotec dictionary (Munro & Lopez, 1999), after borrowings I include in parentheses the symbol < Sp. and the Spanish spelling of the source word.

One could question whether the reversed sonority clusters in (9) are tautosyllabic, since they go against the SSP. The question of their syllabicity, however, falls outside of the scope of this dissertation; I will assume these sequences form complex onsets and, therefore, that the SSP plays only a restricted role in determining the phonotactics of Quiaviní Zapotec.

The table below summarizes the possible consonant sequences in onset position in Quiaviní Zapotec. The only sequences not attested are stop + nasal and glide + glide.

Table 5. Phonotactics of onset consonant clusters by sonority (mode of articulation)

C1↓	C2→	Stop	Fricative	Nasal	Liquid	Glide
Stop		√	√	*	√	√
Fricative		√	√	√	√	√
Nasal		√	√	√	√	√
Liquid		√	√	√	√	√
Glide		√	√	√	√	*

These gaps seem to be systematic ones. The cluster stop + nasal is banned in many languages (e.g. English), and even more so is the glide + glide sequence (Greenberg, 1965, 1978).

Consonant clusters in coda position are less common than in onset. In the native lexicon, practically the only native underlying sequence seems to be a consonant + glide,[8] which surface as a complex segment in the form of stops with secondary articulation, either labialization (for dorsals, e.g. [kʷ, g ʷ, xʷ]) or palatalization (for coronals, e.g. [dʲ, ɲ, lʲ]).

(10) *Native words*

a. / bḛkw / → [bḛˀkʷ] 'dog'

b. / bṳdj / → [bṳ͡ṳð̥ʲ] 'chicken'

[8] The native coda cluster /lꞏ+d/ appears in the QZ dictionary, but all these cases seem to be phonetic alternations derived from a simple fortis /lꞏ/. E.g. *rzàa'll, rzàa'lld* 'drops', *behll, behlld* 'fish'.

The detailed analysis of these segments is beyond the scope of this dissertation. Following Munro and Lopez (1999), I will assume they are separate segments underlyingly.

Other sequences are found in loanwords. Apart from single coda consonants (examples above), loanwords present coda clusters of two and, rarely three consonants.

(11) *Loanwords*

a. / liebɾ /	'book'	(< Sp. *libro*)
b. / alt /	'tall'	(< Sp. *alto*)
c. / mandaɾjenˑd /	'tangerine'	(< Sp. *mandarina*)
d. / njespɾ /	'loquat'	(< Sp. *níspero*)

With respect to the syllable nucleus, this constituent has to be occupied by a vowel; there are no syllabic consonants, although more research on the topic is necessary, especially with respect to consonant clusters that go against the Sonority Sequencing principle. Below, I present examples of all six Quiaviní Zapotec vowel qualities, / a e o i u ɨ /, in both monosyllabic and disyllabic words.

(12) Quiaviní Zapotec Vowels

Monosyllabic words

a. / gaz /	→ [gaːz]	'seven'	
b. / ge̤s /	→ [ge̤sː]	'clay pot, earthenware pot'	
c. / ʂop /	→ [ʂopː]	'six'	
d. / giʒ /	→ [giːʒ]	'city person'	
e. / ɾ-dṵb /	→ [ɾ-dṵːb]	'sweeps'	
f. / tsɨ̰ ~ tsɨ̰a /	→ [tsɨ̰ː ~ tsɨ̰ːa]	'ten'	

Disyllabic words

g. / sjuda /	→ [sju.ˈdaː]	'city'	(< Sp. *ciudad*)
h. / juhkwḛl /	→ [juh.ˈkwḛːl]	'type of yellowish clay'	
i. / teʔblo̤ /	→ [teʔ.ˈblo̤ː]	'flat'	
j. / giˈʒillj /	→ [gi.ˈʒillʲ]	'chair'	

k. / candṵb / → [can.ˈdṵːb] ‘is sweeping’
l. / bageiʒ ~ bagɨiʒ / → [ba.ˈgeiːʒ ~ ba.ˈgɨiːʒ] ‘fly’

Quiaviní Zapotec vowels may be combined to form a number of diphthongs (Munro & Lopez, 1999, p. 3): / ai, au, ei, eu, ia, ie, iu, ua, ue, ɨi /, as well as other diphthongs that may appear in certain Spanish loanwords. Consider the following examples (both rising and falling diphthongs). Vowel duration on diphthongs is comparable to with monophthongs, and is addressed in Chapter 7.

(13) Quiaviní Zapotec Diphthongs

a. / ɾ-a̰ḭ /	→ [ɾa̰ˑḭ]	‘gets cooked’	
b. / kau /	→ [kau]	‘Claudia’	
b. / ge̤i̤ʒ /	→ [gè̤i̤ʒ]	‘town’	
c. / gḛṵ /	→ [gḛˑṵ]	‘river’	
d. / gjia̰ /	→ [gʲḭˑa̰]	‘flower’	
e. / njienj /	→ [ɲieˑɲ]	‘is audible’	
f. / bien /	→ [biˑen]	‘wine’	(< Sp. *vino*)
g. / bjiṳ /	→ [bjiṳ]	‘ground up’	
h. / bangual /	→ [ban.ˈguˑal]	‘elder’	
i. / ɾ-dṵa̰ʒ /	→ [ɾdṵˑa̰ʒ]	‘finishes’	
j. / luas /	→ [luas]	‘light’	(< Sp. *luz*)
k. / rued /	→ [rueˑd]	‘wheel’	(< Sp. *rueda*)
l. / n-kwɨibj /	→ [nkwɨibj]	‘new’	(< Sp. *nuevo*)

1.2.5 Morphosyntax

The goal of this section is to provide an overview of the basic morphosyntactic properties of Quiaviní Zapotec. Many of these properties will be considered when presenting the data in the following chapters, particularly in the metrical structure chapter, where morphologically complex words are analyzed.

This section largely draws from the Quiaviní Zapotec dictionary (Munro & Lopez, 1999), as well as from Lee (2006); the orthography used in this section is from Munro and Lopez (1999).

The basic word order in Quiaviní Zapotec is VSO. This can seen in the following examples:

(14) *R-gwèe'* *Chie'cw* *Dìi'zhsah*
HAB-speak Chico Zapotec
'Chico speaks Zapotec'

(15) *B-guhty* *bèe'll* *bzihihny*
PERF-kill snake mouse
'The snake killed the mouse'

Quiaviní Zapotec also allows SVO and OVS word orders when the fronted argument is interpreted with contrastive focus:

(16) *Bèe'll* *b-guhty* *bzihihny*
snake PERF-kill mouse
'The snake killed the mouse' / 'The mouse killed the snake'

(17) *Bzihihny* *b-guhty* *Bèe'll*
mouse PERF-kill snake
'The mouse killed the snake' / 'The snake killed the mouse'

As seen in the previous examples, Quiaviní Zapotec lacks overt case marking. When arguments are fronted, the thematic role of arguments is ambiguous. Embedded clauses generally appear without complementizers or other markers of subordination and their word order is identical to that of matrix clauses.

As Lee (2006, p. 7) points out, Quiaviní Zapotec "shows the canonical features of most VSO languages: it has prepositions rather than postpositions, adjectives generally follow nouns, relative clauses are head-initial, and possessive constructions are possessor final".

Quiaviní Zapotec uses body part words as prepositions (grammaticalized nouns), for instance, *lohoh* 'face' is used as a preposition meaning 'at' or 'on'; *laa'iny* 'stomach' means 'inside' in its prepositional use; and *dehts* 'back' conveys the meaning of 'back side, behind'. The grammatical analysis of these types of words is provided in detail in Lillehaugen (2003, 2005).

(18) *loh* *yu'uh* 'in front of the house'
face/PREP house

(19) *dehts* *yu'uh* 'in the back of (behind) the house'
back/PREP house

(20) *laa'iny* *yu'uh* 'inside the house'
stomach/PREP house

Nouns without determiners or quantifiers can be interpreted as either definite or indefinite entities, and either singular or plural. The use of the plural marker *ra* is optional.

Possessive constructions are possessor-final. The possessed nominal is preceded by the possessive marker / ʂ̰-, ʃ- / (*x:-, x-*) and followed by the possessor (Lee, 2006, p. 9):

(21) *x:-ca'rr* *Wsee* 'Joe's car'
POSS-car Joseph

An alternate possessive construction, which apparently does not differ in usage or meaning from the one shown above, is formed with the possessed nominal *x:tèe'* (or *x:tèe'n*):

(22) *x:-me's-a'* 'My teacher'
POSS-teacher-1S

(23) *me's* *x:-tee'n-a'* 'My teacher'
teacher POSS-1S

Verbal morphology

Quiaviní Zapotec verbs can take complex forms. Besides carrying standard inflectional features (tense and agreement), they may also carry additional morphological material encoding direction, causation, manner, and modality, among other things.

Following a long-standing tradition in Zapotec linguistics, Quiaviní Zapotec aspectual and mood prefixes are classified under the broad category of aspectual prefixes (Munro 2006). Further, Lee (2006) argues that these markers can also express tense covertly. Table 6 illustrates the seven inflectional prefixes of Quiaviní Zapotec, along with the verbal paradigm of *rtàa'az* 'beats'.

Table 6. Quiaviní Zapotec aspectual prefixes (adapted from Lee, 2006, p. 11)
Terminology from Munro and Lopez (1999)

		Prefix	-*tàa'z* (beat)	Translation
Aspect	Habitual	*r-*	***r****tàa'aza'*	'I beat (regularly)'
	Progressive	*ca-*	***ca****tàa'aza'*	'I am/was beating'
	Perfective	*b-, w-, gu-, m-*	***b****tàa'aza'*	'I beat'
	Neutral[9]	*n-, ∅-*	—	
Mood	Irrealis	*y-, chi-, g-, l-*	***y****tàa'aza'*	'I will beat'
	Definite	*s-, z-*	***s****tàa'aza'*	'I will surely beat'
	Subjunctive	*n-, ny-*	***n****tàa'aza'*	'I was going to beat'

Quiaviní Zapotec verbs obligatorily appear with aspect markers, but no more than one is permitted (no stacking). Furthermore, there are neither bare nor infinitive forms.

Adapted from Lee (2006: 27), (24) schematizes the internal structure of Quiaviní Zapotec verbal morphology.

(24) Quiaviní Zapotec verbal morphology (based on Lee 2006: 27)

ASP (DIR/CAUS) ROOT (APPL/INT)(ADV)(SUBJECT CLITIC)(OBJECT CLITIC)

Verbal morphology is illustrated with the verb *rda'uh* 'eats' in perfective form in the following examples. Samples are presented on the left-hand side, whereas morpheme-class labels appear on the right-hand side.

[9] The neutral prefix appears on a small number of mostly stative or locational verbs. It also has been analyzed as an affix used to derive adjectives (R. Rojas & T. Smith-Stark, personal communication, April 2008).

(25) <u>*B-da'uh*</u> *nàa'* ASP-ROOT
PERF-eat 1s
'I ate'

(26) *B-<u>t-</u>a'uh* *nàa'* ASP -DIR-ROOT
PERF-*DIR*-eat 1s
'I went to eat / I went and ate'

(27) *B-<u>z-</u>a'uh* *nàa'* *Gye'eihlly* ASP -CAUS-ROOT
PERF-*CAUS*-eat 1s Mike
'I made Mike eat'

(28) *B-da'uh<u>=a'</u>* ASP -ROOT=SUBJECT CLITIC
PERF-eat=*1s*
'I ate'

Pronouns and Pronominal clitics

Quiaviní Zapotec has no subject agreement morphology; pronominal subjects appear as clitics that follow the verb stem.

Table 7. Quiaviní Zapotec pronouns and clitics
(adapted from Lee 2006; and Munro & Lopez, 1999)

	Pronoun	Clitic	Gloss
1s	*nàa'*	*-a'*	'I'
2s informal	*liu'*	*-u'*	'you (informal)'
2s formal	*làa'yuu*	*-yuu'*	'you (formal)'
3s proximate	*la'anng*	*-ëng*	'he/she/it (nearby)'
3s distal	*la'ai*	*-ih*	'he/she (out of sight)'
3s formal	*làa'b*	*-ëb*	'he/she (formal)'
3s animal	*làa'mm*	*-ëmm*	'he/she/it(animal/child)'
1p	*dannoohnn*	*-ënn*	'we'
2p informal	*làa'd*	*-ad*	'you (plural, informal)'
2p formal	*làa'yuad*	*-yùad*	'you (plural, formal)'
3p proximate	*làa'rëng*	*-rëng*	'they (nearby)'
3p distal	*làa'rih*	*-rih*	'they (out of sight)'
3p formal	*làa'rëb*	*-rëb*	'they (formal)'
3p animal	*làa'rëmm*	*-rëmm*	'they (animals/children)'

Quiaviní Zapotec pronouns and clitics are semantically rich. Munro and Lopez (1999) observe four distinct levels of reference to living beings in third-person pronouns, depending on age and social status. Two other forms of reference, the distal and proximate, are determined by the proximity of the referent to the speaker (See also Munro, 2001).

Suffixes

Quiaviní Zapotec makes use of different types of suffixes, including adverbial suffixes (Munro, 2006) and the diminutive suffix. The latter is one of the major types of derived nominal forms and its frequency is high. (See Munro et al. (2008) for details on the diminutive suffix analysis, and variation.)

(29) a. *bra'au-e'eh* 'little lizard'
lizard-DIM

b. *zhyàa'p-e'eh* 'little girl'
girl-DIM

In conclusion, this chapter has provided an overview of the phonological and morphosyntactic characteristics of Quiaviní Zapotec. This serves as a background for the rest of the dissertation, where the metrical structure, tone and phonation types of this language are analyzed in detail.

Chapter 2:

Vowel length and the fortis/lenis distinction in Quiaviní Zapotec

2.1 Introduction

Vowel-length in Zapotec languages has been a matter of some contention in terms of whether it is lexically specified, prosodically, or segmentally determined. In Quiaviní Zapotec, this issue closely interacts with the fortis/lenis distinction, which is pervasive in the consonantal system of this language (Munro & Lopez, 1999). This chapter demonstrates that vowel length in Quiaviní Zapotec is dependent on the type of syllable and on the type of coda consonant: stressed vowels are short before fortis consonants (both obstruents and sonorants), and long before lenis consonants or in open syllables. As such, the categorization of this vowel length pattern relies on the fortis/lenis contrast, which in turn involves a complex set of phonetic properties of unclear phonological status.

Phonological research from a variety of language stocks (Indo-European, Austronesian, Niger-Congo, Afro-Asiatic, Otomanguean, Mixe-Zoque, Athabaskan, Pama-Nyungan, North Caucasian (see Kohler, 1984; and DiCanio, 2008, for an overview)) describes consonants with a *fortis/lenis* contrast. These terms are generally considered to capture a contrast in articulatory strength, where articulations are produced with greater versus lesser muscular or pulmonic force. Despite similar phonetic correlates in languages with a fortis/lenis distinction (such as length, voicing, intensity (Jaeger, 1983; Avelino, 2001; DiCanio, 2008, among others)), the precise manifestation of the fortis/lenis distinction seems to be language-specific, with no universal phonetic property.

Such variation in phonetic correlates can be found in a range of phonological phenomena and features. Among others, the tense/lax categories in vowels are vague in terms of their specific phonetic correlates (Jakobson, Fant, & Halle, 1951, p. 38, see definition below), but their phonological status is crucial in several languages (e.g. for English high vowels). Stress, like other prosodic phenomena, is another relevant example for this discussion (see Kenstowicz, 1994; Hayes, 1995). Acoustic correlates of stress include pitch, duration and intensity, among others, but none of these can be unambiguously and universally associated with prominent syllables. In other words, what distinguishes one category (e.g. fortis, tense, stressed, etc.) in a particular language may differ from what distinguishes it in another language.

What unifies all these phenomena is that they can be encoded by a composite of properties, including both language-specific phonetic and phonological characteristics of the attested distinctions. Based on this, it is possible to postulate categories that most accurately correspond to those sets of properties. *Mutatis mutandis*, this is the proposal of the emergent feature approach, as represented by Mielke (2008 [2004]; see also Pulleyblank, 2006).

With this background, the goal of this chapter is to explain vowel length in Quiaviní Zapotec and establish the characteristics of the fortis/lenis distinction in this language, foundational issues for the prosodic analyses presented in subsequent chapters. The hypothesis is that several gradient properties interact to create the fortis/lenis contrast. These properties include voicing, degree of constriction, sonority, and duration, as well as phonological distribution, markedness, and prosodic prominence. As shown below, some of these characteristics crosscut both obstruent and sonorant categories. Under an emergent feature approach (Mielke, 2008 [2004]), this composite of properties can be encoded with the feature [+/-fortis] (Kohler, 1984; Pulleyblank, 2006).

This chapter is organized as follows: §2.2 describes vowel length in Quiaviní Zapotec in light of the orthography of Munro and Lopez (1999). Having established this distribution, §2.3 presents a detailed description of the full range of realizations of fortis and lenis consonants in Quiaviní Zapotec, determining the distinctive characteristics involved in their contrast. Based on the described sound patterns, §2.4 validates the use of a feature [+/-fortis] within Quiaviní Zapotec grammar.

2.2 Quiaviní Zapotec vowel length

This section shows that the type of coda consonant determines vowel length in this language. In doing so, I analyze the vowel patterns *a'* (single checked vowel /Vˀ/)[10] and *aa* (*long* vowel /VV/) in the orthography of Munro and Lopez (1999) as underlying short modal vowels.

As reflected in the Quiaviní Zapotec dictionary (Munro & Lopez, 1999), a salient feature in this language is vowel length, for which the following distribution can be drawn: In prominent syllables[11], checked vowels (*a'*) appear before fortis consonants, whereas long vowels (*aa*) are followed by lenis consonants or occur in open syllables.

(1) Short vowels (*a'*) before fortis coda consonants

a. *yuhdye'p* 'uncultivated land'
b. *Mihste'c* 'Mixtec'
c. *a's* 'hi'
d. *yze'nny* 'will arrive'
e. *rcah gye'rr* 'gets branded'

[10] Other vowel patterns from Munro and Lopez (1999) containing checked vowels are analyzed in subsequent chapters, especially in Chapter 6.
[11] In this study, I will use interchangeably the terms stressed or prominent syllable, to refer to the most salient syllable in a word based on the prosodic properties assumed by metrical theory (to be presented in the next chapter).

(2) Long vowels (*aa*) before lenis coda consonants

a. *teeby*	'only, alone'
b. *rrueeg*	'basil'
c. *wyaazh*	'rented'
d. *x:eeny*	'stupid'
e. *ma'anyseer*	'bee'

(3) Long vowels (*aa*) in open syllables

a. *bdaa*	'shadow'
b. *maa*	'girlie, little girl'
c. *ndii*	'right'
d. *canoo*	'than'
e. *zuu*	'is standing'

The Munro and Lopez (1999) orthography is extremely consistent with this pattern, particularly with obstruents. In terms of loanwords (analyzed in more detail in Chapter 3), the pattern above is also very clear.

(4) Short vowels (*a'*) before fortis coda consonants [12]

a. *la't*	'can tin'	(< Sp. *lata*)
b. *Be't*	'Alberto'	(< Sp. *Beto* < *Alberto*)
c. *Lu'c*	'Lucas'	(< Sp. *Lucas*)
d. *naba'j*	'razor'	(< Sp. *navaja*)
e. *cla's*	'class'	(< Sp. *clase*)
f. *Ba'll*	'Valeriano'	(< Sp. *Vale* < *Valeriano*)

(5) Long vowels (*aa*) before lenis coda consonants

a. *laad*	'side'	(< Sp. *lado*)
b. *Beed*	'Pedro'	(< Sp. *Pedro*)
c. *juug*	'juice'	(< Sp. *jugo*)
d. *nabaazh*	'pocket knife'	(< Sp. *navaja*) [13]
e. *laaz*	'twine'	(< Sp. *laso*)
f. *baal*	'bullet'	(< Sp. *bala*)

[12] Short vowels (*a'*) also appear before coda consonant clusters in Spanish borrowings (there are no native complex codas). This issue is analyzed in the next chapter within the loanword phonology section (§3.5).

[13] The "lexical split" between (4d) and (5d) is particularly illustrative of Quiaviní Zapotec vowel length. Even if it is not completely predictable whether the final consonant gets borrowed as fortis or lenis, the length of the vowel follows automatically from that "choice" (short vowel before fortis and long vowel before lenis).

(6) Long vowels (*aa*) in open syllables

a. *Lia Daa*	'Soledad'	(< Sp. *Soledad*)
b. *Nabidaa*	'Christmas'	(< Sp. *Navidad*)
c. *Wsee*	'José'	(< Sp. *José*)
d. *tee*	'tea'	(< Sp. *té*)
e. *rreloo*	'watch'	(< Sp. *reloj*)
f. *Chuu*	'Chuy, Jesus'	(< Sp. *Chuy*)

Despite some exceptions to this distribution,[14] this pattern clearly resembles what has been reported for several Zapotec languages.

The first work reporting vowel length in Zapotec languages is an unpublished manuscript by Swadesh quoted in Pike (1948, p. 167). Swadesh describes vowel length in several variants of Zapotec as being non-phonemic, but predictable from consonant environment. "La vocal tiende a ser corta ante el saltillo [ʔ] y ante las consonantes fuertes […], mientras que ante las demás consonantes y, en menor grado, al final de las palabras generalmente es larga." [15]

The pattern of having short vowels before fortis consonants and long vowels before lenis consonants has been described for a number of Zapotec languages, including Cajonos Zapotec (Nellis & Barbara E. Hollenbach, 1980), Chichicapan Zapotec (Smith-Stark, 2003), Yalálag Zapotec (Avelino, 2004), San Francisco Ozolotepec Zapotec

[14] Within obstruents this pattern is found for the majority of entries in the dictionary. Some potential exceptions are *bax:aa't* 'toad', *zh:aa'cw* 'cockroach', *see'st* 'sixth', *mbii'sy* 'stingy', among others. I compared the vowel duration of 20 of these potential exceptions (recorded by a Quiaviní Zapotec speaker), with the duration of 20 items with short (checked) vowels. Results show the similarity of these items: vowels with the pattern *aa'* average a duration of 82 ms versus 81 ms for *a'* items (the difference was not significant). As we will see in the next chapter, this duration corresponds to that of short vowels. Accordingly, it seems appropriate to reanalyze these *aa'* vowel patterns as short vowels.

Among sonorants, differences were also non-significant for nasals when comparing apparent exceptions like *Juu'nny* 'June' versus items with the vowel pattern *a'*. For liquids, apparent exceptions include long vowels followed by fortis liquids, such as *bchiilly* 'knife' or *ganiilly* 'ring'. The results for these words were in the opposite direction, as the vowels were in fact long (~150 ms), but the coda consonants were too short to be considered fortis (below 100 ms). The fortis/lenis distinction among sonorants is challenging because the difference relies only on duration. This asymmetry has also been found with other vowel patterns, including non-modal phonation as in *rguìi'lly* 'waters', which seems to have a long vowel followed by a lenis sonorant (see fortis/lenis duration differences in coda in the acoustic comparison for the creaky vowels section of Chapter 6).

[15] "Vowels tend to be short before glottal stop and fortis consonants, whereas before the rest of the consonants and, to a lesser degree, in utterance final position they are generally long." [*Translation mine*]

(Leander 2008), Quioquitani Zapotec (Ward, Sánchez, & Marlett, 2008), and San Pablo Güilá Zapotec (Arellanes, 2009), among others. In what follows, I would like to draw the reader's attention to some of these analyses, where a clear relationship between prosody and the vowel and consonant duration has been reported.

For Cajonos Zapotec, Nellis & Hollenbach (1980, p. 93) state the following: "All fortis consonants are lengthened following a vowel with primary stress, whereas stressed vowels are themselves lengthened preceding a lenis consonant. This lengthening serves to maintain a fairly constant length for stressed syllables […] and provides an additional distinction between the two series [fortis versus lenis]." Smith-Stark (2003, p. 124) describes a similar relation between vowel and consonant length in Chichicapan Zapotec: "Las raíces simples de dos sílabas varían en la duración de la vocal tónica [referring to the first syllable]. Si la consonante intermedia es débil […], la vocal tónica se alarga; si es fuerte […], la vocal tónica es breve y la consonante intermedia se alarga".[16] In sum, Smith-Stark reports that a stressed vowel followed by a lenis consonant is lengthened, whereas if followed by a fortis consonant the vowel is shortened and the fortis consonant is lengthened.

For Quiaviní Zapotec, Munro and Lopez (1999, p. 2) state: "Some phonological rules refer to the classes of fortis and lenis consonants. The main such rule lengthens otherwise identical vowels or vowel sequences before lenis (but not fortis) consonants, which is generally comparable to the behavior of fortis versus le nis consonants in other Zapotec languages, as described, for example, by Nellis and Hollenbach (1980) and Jones and Knudsen (1977)". Despite noting the predictability of vowel duration differences, Munro and Lopez (1999) nonetheless encode these vowel-length differences in the orthography. Phonologically, however, since this length is predictable (i.e. not contrastive), it is possible to analyze the vowel pattern *aa* (long surface vowel) as an

[16] "Simple disyllabic roots vary with respect to the duration of the stressed vowel [in the first syllable]. If the intermediate consonant is lenis […], the stressed vowel is lengthened; if it is fortis […], the stressed vowel is shortened and the intermediate consonant is lengthened." [*Translation mine*]

underlying short modal vowel /a/, which in prominent positions lengthens in open syllables and before lenis coda consonants: /a/ → aː / _ $(C_{lenis})]_{\sigma}$.[17]

Related to this short/long vowel distribution, I argue that checked vowels in content words should be reanalyzed as short modal vowels; specifically I refer to vowels followed by fortis (voiceless) stops. Let us examine this issue in more detail by reviewing some examples to investigate the voice quality of this vowel pattern.

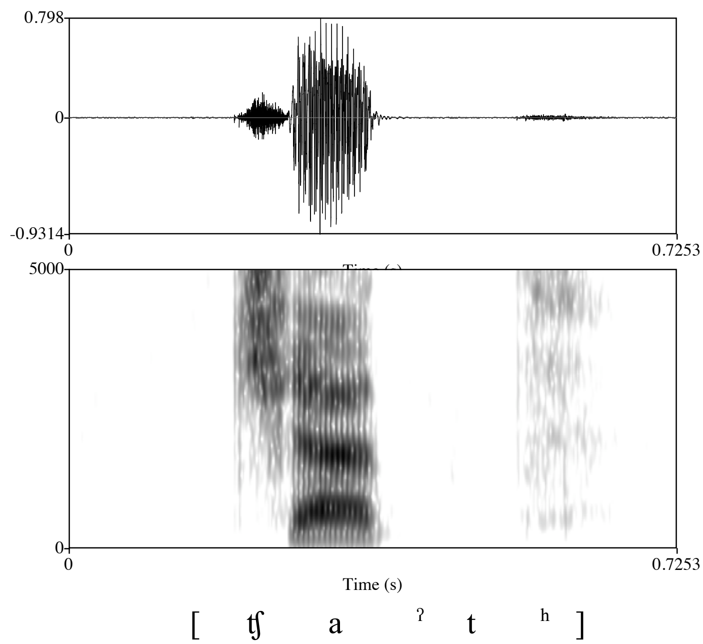


Figure 1. Waveform and spectrogram of *cha't* [tʃaˀtʰ] 'kiss' by male speaker TiuL[18] (sound file from Munro et al., 2008).

[17] Another conceivable analysis would be that long vowels shorten before fortis consonants. This is rejected on the basis that vowel length is not lexically contrastive (as noted by Munro & Lopez, 1999, p. 2 and confirmed in my fieldwork research). Moreover, phonetic long vowels only appear in prominent syllables.

[18] Throughout the dissertation, I will use the title *Tiu* —a respectful title used before a man's name— and the first letter of my consultant's name to refer to male speakers; likewise, I will refer to female speakers with the first letter my consultant's name, preceded by the title *Lia* — the title used before a woman's given name.

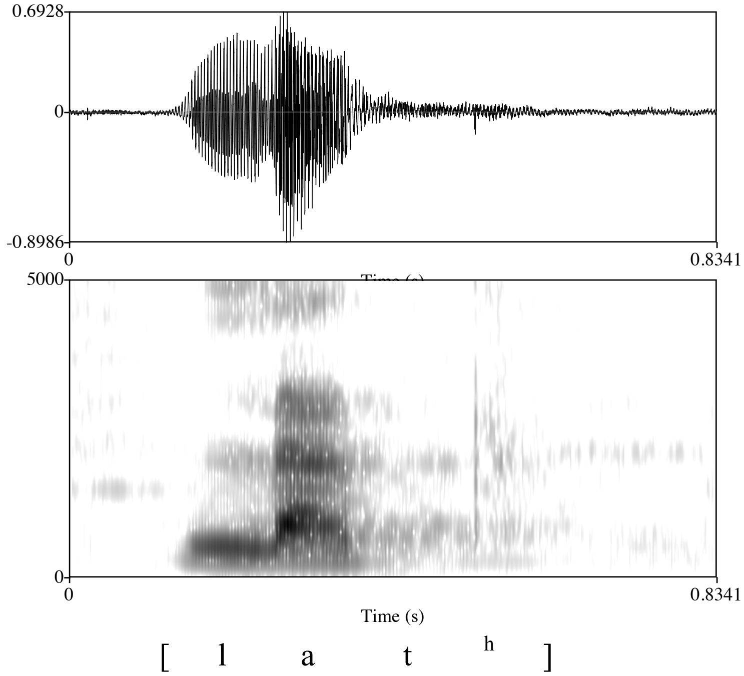


Figure 2. Waveform and spectrogram of *la'te* [lat^h] 'tin can' by female speaker LiaT.

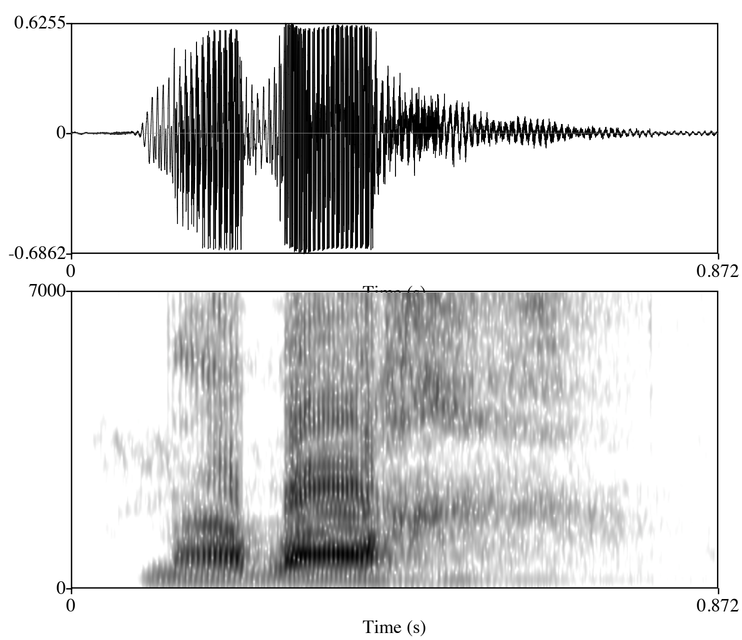
The presence of creakiness at the end of the vowel (see §4.1.1 and §6.5) and the abrupt cessation of vocal fold vibration may signal the presence of a glottal stop (the second characteristic is clearly found in Figure 1). However, these phonetic characteristics are not consistent in all the sequences of "checked" vowel plus oral stop that I have analyzed. Figure 2 illustrates a case with no glottal stop. Both the waveform and the spectrogram show that the vibration of the vocal folds does not cease immediately at the end of the vowel. In fact, it seems that the voicing bar and formant structure (echo) continue throughout the closure and (less noticeably) at the release of the stop. This vibration clearly indicates the absence of the glottal stop (which implies a complete cessation of the vocal fold vibration).

I have not found a phonetic or phonological factor to determine the presence or absence of the glottal stop; it simply seems to be variable. It is possible that the type of speech (careful/emphatic versus colloquial), or extra-linguistic factors (such as gender and age) play a role with respect to the presence or absence of the glottal stop.

In addition, fortis consonants are considerably longer in coda position compared to syllable-initially (see phonetic experiment in Chapter 3); thus, this "unusual" fortis stop length (with closure sometimes lasting more than 200ms) may be perceived as a glottal stop — whether it is articulated with the oral stop or not. (It is worth mentioning that fortis stops are long in coda regardless of the voice quality of the vowel.)

The presence of an allophonic glottal stop in the context of vowel + oral stop has also been found in other languages and dialects. Notably, this phenomenon is well documented for the British English "Received Pronunciation" (Christophersen, 1952; Roach, 2004), where coda voiceless plosives /p/, /t/, /tʃ/, and /k/ may be preceded by a glottal stop. This phenomenon is also well known for Japanese geminate voiceless stops (Sawashima & Miyazaki, 1973) and coda voiceless stops in some Chinese languages (Haudricourt, 1954; Hombert, Ohala, & Ewan, 1979). The phenomenon is called pre-glottalization or glottal reinforcement, and, as in Quiaviní Zapotec, it takes place with consonants in coda position and to a certain extent it is variable. As its name indicates, the glottal stop reinforces the oral closure, ensuring the stoppage of airflow during the closure.

I turn now to alleged cases of checked vowels followed by fortis (voiceless) fricatives. Figure 3 shows the spectrogram of *naba'j* 'razor', whereas Figure 4 provides the spectrogram of *a's* 'hello'.



[n a ˈβ a x]

Figure 3. Waveform and spectrogram of *naba'j* [naˈβax] 'razor' by male speaker TiuR.

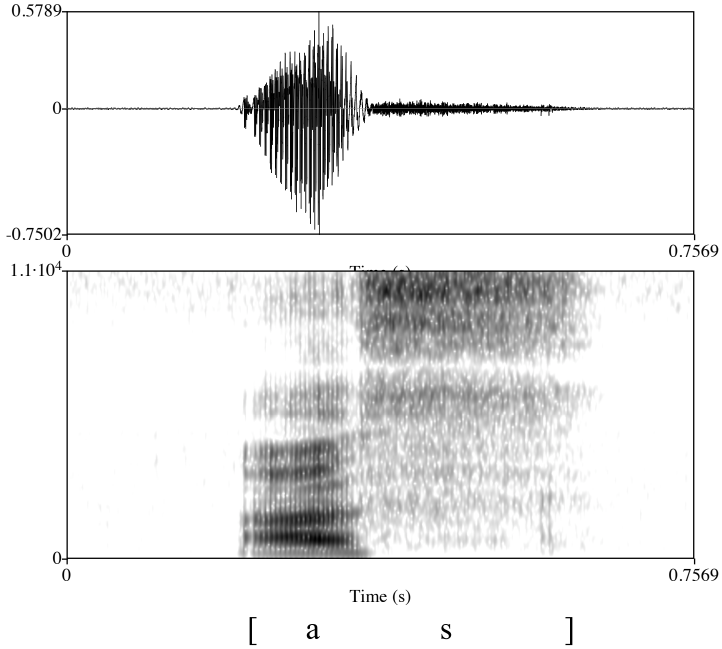


Figure 4. Waveform and spectrogram of *a's* [as] 'hi' by male speaker TiuL (sound file from Munro et al., 2008).

All the sequences I have analyzed of putative checked vowels plus fricatives show no glottalization. As the waveforms and the spectrograms in Figures 3 and 4 show, there is neither a glottal stop nor any indication of creaky voice, but rather a smooth transition from the vowel into the fricative. Other properties such as intensity, periodicity, and pitch are stable and similar to those of (prototypical) modal vowels.

Based on the above findings, I propose to reanalyze short checked vowels in prominent syllables as short modal vowels (/a/ instead of /aˀ/). In Munro and Lopez's (1999) analysis, single modal vowels were not included as part of the vowel inventory within prominent syllables.

In summary, Table 8 includes the vowel patterns *a'* (single checked vowel) and *aa* (long vowel) from the Munro and Lopez (1999) orthography, the corresponding phonemic transcription and tone, as well as the present reanalysis, where I reexamine these vowel patterns as phonemic short modal vowels.

Table 8. Vowel patterns *a'* and *aa* reanalyzed as phonemic short modal vowels

Munro and Lopez (1999)			Reanalysis	
Orthography	phonemic[19]	Tone	phonemic	Surface realization
a'	/ aˀ /	˥	/a/	[a] *before fortis C*
aa	/ aa /	˥	/a/	[aː] *before lenis C*

Table 9 presents examples of the vowel patterns under consideration. On the left side of the table, I include Munro and Lopez's (1999) orthography, a phonemic transcription and the gloss. The reanalysis, on the right, shows the proposed phonemic transcription and its phonetic realization.

Table 9. Examples of vowel patterns *a'* and *aa* with reanalysis

	Munro and Lopez (1999)			Reanalysis	
	orthography	phonemic	Gloss	phonemic	Surface realization
(7)	*tyo'p*	/ tjoˀp /	'two'	/ tjop / ˥	[tjopʰ] ~ [tjoˀpʰ]
(8)	*cha't*	/ ʧaˀt /	'kiss'	/ ʧat / ˥	[ʧatʰ] ~ [ʧaˀtʰ]
(9)	*naba'j*	/ nabaˀx /	'razor'	/ nabax / ˥	[naβax]
(10)	*a's*	/ aˀs /	'hi'	/ as / ˥	[as]
(11)	*teeby*	/ tebj /	'alone'	/ tebj / ˥	[teːβʲ]
(12)	*laad*	/ laad /	'side'	/ lad / ˥	[laːd]
(13)	*laaz*	/ laaz /	'twine'	/ laz / ˥	[laːz]
(14)	*baal*	/ baal /	'bullet'	/ bal / ˥	[baːl]

As a final note, in contrast to single checked vowels in content words, an exception to this reanalysis is clitics. First and second person singular clitics are described in the dictionary (Munro & Lopez, 1999) as containing checked vowels / aˀ /, and I agree with this specification on the basis of my own research.

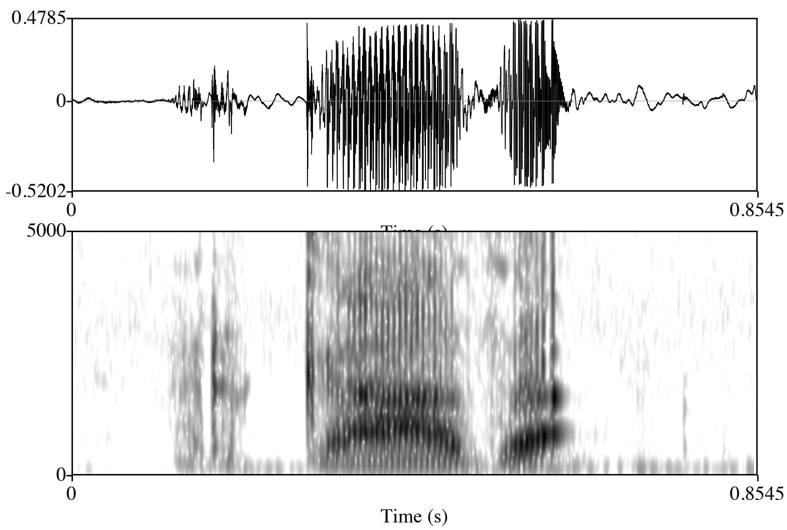
[19] Munro and Lopez (1999) do not provide a phonemic transcription of the entries in the dictionary; the orthography, however, is phonologically goal-oriented, thus, the phonemic transcription presented here is my interpretation of their orthography.

Table 10. 1s and 2s Quiaviní Zapotec clitics.

	Munro and Lopez (1999)			Reanalysis	
	orthography	phonemic	Gloss	phonemic	Surface realization
(15)	*=a’*	/ aˀ /	1s	/ aˀ / ˥	[aʔ] ~ [aᵃʔ] ~ [aʔᵃ̥]
(16)	*=u’*	/ uˀ /	2s (informal)	/ uˀ / ˥	[uʔ] ~ [uᵘʔ] ~ [uʔᵘ̥]
(17)	*=yuu’*	/ juuˀ /	2s (formal)	/ juˀ / ˥	[juʔ] ~ [juᵘʔ] ~ [juʔᵘ̥]

As with previous tables, Table 10 shows orthography, phonemic transcription and gloss for clitics according to Munro and Lopez (1999), followed by my reanalysis, along with the phonetic transcription. In these clitics, the glottal stop may be fully realized, it may be short, or it may consist of a period of creakiness. As an illustration, consider the following example.

(18) *r-càa’z=a’* / ɾka̰zaˀ / ‘I want…’
HAB-wants-1s



[ɾ kʰ a̰ z a a̰ ʔ]

Figure 5. Waveform and spectrogram of *r-càa’z=a’* [ɾkʰa̰ːzᵃa̰ʔ] ‘I want…’ by male speaker TiuT.

In the spectrogram above, the last vowel, the clitic / =aˀ /, starts with a very short period of modal phonation, followed by creaky voice (two or three pulses); after that, we observe a glottal stop. As mentioned before, short creakiness and the abrupt cessation of vocal fold vibration indicate the presence of a glottal stop; both are present in this sample. I return to the analysis of clitics in Chapter 6, §6.5.

To conclude, this section established that prominent vowels are short before fortis consonants (both obstruents and sonorants), and long in open syllable and before lenis consonants. Although the data presented here corresponds to modal voice, the prediction is that this pattern also applies for non-modal phonation (see Chapters 6 & 7). Finally, vowel length is one of several components that contribute to the fortis/lenis contrast, to which I now turn.

2.3 Fortis and lenis consonants in Quiaviní Zapotec

Fortis and lenis are controversial terms. Linguists disagree about both their definition and their validity. The terms are used to characterize a basic phonological contrast in consonant systems, which cannot be explained in terms of a simple voicing distinction. The basic claim is that one member of a contrasting pair of phonemes is produced with greater "force of articulation" than the other (Jakobson et al., 1951; Malécot, 1966; Fischer-Jørgensen, 1968; Catford, 1977, pp. 199-208; Jakobson & Waugh, 1979, pp. 135-9).[20] However, "force of articulation" refers to different phonetic aspects, hence, there is no consensus on a phonological feature that refers to a specific phonetic characteristic.

Most descriptions of systems with a fortis/lenis distinction have focused on obstruents, including the following characteristics for each class:

Table 11. Fortis/lenis characteristics (adapted from Jaeger, 1983) [21]

Fortis	*Lenis*
long (contextually)	short
voiceless	fluctuate in voicing (e.g. [b, b̥, p])
high intensity noise	lower intensity noise
closure (stops)	stop closure varies with low-amplitude frication ("stops" only)

[20] A wide range of phonetic phenomena have been included in this "force" including: pulmonic, articulatory, timing and glottal factors (see Jaeger, 1983, p. 178).
[21] Based on Yaté Zapotec and Jawoñ (an Australian language).

Jaeger (1983, p. 184) states that “the prototypical fortis obstruent is long and voiceless, with no variation in closure type, and higher amplitude noise. The prototypical lenis consonant is short, usually voiced but often voiceless, has much variation in closure type, and lower amplitude noise.” Furthermore, she mentions that the terms *fortis* and *lenis* may be considered phonological categories, which are associated with a set of phonetic cues. In what follows, this consideration is evaluated in light of the Quiaviní Zapotec data.

Munro and Lopez (1999) propose the fortis/lenis distinction as the most comprehensive and persistent contrast for consonants in this language. They maintain that “the distinctive characteristic of fortis obstruents is articulatory tension; that of fortis sonorants is increased duration” (Munro & Lopez, 1999, p. 2). This four-way contrast is illustrated in Table 12.

Table 12. The four-way contrast in Quiaviní Zapotec (fortis/lenis-obstruent/sonorant)

	Fortis	Lenis
Obstruents	√	√
Sonorants	√	√

The fortis/lenis contrast mostly occurs in pairs, as illustrated in Table 13.

Table 13. Quiaviní Zapotec fortis/lenis consonant pairs

	stops	affricates	fricative	nasals	liquids
fortis	p t k	ts ʧ	s ʃ ʂ f x	mˑ nˑ ŋˑ	lˑ r
lenis	b d g		z ʒ ʐ	m n ŋ	l ɾ

The fricative phonemes / f, x / appear only in Spanish borrowings, and along with affricates they pattern with fortis consonants (see properties below) and they do not have lenis counterparts. Within liquids, we could arguably analyze the trill and tap phonemes / r, ɾ / as a fortis/lenis pair, although apart from loanwords [r] only appears as a result of morpheme concatenation / ɾ-ɾ / → [r].

The fortis/lenis contrast is well attested in Quiaviní Zapotec, motivated by numerous minimal pairs in the Munro & Lopez (1999) dictionary. In addition, there are two morphosyntactic cases of fortition in Quiaviní Zapotec that illustrate the fortis/lenis distinction: the possessive and the causative (Munro & Lopez, 1999, p. 2).

Possessive constructions are possessor-final. The possessed nominal is preceded by the possessive marker ʂ̥- /ʃ- and followed by the possessor (Lee, 2006, p. 9):

(19) ʃ-kaɾ gje̤lʲj 'Mike's car'
POSS-car Mike

(20) ʃ-tiu-aʔ 'my uncle'
POSS-uncle-1s

When the possessed noun underlyingly begins with a lenis consonant, the initial consonant of the noun surfaces as its fortis counterpart, showing fortition.

(21) / ʃ-dad-aˀ / → [ʃtaːdaʔ] 'my father'
POSS-father-1s

With respect to the morphological causative, a subset of verbs shows fortition of root-initial lenis consonants (Lee, 2006, p. 24), as illustrated below.

(22) ɾ-**g**aʔ 'gets caught'
HAB-gets caught

(23) ɾ-**k**aʔ 'takes, gets'
HAB-take

In what follows, I present in more detail the contextual realization of Quiaviní Zapotec consonants, in order to shed light on their phonological properties (detailed descriptions of the fortis/lenis contrast in Zapotec languages include, among others, Nellis & Hollenbach, 1980; Avelino, 2001; Antonio Ramos, 2007; and Arellanes, 2009, from which I adopt the format to present the Quiaviní Zapotec data).

Fortis stops, / p t k /, “are voiceless and often aspirated” (Munro & Lopez, 1999, p. 3), particularly word-finally. In addition, these consonants are never weakened to fricatives, and they are long in coda position. This is illustrated with the following examples word-initially, in intervocalic position and word-finally.

Fortis stops: / p t k /

(24) Word-initially (#_): voiceless stops

a. / pes / ˥ → [pésː] ‘peso’
b. / tiu / ˩˥ → [tìú] ‘Mr. / uncle’
c. / kṳb / ˥˩ → [kû͡ṳɸ][22] ‘tejate (traditional beverage)’

(25) Intervocalic (V_V): voiceless stops

a. / ʃ-tjop=uˀ / ˥ ˥ → [ʃtjó.púʔ] ‘your two’
b. / ʃ-tʃat=uˀ / ˥ ˥ → [ʃtʃá.túʔ] ‘your kiss’
c. / ʃ-luk=uˀ / ˩˥ ˥ → [ʃlˑǔ.kúʔ] ‘your Lucas’

(26) Word-finally (_#): long voiceless stops

a. / tjop / ˥ → [tjópːʰ] ‘two’
b. / tʃat / ˥ → [tʃátːʰ] ‘kiss’
c. / luk / ˩˥ → [lǔkːʰ] ‘Lucas’

Lenis stops, / b d g /, “range in most positions from voiced stops to very lenited voiced fricatives” (Munro & Lopez, 1999, p. 2). More specifically, and according to my data, lenis stops tend to be fricated and voiced intervocalically, and fricated and devoiced word-finally. Word-initially, they are in free variation, fluctuating in both voicing ([voice]) and in closure width ([continuant]).

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[22] The transcription of non-modal vowels in some of these examples implies a surface sequence of modal plus non-modal phonation. These realizations are explained in detail in Chapter 6.

Lenis stops: / b d g /

(27) Word-initially (#_): voiced stops or voiced fricatives [23]

a. / ba / ꜛ → [bǎː ~ βǎ] 'already'
b. / danj / ˩ → [dàːɲ ~ ðàːjɲ] 'mountain'
c. / ge̤t / ˩ → [gè̤tː ~ ɣè̤tː] 'tortilla'

(28) Intervocalic (V_V): voiced fricatives

a. / ʃ-dub=uˀ / ˩ ˥ → [ʃtùː.βúʔ] 'your maguey'
b. / ʃ-gi̤a̤d=uˀ/ ˩ ˥ → [ʃkì̤à̤ː.ðúʔ] 'your century plant'
c. / ʃ-neg=uˀ / ˥ ˥ → [ʃnˑéː.ɣúʔ] 'your fanega (large sack)'

(29) Word-finally (_#): voiceless fricatives (most of the time) [24]

a. / dub / ˩ → [dùːɸ] 'agave, maguey'
b. / gi̤a̤d / ˩ → [gì̤à̤θ] 'century plant'
c. / xug / ˥ → [xúːx] 'juice'

Clearly, in terms of voice and manner of articulation, fortis stops (specified as [-voice] and [-continuant]) are stable regardless of the context, whereas lenis stops (*presumably* specified as [+voice] and [-continuant]) vary according to the phonological context. Since lenis stops are the most variable of all lenis consonants, I list their allophones in (30).

(30) Lenis stop allophones

Phonemes Allophones
a. / b / → [b, b̥, β, ɸ]
b. / d / → [d, d̥, ð, θ]
c. / g / → [g, g̊, ɣ, x]

[23] Word-initially and intervocalically, lenis stops may also surface as devoiced segments [b̥ d̥ g̊], but these examples show the most common realizations.

[24] Occasionally, word-final lenis "stops" appear as stops.

Note that these fricative allophones of lenis stops cannot neutralize with other lenis fricatives in the language (because there are no / β ɸ ð θ ɣ / phonemes), except for / x /; nonetheless, the phoneme / x / is relatively restricted as it only occurs in Spanish loanwords. Furthermore, /g/ is rarely devoiced in onsets (the onset alternation is mainly between [g] and [ɣ]), whereas in coda position the fricative phoneme /x/, being fortis, is always longer than the [x] allophone of /g/.

The affricates / ts / and / tʃ / are parallel with fortis obstruents, as they show the same invariant contextual characteristics in terms of voicing (always voiceless) and manner of articulation. They are also long in coda position. In accordance with LaCharité (1995), Clements (1999), among others, affricates can be grouped with stops as [-continuant] segments (strident stops). As described by Munro and Lopez (1999), there are no lenis affricates.

Fortis fricatives, / s ʃ ʂ /, are always voiceless ([-voice]) and long in coda position; whereas lenis fricatives, / z ʒ ʐ /, "are devoiced in final position" (Munro & Lopez, 1999, p. 2). However, fortis and lenis fricatives do not neutralize in coda position, as the former are always longer (see phonetic experiment in Chapter 3). This is an exact parallel to the /g/ → [x] (word-finally) vs. /x/ case discussed above. The retroflex characteristic of /ʂ ʐ/ is "a feature that varies in salience from speaker to speaker" (Munro & Lopez, 1999, p. 2). In my experience, it is quite common for retroflex segments to neutralize with their corresponding prepalatal fricatives / ʃ ʒ /. Below, I illustrate Quiaviní Zapotec fricatives. As with stops, initial, intervocalic and word-final positions are presented.

Fortis fricatives: / s ʃ ʂ̻ /

(31) Word-initially (#_): voiceless fricatives

a. / silʲ / ˥ → [síːlʲ] ‘Basilio’

b. / ʃabdi̤a̤ / ˥ ˩→ [ʃáb.dì̤à̤] ‘locust’

(32) Intervocalic (V_V): voiceless fricatives

a. / ʃ-mes=uˀ / ˥ ˥ → [ʃmˑé.súʔ] ‘your professor’

b. / ʃ- nˑa̤ʃ=uˀ / ˩ ˥ → [ʃnˑà̤.ʃúʔ] ‘your chocolate’

(33) Word-finally (_#): long voiceless fricatives

a. / mes / ˥ → [mésː] ‘professor’

b. / nˑa̤ʃ / ˥˩ → [nˑà̤ʃː] ‘much, a lot of’

Lenis fricatives: / z ʒ ʐ̻ /

(34) Word-initially (#_): voiced fricatives

a. / za̤ / ˩ → [zà̤ː] ‘grease, fat’

b. / ʒ ḭʒ / ˥˩ → [ʒî͡i̤ʒ̊] ‘pineapple’

(35) Intervocalic (V_V): voiced fricatives

a. / ʃ-bga̰z=uˀ / ˩ ˥ → [ʃab.gà̰.zúʔ] ‘your place in the mountains’

b. / ʃ-wbwi̤ʒ=uˀ / ˥˩ ˥ → [ʃaw.bwî͡i̤.ʒúʔ] ‘your sun’

(36) Word-finally (_#): voiceless fricatives

a. / bga̰z / ˩ → [bgà̰ːz̥ ~ bgà̰ːs] ‘name of a place in the mountains’

b. / wbwi̤ʒ / ˥˩ → [wbwî͡i̤ʒ̊ ~wbwî͡i̤ʃ] ‘sun’

Finally, as reported by Munro and Lopez (1999), the fricatives / f / and / x / appear primarily in Spanish loanwords. These sounds pattern with the other fortis fricatives.

As a final remark with regard to obstruents, we observe a clear difference with respect to fortis versus lenis, in that the former are more stable in the way they are produced. Fortis stops are invariant in terms of voice and manner, whereas lenis stops vary depending on the context. For fricatives, fortis are invariant, and lenis vary in their voicing.

Cross-linguistically, obstruents form a complementary class to sonorants. Obstruents are produced by a narrowing or complete closure of the vocal tract, and the lack of voicing is the default setting for this type of segment, i.e. the existence of voiced obstruents implies voiceless ones. In summary, fortis obstruents are not only invariant in voicing and manner, but also the ones that manifest the prototypical, or typologically unmarked, properties of obstruents. I now turn to the analysis of fortis and lenis sonorants.

Quiaviní Zapotec fortis sonorants are the nasals / m˙ n˙ ŋ˙ /, and the liquid / l˙ /. They have similar characteristics, as they are voiced, and long in coda (although fortis sonorants may be partially devoiced following breathy vowels, especially / l˙ /, Munro & Lopez, 1999, p. 2). The lenis sonorants / m n ŋ / and / l / are shorter than their fortis counterparts and may devoice word-finally, particularly after interrupted vowels.

Fortis sonorants

(37) Word-initially (#_): voiced sonorants

a. / m˙uʒ / ˥ → [m˙úːʒ̊] ‘blond’
b. / n˙an / ˩˥ → [n˙ăːn] ‘mother’
c. / l˙a̤n˙ / ˥˩ → [l˙â̤nː] ‘smelling of eggs’

(38) Intervocalic (V_V): voiced sonorants

a. / ʃ-dam˙=uˀ / ˩˥˥ → [ʃtămːúʔ] ‘your owl’
b. / dan˙o̤n˙ɨŋ / ˥ ˥˩ → [dán˙ô͡o̤nːɨŋ] ‘It's us’
c. / nsual˙-eˀ / ˥ ˩ → [nsuálːèʔ] ‘little blue’

(39) Word-finally (_#): voiced sonorants

a. / dam˙ / ˩˥ → [dămː] ‘owl’
b. / dan˙o̤n˙ / ˥˥˩ → [dán˙ôo̤nː] ‘we’
c. / nsual˙ / ˥ → [nsuálː] ‘blue’

Lenis Sonorants

(40) Word-initially (#_): voiced sonorants

a. / nan / ˩ → [nàːn] ‘thick’
b. / laŋ˙ / ˩˥ → [lăŋː] ‘s/he/it (nearby)’

(41) Intervocalic (V_V): voiced sonorants

a. / ʃ-guˀan=uˀ / ˥˩ ˥ → [ʃkúˀànúʔ] ‘your bull’
b. / ʃ-lua̰n=uˀ / ˥˩ ˥ → [ʃl˙úà̰ːnúʔ] ‘your sleeping platform’

(42) Word-finally (_#): voiced or voiceless sonorants

a. / guˀan / ˥˩ → [gúˀàn ~ gúˀàn̥] ‘bull’
b. / lua̰n / ˥˩ → [lúà̰ːn ~ lúà̰ːn̥] ‘sleeping platform’

According to Munro and Lopez (1999, p. 2), the trill / r / “appears in Spanish loans or over a morpheme boundary in non-loans, where it functions phonologically as a cluster […]; only the tap *r* occurs internal to native morphemes.” As mentioned above, arguably, trill and tap act as fortis/lenis counterparts.

The feature [+sonorant] characterizes sounds that are produced in such a way that the vocal cords vibrate spontaneously (i.e. vowels, glides, liquids and nasals), thus voicing is the default property of sonorants, as is the case for fortis sonorants in Quiaviní Zapotec. However, voicing variation between fortis and lenis sonorants is not as salient as in the case of obstruents. Munro and Lopez (1999, p. 2) propose that duration is the most important cue to differentiate fortis versus lenis sonorants.

Similar characteristics to the ones presented above are described for Güilá Zapotec by Arellanes (2009). He makes use of the markedness concept in the analysis of the fortis/lenis contrast. "The concept of markedness, in its most general characterization is concerned with the distinction between what is neutral, natural, or most expected (unmarked), and what departs from the neutral (marked) along some designated parameter" (Kean, 1992, p. 390). Along these lines, Arellanes (2009, p. 176) establishes for Güilá Zapotec that "…las fortis son los elementos más básicos del sistema tanto porque constituyen un mayor número de en el inventario consonántico, como porque tienen una distribución más amplia en los distintos contextos fonológicos básicos".[25]

In Quiaviní Zapotec, fortis consonants manifest the unmarked features of the class they belong to (stable in all contexts), whereas lenis consonants may have the marked features of the class and their realization fluctuates depending on the context. What unifies fortis consonants as a natural class in Zapotec, then, is the fact that they express the unmarked features of the sub-class they belong to, and their production is phonetically constant. Fortis obstruents are always voiceless (and stops always [-continuant]); whereas fortis sonorants are always voiced. In turn, these characteristics make fortis segments "stronger" than lenis ones in terms of duration, tension and intensity.

In addition, the length of fortis *vs*. lenis consonants is also worth remarking on. All fortis consonants are particularly long in coda position; this phonetic duration is taken to be prosodically relevant in that fortis consonants are moraic in coda position, as proposed and explained in detail in Chapter 3. This fact provides additional evidence for these segments as a natural classes. (A singleton-geminate alternative analysis is also discussed in Chapter 3.) Accordingly, the fortis/lenis contrast (or phonological strength) is not something we can characterize with the heretofore-standard features or properties, although it clearly encodes a phonological contrast.

[25] "Fortis consonants are the most basic elements of the system as they are more numerous in the consonant inventory, and they have a wider distribution in basic phonological contexts." [*Translation mine*]

2.4 The emergence of the [+/-fortis] feature

In emergent feature theory (Mielke, 2008 [2004]), features are abstract categories based on generalizations that emerge from phonological patterns. In other words, different phonetic properties can be relevant for defining sound patterns, and as such, we would expect some degree of variation cross-linguistically (contra the nativist approach of Universal Grammar of a single set of features present in all languages (Chomsky & Halle, 1968, etc.)).

The argument for emergence partially depends on distinctions like fortis/lenis, tense/lax, stressed/unstressed being vague composites of properties that vary across languages but that clearly combine to create some overall distinction (strength, loudness, prominence, etc.). Along these lines, phonological strength may be encoded differently in the languages of the world. In Quiaviní Zapotec, the sound pattern that arises from the description of the previous section is that fortis obstruents and fortis sonorants form a natural class based on the following two facts: (i) fortis consonants are the unmarked segments of the class (determined by different phonetic characteristics); and (ii) fortis consonants are long in coda position (playing a crucial role in the prosodic system of this language, in terms of moraicity (Chapters 3 & 5) and tone (Chapter 5)). Based on these phonetic and phonological properties, there must be a way in which the grammar classifies these subsets of consonants (across obstruents and sonorants). A feature that emerges from these language-specific patterns is a legitimate approximation.

What is the best feature then for the fortis/lenis contrast? Hollenbach (1984) adopts the feature [+/-tense] to account for the fortis/lenis contrast in Copala Trique. She defines lenis obstruents as [+voice] but [-tense] while fortis ones are [-voice] and [+tense]. The original definition of this term, may certainly encode the fortis/lenis observed properties. As defined in (Jakobson et al., 1951, p. 38):

> Tense phonemes are articulated with greater distinctness and pressure than the corresponding lax phonemes. The muscular strain affects the tongue, the walls of the vocal tract and the glottis. The higher tension is associated with a greater deformation of the entire vocal tract from its neutral position. This is in agreement with the fact that tense phonemes have a longer duration than their lax

counterparts. The acoustic effects due to the greater and less rigidity of the walls remain open to question.

The feature [+/-tense], however, has been used for a wide variety of phenomena and it is most often associated with vowel contrasts (e.g. / i, u / *vs*. / ɪ, ʊ /). It seems that we can simply refer to the feature [+/-fortis], employed in a diverse and compelling literature (Debrock, 1978; Gerhardt, 1980; Kohler, 1984; Pulleyblank, 2006; among others). [26] To conclude, the composite properties from which the fortis/lenis distinction arises in Quiaviní Zapotec, across both obstruents and sonorants, is encoded here with the feature [+/-fortis].[27]

An alternative analysis is presented by Arellanes (2009) for Güilá Zapotec. The author explains the variation of lenis consonants on the basis of feature underspecification. The described generalizations, however, do not hold for the Quiaviní Zapotec data presented here. As described above, I assume that Quiaviní Zapotec consonants are specified for the features [+/-voice], [+/-continuant], [+/-sonorant], as these features maintain particular contrasts (e.g. voicing is clearly distinctive for obstruents in initial and intervocalic positions) or predict specific patterns (see the role of [+/-sonorant] in the expression of tone in Chapter 5). However, in order to account for the full range of properties of the fortis/lenis contrast in Quiaviní Zapotec, and to encode a natural class across obstruents and sonorants, an additional specification is necessary, that of the [+/-fortis] feature.

[26] Kohler (1984), for instance, presents evidence for the importance of a [+/-fortis] feature in the description of phonological segment systems in the world's languages, particularly for Germanic languages. In his proposal, the feature is associated with articulatory timing ("power in the supraglottal movements and in the air stream" (p. 168)) and with laryngeal tension. Both features [tense] and [fortis] refer to phonological and phonetic strength. More recently and within an emergent feature approach, Pulleyblank (2006) proposes the use of the feature [+fortis] in Luo, to group oral stops and pre-nasalized stops.

[27] Under Optimality Theory (Prince & Smolensky, 2004 [1993]), the markedness distinction between fortis and lenis consonants in Quiaviní Zapotec, may be conceptually analyzed by the following harmonic scale: FAITH[fortis] >> MARKEDNESS >> FAITH[lenis] (see Howe & Pulleyblank, 2004 for an analysis of harmony as faithfulness; cf. de Lacy, 2006). Accordingly, the feature specification of fortis consonants (e.g. voicing, manner) requires a faithful input-output correspondence, whereas that of lenis consonants is subject to markedness constraints (e.g. an intervocalic context demanding voicing versus a final utterance position that favors devoicing; cf. Arellanes, 2009, Chapter 4). This is in fact what we observed in the adaptability of lenis consonants. The details of such an analysis, however, are beyond the scope of this study.

2.5 Conclusions

In this chapter, based on Munro and Lopez (1999), I showed that vowel length is predictable from the consonant type in stressed syllables (short before fortis, and long before lenis). The relevance of the fortis/lenis distinction in determining this vowel pattern represents an important characteristic of Quiaviní Zapotec consonants, as both fortis obstruents and sonorants are long in coda position. In addition, fortis segments present phonetic characteristics that make them the unmarked elements of their consonantal class: fortis stops are the extreme of "strong" articulation, being always voiceless, and invariant in their constriction. Fortis fricatives are also always voiceless and, consequently, of higher amplitude compared to their lenis counterparts (cf. Jaeger, 1983). Finally, fortis sonorants are always voiced. These language-particular properties support the hypothesis that a number of phonetic and phonological characteristics contribute to the fortis/lenis contrast in Quiaviní Zapotec, and that the grammar of this language needs to refer to these patterns. This is in accordance with emergent feature theory (Mielke, 2008 [2004]; Pulleyblank, 2006), for which features emerge from phonological patterns rather than the other way around (as in a nativist approach with a set of universal features). Accordingly, I adopt the feature [+/-fortis] (Kohler, 1984; Pulleyblank, 2006) to account for Quiaviní Zapotec consonant contrasts.

The importance of this chapter derives from the characterization of the fortis/lenis distinction in Quiaviní Zapotec, as a pervasive contrast in the consonants of this language and of particular relevance for its metrical structure and tone. The generalizations arrived at in this chapter form the basis and preamble for the analysis of different prosodic patterns of Quiaviní Zapotec, presented in subsequent chapters.

Chapter 3:

Metrical structure of Quiaviní Zapotec

3.1 Introduction

Metrical structure refers to the organization of segments in terms of prosodic units (e.g. mora, syllable, foot). This organization, or rhythmic structure, may be reflected as the stress or prominence pattern of a language. According to Munro and Lopez (1999), the last syllable of uninflected words is stressed in Quiaviní Zapotec. Nonetheless, no further study has accounted for more details of the prosodic system of this language, such as the moraicity of its segments, the properties of foot structure, or minimality effects. The goal of this chapter is to account for the metrical structure in this language (up to the Prosodic Word (PrWd)), establishing the foundations needed for two central topics of this dissertation: tone and phonation type.

All the examples used in this chapter are content words (nouns, verbs, adjectives); most function words (articles, some adverbs, clitics, etc.[28]) do not need to be stressed, and are prosodically dependent on content words.

In order to account for the constituency of the PrWd in this language, the chapter begins with the analysis of the smallest prosodic domain: monosyllables, where I establish the prosodic minimality and moraicity of Quiaviní Zapotec (§3.2). Section 3.3 continues to the next morphological level, analyzing prefixed, suffixed and clitisized words and compounds. These disyllabic and longer words will provide evidence for a trochaic (foot type) rhythm in Quiaviní Zapotec as well as its demarcative characteristic, with the root consistently carrying prominence. Finally, loanword phonology, §3.4, concludes the analysis of word stress in Quiaviní Zapotec. Focusing on modal phonation, all these sections present a formal analysis within the approach of Optimality Theory (OT; Prince & Smolensky 2004 [1993]).

3.2 Moraicity and minimality

This section analyzes monosyllables in Quiaviní Zapotec. In this language, most noun roots are monosyllables and coextensive with prosodic words. Verbs require the presence of an aspectual prefix, but many of these prefixes (see Chapter 1, §1.4.5) are single consonants; thus, verbs may also surface as monosyllables. These words constitute the minimal words in Quiaviní Zapotec and are the focus of this section. The goal is to account for the prosodic requirements of monosyllabic native words in Quiaviní Zapotec.

As explained in the preceding chapter, vowel length is a perceptually salient feature of Quiaviní Zapotec; however, it is not contrastive, but rather conditioned by prominence and by the consonant type in coda position. In stressed syllables (all monosyllabic nouns and verbs being stressed), short vowels appear before fortis

[28] As presented in Chapter 1, most prepositions originally come from grammaticalized nouns (Lillehaugen, 2003, 2006), for instance *làa'iny*, listed in the dictionary of Munro and Lopez (1999) as 'stomach', but also as the preposition 'inside, in, into'. The precise prosodic status of these "prepositions" is unclear and beyond the scope of this study.

consonants and long vowels before lenis consonants or in open syllables. Consider the following examples.

(1) Short vowels before fortis coda consonants

a. / bak / → [bakː] ‘person from Tlacolula’
b. / nanˑ / → [nanː] ‘knows’
c. / damˑ / → [damː] ‘owl’
d. / mes / → [mesː] ‘professor’ (< Sp. *maestro*)
e. / bʧilˑj / → [bʧilː^{j}] ‘knife’ (< Sp. *cuchillo*)

(2) Long vowels before lenis coda consonants

a. / bag / → [baːx] [29] ‘cow’ (< Sp. *vaca*)
b. / nan / → [naːn] ‘thick’
d. / bal / → [baːl] ‘bullet’ (< Sp. *bala*)
e. / sɨby / → [sɨːɸ^{j}] ‘Eusebio’ (< Sp. *Eusebio*)

(3) Long vowels in open syllables

a. / la / → [laː] ‘is named’
b. / n-gi / → [ŋgiː] ‘sour’
c. / wi / → [wiː] ‘guava’
d. / tu / → [tuː] ‘who’
e. / ʃnia / → [ʃniaː] ‘red’

Cross-linguistically, it is well known that vowels are shorter before voiceless consonants and longer before voiced ones. The magnitude of this effect in most languages without contrastive vowel length may vary between 10 to 20 ms (e.g. Mendoza et al., 2003 report a difference of 16 ms for Spanish, with means of 126 ms vs. 142 ms). However, the magnitude ratio in Quiaviní Zapotec exceeds this phonetic universal and resembles that of languages with contrastive vowel length (e.g., in Tamil (Dravidian), short vowels average 93ms, long vowels 152ms (Maddieson, 1984)).[30] Nevertheless, in Quiaviní Zapotec, voicing is clearly not the determining factor for this vowel-duration difference, but the fortis/lenis contrast, as established in the previous Chapter. On the one hand,

[29] As presented in Chapter 1, lenis stops are frequently fricated, devoiced and short word-finally.
[30] English seems to be a language with middle range values, reporting differences of 30 to 40 ms, or more before pause (e.g. Chen, 1970; Keating, 1984; Erickson, 2000 among others).

obstruent fortis consonants are always voiceless and so the realization of vowels as short is expected, but lenis obstruents also tend to be voiceless in word-final position, and preceding vowels are nonetheless long. On the other hand, fortis sonorants are always voiced, whereas lenis may devoice word-finally. Despite this difference with respect to obstruents, the vowel-lengthening pattern is the same: short before fortis sonorants, and long before lenis ones.

Previously, I reviewed how this vowel and consonant length has been reported for different Zapotec languages (Swadesh in Pike 1948: 167; Nellis & Hollenbach 1980, Smith-Stark 2003; Avelino 2004; Leander, 2008; Ward et al. 2008, Arellanes 2009, among others). According to Arellanes (2009), vowel length in San Pablo Güilá Zapotec is adequately explained in terms of minimality and moraicity. Arellanes proposes that the minimal prosodic word in San Pablo Güilá Zapotec consists of a bimoraic foot (Prince & Smolensky, 2004 [1993]). This condition, in conjunction with the predominance of monosyllables in the language, forces content words to form bimoraic syllables. In words of the $CVC_{\textit{fortis}}$ type, the vowel contributes an underlying mora, and the fortis coda consonant gets a mora by virtue of Weight by Position (applicable to fortis consonants only, see discussion below). The claim that lenis consonants are not moraic follows from the fact that in $CV{:}C_{\textit{lenis}}$ words, the vowel lengthens to satisfy the minimality requirement of bimoraicity. (The same is observed in CV words.) Further, Arellanes and Chávez-Peón (2009) extend this analysis to Valley Zapotec (including the variants of Güilá and Quiaviní Zapotec, which are mutually intelligible and spoken in neighboring towns).

Quiaviní Zapotec word types are presented again in (4-5), with their moraic analysis in (8).

(4) CVC_{fortis}

a. / bak / → [bakː] ‘person from Tlacolula’

b. / nanˑ / → [nanː] ‘knows’

(5) $CV{:}C_{\text{lenis}}$

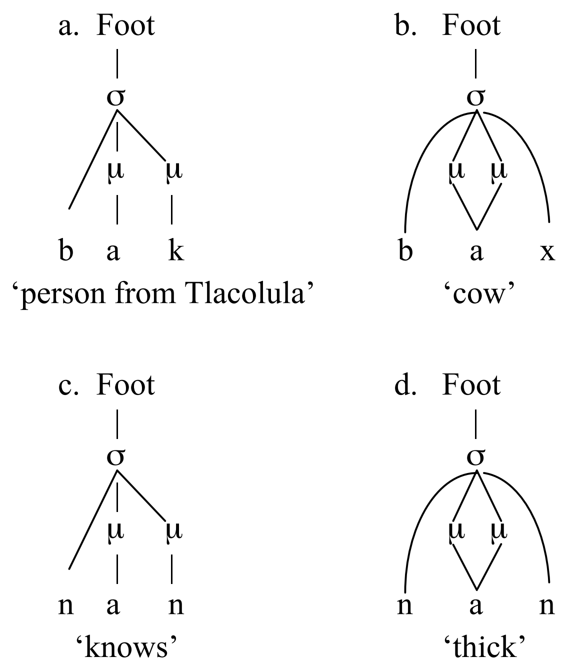
a. / bag / → [baːx] ‘cow’

b. / nan / → [naːn] ‘thick’

(6) *CVC$_{lenis}$

(7) *CV:C$_{fortis}$

(8) Moraic representation of Quiaviní Zapotec words



Fortis coda consonants contribute a mora to the formation of the foot, and the preceding vowel is short (monomoraic) (8a&c). Lenis coda consonants, in contrast, do not contribute a mora (but link directly to the syllable), and the preceding vowel must consequently become bimoraic (8b&d). As a result, both types of rhymes satisfy Quiaviní Zapotec minimality. *Minimality* and *Weight-by-Position*, the two crucial aspects of this analysis, merit discussion.

The notion "minimal word" builds on earlier work by Prince (1980), Broselow (1982), and, particularly, McCarthy and Prince (1986). In many languages, there is a minimum placed on the prosodic size of a word. Some languages require every content word to have at least two syllables (e.g. Mohawk, Michelson 1988); in other languages, every word must contain at least two moras (e.g. Fijian, Hayes 1995); that is, it must consist of at least one heavy syllable or two light ones. Within metrical theory (e.g. Hayes 1995), these requirements can be stated as the requirement that every Prosodic Word by definition (e.g. universally) contains at least one foot (in the same way as a foot requires at least a syllable in it) and that minimality is just a restriction that feet must be binary.

In Quiaviní Zapotec, *minimality* refers to the requirement that a freestanding, stressable (nonclitic) word has a specific minimal weight: bimoraic. Accordingly, vowels lengthen in open syllables and when followed by lenis consonants, whereas fortis consonants get a mora in coda position (as illustrated in (8)). The moraic status of fortis consonants is achieved via the principle *Weight-by-Position*, to which I now turn.

Cross-linguistically, closed syllables vary with respect to their contribution to syllable weight. Coda consonants are moraic in some languages, whereas in others they have no prosodic role.

(9) Typology of moraicity for consonants (cf. Zec 1988; Morén 2003; Gordon 2006)

a. Every coda consonant is moraic
CVV, CVC > CV
(e.g. Latin; Finnish (Kiparsky 1968); Japanese (Vance 1987); Arabic (Broselow 1995))

b. No coda consonant is moraic
CVV > CVC, CV
(e.g. Khalkha Mongolian (Bosson 1964, Walker 1997); Lardil, Huasteco (Broselow 1995: 189))

It is assumed that the difference between these languages is the role of the principle Weight-by-Position (Hayes, 1989: 258), schematized below.

(10) Weight by Position (Hayes 1989: 258)

$$\begin{array}{lcl} \sigma & & \sigma \\ | & & |\backslash \\ \mu & \rightarrow & \mu\ \ \mu \\ | & & |\ \ \ | \\ \alpha\ \ \beta & & \alpha\ \ \beta \end{array}$$

Elements of type β get a mora in the derivation by virtue of being in coda position (i.e. when they belong to the rhyme). Languages of the type in (9a) apply this principle thoroughly, whereas languages of the type in (9b) do not.

In addition, the β element in the configuration of (10) may be defined, not only in terms of syllabic position (e.g. coda), but also in terms of a specific type of segment, e.g.

sonorant. This is the case in some languages, where only a subset of consonants are moraic in coda position.

(11) Extended typology of moraicity for consonants

c. Some types of consonants are moraic, others not
CVV, $CVC^1 > CVC^2$, CV
(Kwakw'ala (Boas 1947, Bach 1975); Lithuanian (Zec 1988); Ponapean (Goodman 1995); Yawelmani (Broselow 1995: 201))

Languages in this category, where only a subset of consonants contribute to syllable weight, normally base this distinction on sonority: sonorant consonants are moraic, whereas obstruent consonants are not.

Arellanes and Chávez-Peón (2009) propose a new distinction among consonants to determine their prosodic status. In Valley Zapotec, including Güilá and Quiaviní Zapotec variants, fortis coda consonants (both sonorants and obstruents) are moraic, whereas lenis coda consonants are not (neither sonorants nor obstruents). The proposal then is that this language also belongs to this third type of languages; however, the distinction between moraic versus non-moraic consonants is based on duration (not sonority), encoded by the class of fortis vs. lenis segments.

Consequently, in Quiaviní Zapotec it is possible to group, on the one hand, fortis obstruents and sonorants, / p t k s ʃ mˑ nˑ ŋˑ lˑ … /, and, on the other, lenis obstruents and sonorants, / b d g z ʒ m n ŋ l … /. Following the schema in (10), in Quiaviní Zapotec, the β type of elements are fortis consonants (i.e. segments specified as [+fortis]).

(12) Weight by Position in Quiaviní Zapotec

```
   σ          σ
   |          |\
   μ    →     μ  μ
   |          |  |
C  V  Cfortis   C  V  Cfortis
```

Onset consonants are non-moraic in Quiaviní Zapotec, regardless of the type of consonant, but crucially, fortis consonants are longer in coda than in onset position. In quantity-sensitive languages, there is a correspondence between duration and quantity: moraic consonants are longer than their non-moraic counterparts, more or less in the same way that bimoraic vowels are longer than monomoraic ones. Duration is still significant in onset position, differentiating fortis versus lenis, but to a much lesser degree (see §3.2.1 below); other features (e.g. voicing), nevertheless, are the main cues to maintain the contrast (see previous Chapter).

To sum up, in this section I showed that short vowels appear before fortis consonants and long vowels before lenis consonants (or in open syllables). This pattern was adequately explained in terms of minimality and moraicity. Prosodic words are required to minimally form a bimoraic foot. Fortis consonants get a mora in coda position by virtue of Weight-by-Position, so that the mora of the short vowel plus the mora of the fortis consonant satisfy minimality. Lenis consonants cannot bear a mora; consequently, vowels followed by a lenis consonant lengthen to become bimoraic and form a bimoraic foot (an OT account of this pattern is presented below in §3.2.2).

In order to confirm this analysis, the following section consists of a phonetic experiment where I test the hypothesis that fortis consonants are moraic in coda position. Considering duration as one phonetic expression of moraicity, I will show that the differences in vowel and consonant length are not simply by-product effects of differences in intrinsic duration between voiceless vs. voiced consonants, but rather enhanced characteristics that must be considered overt prosodic bimoraicity.

3.2.1 Phonetic experiment: Syllable weight and the fortis/lenis distinction

Quiaviní Zapotec presents an uncommon four-way contrast within its consonantal system, which includes the obstruent/sonorant contrast as well as the fortis/lenis distinction.

Table 14. Quiaviní Zapotec four-way consonant contrasts

	Fortis	Lenis
Obstruents	√	√
Sonorants	√	√

The fortis/lenis distinction crosscuts the contrast between obstruents and sonorants. In the previous section, I argued that fortis coda consonants —both sonorants and obstruents— are moraic, whereas lenis consonants are not —neither sonorants nor obstruents. Onset consonants do not contribute to syllable weight. This section tests this analysis acoustically.

This experiment assumes consonant duration as one phonetic expression of moraicity resulting from Weight-by-Position, supported by numerous studies (e.g. Hyman, 1985; Hayes, 1989; and more recently Cohn, 2003; Gordon, 2006; de Lacy, 2007, p. 293). Moreover, onset versus coda differences are considered. It has been shown that these syllabic positions have phonetic differences in gestures and timing (e.g. Gick & Wilson, 2006). Phonological differences include the well-known observation that only coda consonants may be moraic, along with the fact that moraic consonants are longer than their non-moraic counterparts (Hayes, 1989; Perlmutter, 1995).

From this background, the two main predictions of this study are, first, that fortis coda consonants are significantly longer than lenis coda consonants, and, second, that fortis consonants are longer in coda than in onset position. The second prediction also follows from the fact that fortis consonants are singleton segments (Munro & Lopez, 1999), moraic in coda (as argued here), but not underlyingly (see discussion below in §3.2.2).

Based on previous studies in Zapotec languages (e.g. Jaeger 1983, Avelino 2004), the fortis/lenis distinction is expected to show duration differences regardless of syllable position, so we also expect a significant difference between fortis/lenis in onset, but to a lesser magnitude than that of coda position.

Finally, no theory predicts much difference for non-moraic lenis consonants in onset vs. coda position.

In summary, the hypothesis of this study is that fortis consonants are moraic, from which the predictions listed in (13) follow.

(13) Predictions

1. Fortis coda consonants are longer than lenis coda consonants
   (expected ratio ≈2:1[31])

2. Fortis consonants are longer in coda than in onset position

3. The duration difference between fortis and lenis in onsets is smaller

4. The duration difference between onset and coda lenis consonants is not significant

Methodology

Subjects: Two native speakers of Quiaviní Zapotec participated in the study: female Speaker Lia L (30 years old), and male speaker Tiu C (46).

Stimuli: Obstruent and sonorant consonants were included in the stimuli (including both stops and fricatives for obstruents).[32] Because place of articulation plays no major role distinguishing sonority or moraicity, all segments in the stimuli were coronals.

(14) Segments considered in the stimuli

```
               Obstruents              Sonorants
              /          \                 |
          Stops           Fricatives     Nasals
          /   \           /    \         /    \
     Fortis   Lenis   Fortis   Lenis  Fortis   Lenis
       |        |       |        |      |        |
       t        d       s        z      nˈ       n
```

[31] The salient difference between fortis vs. lenis consonants in coda position allows us to predict an approximate ratio of 2:1 (similar to that found in languages with a singleton/geminate contrast). No specific ratios are expected for the other predictions.

[32] Because of the dissimilar manner of articulation, both stops and fricatives were included in this experiment. In addition, future comparisons between obstruents and sonorants may include intensity as a phonetic parameter (impossible to obtain from stops, but recoverable from fricatives). For sonorants, the assumption was that the difference between nasals and liquids would be minimal; only nasals were included.

The words used as stimuli, listed in Table 15 and Table 16, were chosen so that each of the consonants in (14) appears four times in onset position and four times in coda position.

Table 15. Stimuli by ONSET (4 items for each consonant: / t, d, s, z, nˑ, n /)

1	/tan/ ˥	‘Cayetana’
2	/tuat/ ˥	‘marrow bone’
3	/tas/ ˥	‘cup’
4	/ta̤p/ ˩	‘four’
5	/dad/ ˥	‘dice’
6	/dad/ ˩˥	‘father’
7	/damˑ/ ˩˥	‘owl’
8	/danj/ ˩	‘mountain’
9	/sanˑ/ ˩˥	‘Santos’
10	/sanˑʒ/ ˩˥	‘pet sheep’
11	/sja̰b/ ˥˩	‘atole’
12	/sualˑ/ ˥	‘blue’
13	/zuas/ ˥˩	‘type of plant’
14	/zak/ ˥	‘good’
15	/zeˀ/ ˥˩	‘corn on the cob’
16	/zua̤z/ ˥˩	‘drunk’
17	/nˑad/ ˩	‘hard-headed’
18	/nˑan/ ˩˥	‘mother’
19	/nˑje̤s/ ˥˩	‘water’
20	/nˑuan/ ˥	‘chirimoya’
21	/nan/ ˩	‘thick’
22	/nanˑ/ ˥	‘woman's nickname’
23	/njanˑ/ ˥	‘Marcelo’
24	/njan/ ˩˥	‘spicy’

Table 16. Stimuli by CODA (4 items for each consonant: / t, d, s, z, n·, n /)

1	/tʃat/ ˥	‘kiss’
2	/lat/ ˥	‘tin can’
3	/tuat/ ˥	‘marrow bone’
4	/ʒyet/ ˩˥	‘cat’
5	/lad/ ˥	‘side’
6	/dad/ ˥	‘dice’
7	/dad/ ˩˥	‘father’
8	/n·ad/ ˩	‘hard-headed’
9	/na̤s/ ˩	‘the day before yesterday’
10	/tas/ ˥	‘cup’
11	/zuas/ ˥˩	‘type of plant’
12	/n·je̤s/ ˥˩	‘water’
13	/n̤i̤a̤z/ ˥˩	‘corn field’
14	/gaz/ ˩	‘seven’
15	/klaaz/ ˥	‘Nicolasa’
16	/zua̤z/ ˥˩	‘drunk’
17	/tʃon·/ ˩	‘three’
18	/san·/ ˩˥	‘Santos’
19	/nan·/ ˥	‘woman's nickname’
20	/njan·/ ˥	‘Marcelo’
21	/tan/ ˥	‘Cayetana’
22	/n·an/ ˩˥	‘mother’
23	/n·uan/ ˥	‘chirimoya’
24	/nan/ ˩	‘thick’

These words were recorded within the following carrier phrases.

(15) Carrier phrases:

a. Stops: [ɾnḭŋ _______ kuan di̯ʒ sa̤] ‘He says _____ in Zapotec’

b. Fricatives: [ɾnḭaʔ ɾa _______ kuan di̯ʒ sa̤] ‘I say _____ in Zapotec’

c. Nasals: [ɾnḭaʔ ɾa _______ steːbj] ‘I say _____ again’

The use of slightly different carrier phrases is due to the different types of consonants that are considered. The main issue is that lenis stops are produced as fricatives intervocalically; thus, in order to maintain the same category in the comparison (lenis stop vs. fortis stop), the first part of the carrier phrase includes a nasal (after which lenis stops are realized as voiced stops). The carrier phrases were intended to obtain the best pronunciation of each of the consonant types for a proper comparison as well as to look for the easiest environments in which to measure these segments.

Four repetitions of each word within its carrier phrase were collected based on a randomized list. In the cases where the speaker was unable to read, the phrase was given in Spanish by the facilitator (the author). Recordings were made with a Marantz 660 solid-state recorder and a Countryman lapel microphone (phantom power).

Each consonant was measured for duration (based on both the waveform and the spectrogram): total constriction in obstruents (closure and release for stops, and frication period for fricatives) and total duration of nasals, cued by change in amplitude and formant transition. In total, 384 consonants were measured by hand in *Praat* for Mac (version 5.1.07; Boersma & Weenink, 2009) (4 /t/ onset + 4 /t/ coda + 4 /d/ onset + 4 /d/ coda + 4 /s/ onset + 4 /s/ coda + 4 /z/ onset + 4 /z/ coda + 4 /nˑ/ onset + 4 /nˑ/ coda + 4 /n/ onset + 4 /n/ coda = 48 x 4 repetitions = 192 tokens/speaker x 2 consultants = 384 total duration measurements). Results were compiled in *Excel 2004* for Mac and the statistics were run in *R* (version 2.8.1, R Development Core Team, 2009). Data was statistically evaluated with two-tailed t-tests.

Results

The results of the experiment are presented (in ms.) in Table 17.

Table 17. Results of phonetic experiment (duration of fortis and lenis consonants)

Female - LiaB	**Mean**	**SD**	**------**	**Male - TiuC**	**Mean**	**SD**
t_coda	142.87	43.93		t_coda	131.68	22.35
t_onset	101.93	7.75		t_onset	99.75	9.11
d_coda	61.05	10.31		d_coda	55.01	8.43
d_onset	58.01	7.89		d_onset	52.68	11.81
s_coda	169.87	52.76		s_coda	145.75	35.71
s_onset	108.31	10.65		s_onset	105.87	18.94
z_coda	86.05	20.61		z_coda	79.42	17.42
z_onset	80.12	25.16		z_onset	72.56	15.91
nn_coda	134.56	25.01		nn_coda	121.56	13.79
nn_onset	70.13	22.09		nn_onset	69.68	17.41
n_coda	85.64	24.81		n_coda	87.43	8.57
n_onset	78.05	25.16		n_onset	60.31	15.74
V before lenis	158.51	26.59		V before lenis	155.51	16.96
V before fortis	82.61	14.75		V before fortis	77.91	14.74

Table 18. t-test results of phonetic experiment (duration of fortis and lenis consonants) [33]

	Female speaker (LiaL)	Male speaker (TiuC)
Prediction 1	$t\ (79.018) = 10.1644,\ p < 0.001$	$t\ (91.721) = 12.1018,\ p < 0.001$
Prediction 2	$t\ (79.089) = 7.8135,\ p < 0.001$	$t\ (97.641) = 7.6297,\ p < 0.001$
Prediction 3	$t\ (99.723) = 4.4029,\ p < 0.001$	$t\ (86.027) = 7.3037,\ p < 0.001$
Prediction 4	$t\ (101.135) = -0.7861,\ p = 0.43$	$t\ (95.132) = -2.8854,\ p = 0.013$

The results in Tables 17 and 18 show the same trends for both speakers. Fortis coda stops, fricatives and nasals in coda are significantly longer than their lenis correspondents, with a ratio of close to 2:1, which confirms the first prediction. The difference between fortis versus lenis consonants in onset position (prediction 2) is also significant with a small ratio, 1.3:1, and with more overlap. Significant differences also

[33] According to standard conventions, results above 0.12 are considered not significant (ns.); results between 0.12 and 0.05 are marginally significant; finally, any value below 0.05 is statistically significant.

arose with respect to the distinction between fortis segments in coda and fortis segments in onset position (prediction 3), with an approximate ratio of 1.5:1. With respect to the last prediction, lenis consonants in coda are only slightly longer than in onset (1.1:1). The difference was not significant for the female speaker, as expected, but significant for the male speaker. In addition, the durational difference between vowels before lenis consonants (long) and vowels before fortis consonants (short) is also large and significant (ratio= 1.9:1; $p < 0.001$).

The following figures illustrate the results of the experiment with box-plot diagrams along with the t-test p-values. Results for stops, fricatives and nasals are presented together.

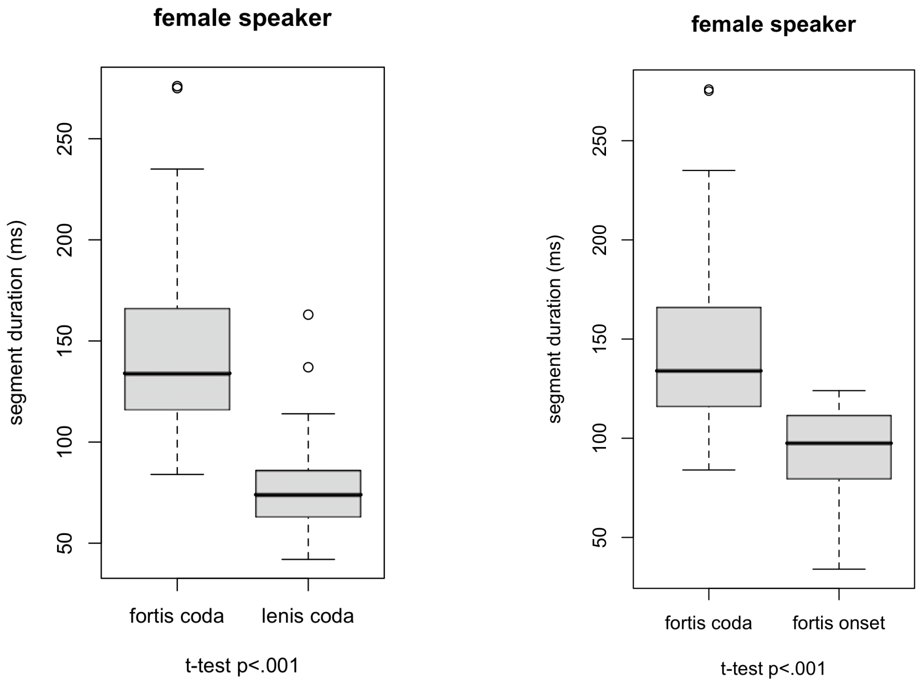


Figure 6. Box plots and t-test p-values for LiaB: fortis coda vs. lenis coda; fortis coda vs. fortis onset.

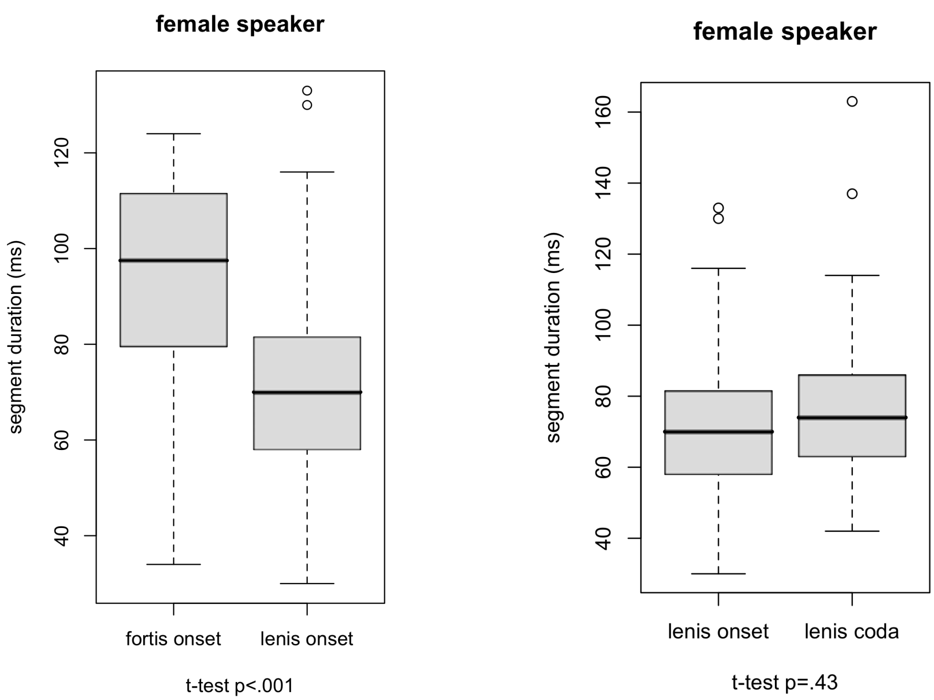


Figure 7. Box plots and t-test p-values for LiaB: fortis onset vs. lenis onset; lenis onset vs. lenis coda.

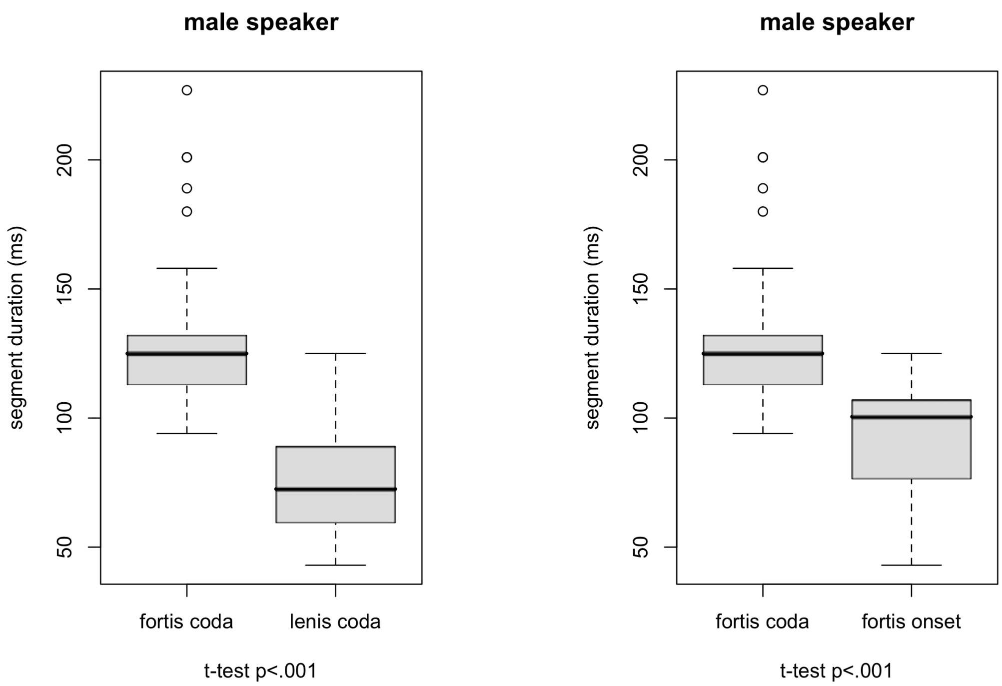


Figure 8. Box plots and t-test p-values for TiuC: fortis coda vs. lenis coda; fortis coda vs. fortis onset.

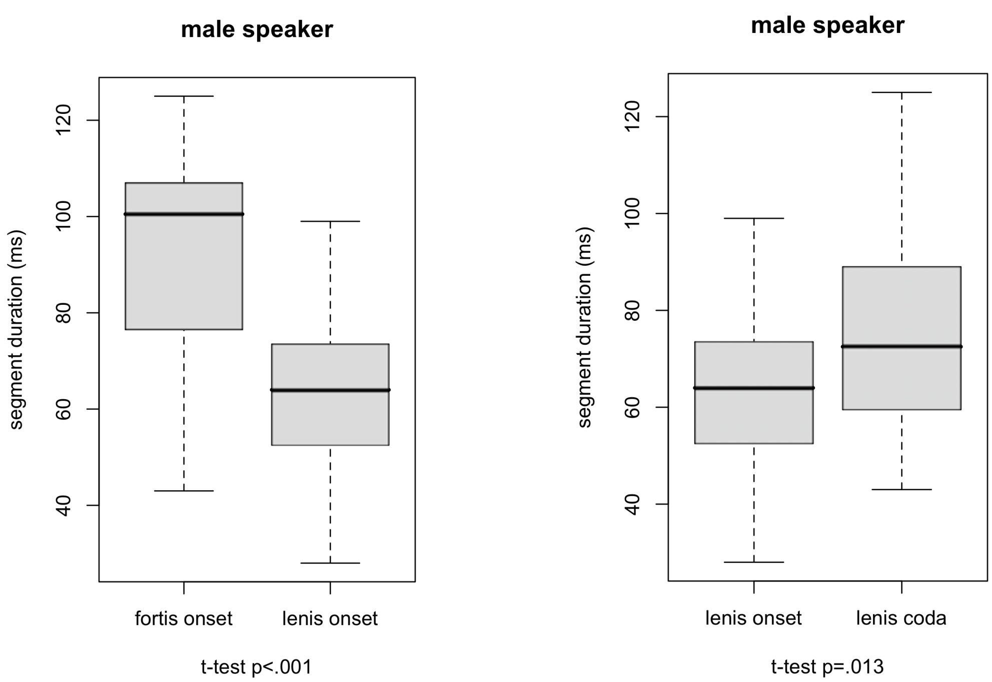


Figure 9. Box plots and t-test p-values for TiuC: fortis onset vs. lenis onset; lenis onset vs. lenis coda.

Discussion

In order to support the hypothesis that fortis coda consonants are moraic, four predictions were tested in this phonetic experiment. The first and most important stated that fortis coda consonants should be longer than lenis coda consonants. This was clearly confirmed in the experiment with a ratio of 2:1 between fortis versus lenis consonants in that position. These results strongly suggest that the contrast relies on a prosodic distinction (i.e. moraicity).

Fortis consonants are only moraic in coda position, not underlyingly, and the second prediction refers to this, as fortis consonants are expected to be longer in coda than in onset. Results confirm this difference with a ratio of 1.5:1. This is in agreement with the assumption that moraic consonants are longer than their non-moraic counterparts (Hayes, 1989; Perlmutter, 1995).[34]

Since the fortis/lenis distinction is expected to show duration differences regardless of syllable position (e.g. Jaeger, 1983; Avelino, 2004), we also expect a significant difference between fortis/lenis in onset, as was the case. Since consonants are not moraic in onset position, we also expect this difference to be considerably less in comparison to fortis consonants versus lenis consonants in coda position. Coda differences are in a ratio of 2:1 (fortis:lenis), whereas in onset we found only 1.3:1. Differences in onset are comparable to those found, for example, between voiceless versus voiced segments in English (e.g. Baum & Blumstein, 1987).

All the comparisons were statistically significant when grouping together stops, fricatives and nasals (above Figures), and importantly, differences were also significant when compared separately (see Figures 69, 70, 72 & 73 in Appendix A). The only exception to this was the comparison between fortis and lenis nasals in onset position ($p = 0.4$). It is possible that the fortis/lenis distinction is neutralized for /n/ (and possibly other sonorants) in onset position in Quiaviní Zapotec (see §2.3 for a description of fortis and lenis sonorants). Lee (1996) also reports contentious numbers with respect to the

[34] The fortis vs. lenis consonant difference in codas is viewed as moraic vs. nonmoraic, as well as the fortis coda vs. fortis onset difference. The ratios are 2:1 and 1.5:1, respectively. This difference in ratios relies on the fact that duration relates to moraicity, but it is also a phonetic correlate for the fortis/lenis distinction, both in onset and coda positions.

duration of fortis/lenis sonorants in onset position for Quiaviní Zapotec. Moreover, Arellanes (2009) claims that in Güilá Zapotec only fortis nasals appear in onset position. This issue, however, is beyond the scope of this study.

Finally, the difference between lenis consonants in onset vs. coda position was predicted to be small. Results were only significant for the male speaker, but the difference is too small to posit any prosodic difference between lenis onsets vs. codas: the means were 75 ms vs. 66 ms, respectively, with a small ratio of 1:1.1. This distinction is simply attributed to the phonetic differences in gestures and timing in terms of syllable position (see Maddieson, 1984; Gick & Wilson, 2006).

In conclusion, the phonological and phonetic evidence shown in this study supports the claim that fortis consonants contribute to prosodic weight in Quiaviní Zapotec, establishing a new distinction—that of fortis/lenis—among the feature contrasts to which Weight-by-Position can be sensitive. These findings emphasize the relationship between syllable weight and syllabic duration as a clear place where phonology and phonetics interact.

3.2.2 Fortis consonants are not geminates

Up to this point, I have proposed that fortis consonants in Quiaviní Zapotec lengthen in the coda and become moraic. An alternative to this analysis is that fortis consonants are geminates, underlyingly moraic, that shorten in the onset. Both approaches are based on the analysis that length may be the expression of syllable weight, by means of moras. This section discusses this alternative, and shows that, although a singleton-geminate distinction has been proposed for Proto-Zapotec (Fernández de Miranda, 1995; cf. Swadesh, 1947), this analysis is not appropriate for the synchronic language.[35]

With respect to the segmental distribution, fortis consonants occur initially and finally in Quiaviní Zapotec, two cross-linguistically unusual positions for geminates.

[35] Swadesh (1947) proposes that lenis consonants diachronically derived from single consonants, whereas fortis consonants derived from consonant clusters.

Moreover, following the Munro and Lopez (1999) consonant inventory, Quiaviní Zapotec has some unpaired obstruents, the affricates / ʧ / and / ts /, not to mention the borrowed sounds / f / and / x / from Spanish. These four sounds pattern with fortis obstruents; they are short in onset and long in coda. That would mean these were underlying geminates with no singleton counterpart, which seems typologically unusual (see Ham, 2001; Curtis, 2003). In contrast, from a feature-based perspective, it is extremely common cross-linguistically to find languages with voiceless obstruents [-voice] and no voiced counterparts (e.g. / s, ʧ / in Spanish).

The following two arguments are structurally and theoretically based, and they are supported by Quiaviní Zapotec phonetic data. Assuming an account that encodes geminates by lexical specification of mora structure (Hyman, 1985; Hayes, 1986; Schein & Steriade, 1989; cf. Curtis, 2003),[36] two testable predictions arise. First, the singleton/geminate contrast should be neutralized in onset (word initially) (cf. Kraehenmann, 2001, 2003). Second, fortis consonants should be long both intervocalically and in coda position. The data indicates that these predictions do not hold in Quiaviní Zapotec.

The fortis/lenis contrast is maintained in onset position in Quiaviní Zapotec, where the main cue for obstruents is voicing or manner (stops vs. low-amplitude fricative). Consider the following examples.

(16)	a. / palˑ /	‘shovel’	vs.	/ balˑ /	‘Valeriano’
	b. / teˀ /	‘one’	vs.	/ de̤ /	‘dust’

The realization of fortis consonant as short in onset vs. long in coda position was confirmed in the preceding phonetic experiment, with a significant average magnitude ratio of 1:1.5. Fortis consonants in onset were always shorter than those in coda, even though they were preceded by a vowel in the carrier phrase (in the case of fricatives and nasals in the phonetic experiment). In turn, results for the durational difference between fortis and lenis consonants in onset were not very different from those reported for other

[36] Curtis (2003) proposes to analyze geminates as underlyingly moraic two-root node segments, both facts being necessary to account for all the typological properties of geminates.

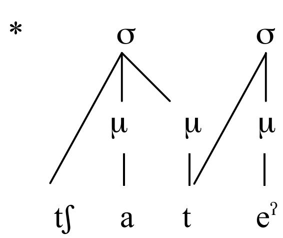
languages with a voicing distinction (see Baum & Blumstein, 1987, for English fricatives).

The second prediction under a geminate analysis is that fortis consonants are long both intervocalically and in coda position; however, this is not the case for fortis obstruents word-internally, as illustrated in (17).

(17) a. / tʃat / → [tʃatː] ‘kiss’
b. / tʃat-eˀ / → [ˈtʃa.teʔ] ‘little kiss’
can-DIM
c. → *[ˈtʃatːeʔ]

Fortis coda obstruents are long word finally, but when a clitic or the diminutive suffix is added, the fortis obstruent resyllabifies as a short (singleton) onset segment. This observation is based originally on data from by-ear transcription from 4 different speakers with several words, followed by phonetic measurements. As shown in more detail below (§3.3.1), duration measurements from one speaker showed that fortis obstruents averaged 230 ms in coda position, whereas the mean of resyllabified fortis obstruents was 113 ms. Similar length differences have been found in languages with singleton/geminate contrast (e.g. Swedish, see Thorén, 2005), but crucially, it is in intervocalic position where we expect these segments to be long if they are geminates. (The different behavior of sonorants will be discussed in subsequent sections.) Consequently, the geminate configuration in (18) is rejected for Quiaviní Zapotec.

(18) Geminate representation



In cases like (17), the fortis consonant alternates from something that could be called a geminate, (17a), to something that appears to be a singleton, (17b), but crucially not a lenis obstruent.[37] In other words, if the fortis/lenis contrast is a geminate/singleton one, then this change in duration should reflect a fortis/lenis neutralization, which is not the case. When obstruent fortis codas resyllabify as onsets, the contrast between fortis and lenis is still maintained. As shown in Chapter 2, fortis stops are voiceless and short in intervocalic position, whereas lenis stops are voiced, normally fricated, and short. These cases then clearly illustrate the fortis/lenis pattern in the phonetics. Accordingly, positing underlying geminates seems to be an indirect and therefore less illuminating way of capturing the distribution of long and short vowels in a situation where consonant and vowel length clearly are prosodically conditioned.

All in all, there is nothing about fortis-lenis obstruents in onsets that would lead anyone to even suspect that it is a short-geminate distinction, partly because of differences in voicing and continuance, and partly because the durations are simply not in the region of short-geminate consonants of languages that have them (see, for instance, Swiss German in Kraehenmann, 2001, 2003). Based on phonetic and phonological evidence, ranging from segmental to prosodic issues, the singleton/geminate analysis fails to account for the full range of facts in Quiaviní Zapotec. Instead the fortis/lenis distinction is the most adequate analysis, where fortis consonants become moraic segments in coda position.

3.2.3 Formal analysis

The phonetic experiment described in §3.2.2 supports the claim that fortis consonants are moraic in codas in Quiaviní Zapotec, whereas lenis consonants are not. As presented in §3.3, this pattern satisfies the prosodic requirement for words to minimally form a bimoraic foot. As a result, two types of syllable rhymes emerge in Quiaviní Zapotec monosyllables: monomoraic vowels followed by moraic fortis coda consonants (19), and bimoraic vowels followed by non-moraic lenis consonants (20).

[37] The duration of this segment is quite similar to that of short stops in Swedish (Thorén, 2005), a language with geminate counterparts that contrast in intervocalic position.

(19) CVC_{fortis} $ba_{\mu}k_{\mu}$ 'person from Tlacolula'

(20) $CV{:}C_{lenis}$ $ba_{\mu\mu}x$ 'cow'

The goal of this section is to formally account for the minimality and moraic characteristics of Quiaviní Zapotec within Optimality Theory (Prince & Smolensky 2004 [1993]). The section focuses on monosyllabic words.

Starting with minimality, languages may require content words to have some minimum size. This minimal word typically equals a single foot, consisting of two syllables or two moras. As already established, in Quiaviní Zapotec, where monosyllables are the majority of words, monomorphemic monosyllabic words form bimoraic feet (21).

(21) Min PrWd in Quiaviní Zapotec = Bimoraic foot

Following the prosodic hierarchy (22), this prosodic requirement is encoded with the constraint FT-BIN, as defined in (23).

(22) Prosodic Hierarchy (Selkirk, 1980, McCarthy & Prince, 1986)

PrWd	Prosodic Word
|	
Ft	Foot
|	
σ	Syllable
|	
μ	Mora

(23) FT-BIN (Kager, 1999, p. 156; cf. Bernhardt & Stemberger, 1998)
Feet are binary under moraic or syllabic analysis

Metrical theory assumes a set of universal prosodic categories in a hierarchical relation, as every prosodic category in the hierarchy has as its *head* an element of the next lower level category. In other words, every PrWd contains a foot, every foot contains a (stressed) syllable, while every syllable contains a mora.[38] Accordingly, in Quiaviní Zapotec every phonological word must contain a bimoraic foot (FT-BIN).

In Quiaviní Zapotec, in order to satisfy FT-BIN, monosyllables insert a mora, either for the fortis coda consonant or for the vowel to become bimoraic. As such, violations to DEP-μ will be incurred.[39]

(24) DEP-μ

Output moras have input correspondents (No insertion of moras)

(25) Minimality: FT-BIN >> DEP-μ

/ ba$_{\mu}$k / ‘Tlacolula’	FT-BIN	DEP-μ
a. ba$_{\mu}$k	*!	
b. ☞ ba$_{\mu\mu}$k		*
c. ☞ ba$_{\mu}$k$_{\mu}$		*
/ ba$_{\mu}$g / ‘cow’		
d. ba$_{\mu}$x	*!	
e. ☞ ba$_{\mu\mu}$x		*
f. ☞ ba$_{\mu}$x$_{\mu}$		*
/ lo̤ / ‘face’		
g. lo̤$_{\mu}$	*!	
h. lo̤ː$_{\mu\mu}$		*

Tableau (25) shows three types of monosyllables, the first one with a fortis consonant in coda, the second with a lenis consonant in coda, and the last word without a coda. In this tableau, all the faithful monomoraic candidates (a), (d), and (g) are eliminated, in fatal violation of the high ranked constraint FT-BIN. For the open syllable / lo̤ / ‘face’, candidate (h) wins because it only violates the low-ranked DEP-μ. With respect to

38 It is also commonly assumed that a ‘grammatical word must be a prosodic word’: GW = PW (Kager, 1999, p. 152). I assume this constraint to be undominated in Quiaviní Zapotec, and thus it indirectly follows that grammatical words must have minimally one foot.

39 If every token of a morpheme has two moras, assuming one mora in the input may appear to violate lexicon optimization; however, as claimed here, bimoraicity in monosyllables corresponds to prosodic requirements rather than underlying parameters. I show below (§3.3) that in compounds and some suffixed words, roots surface as light syllables, which suggests their underlying monomoraicity. In the case of Quiaviní Zapotec, it simply seems more problematic and complex to propose an analysis in which bimoraic roots lose a mora in cases where the root is not prominent.

candidates with a coda, the ranking in (25) is insufficient to decide between candidates with long vowels (b. & e.) and candidates with moraic coda consonants (c. & f.). Both types of candidates satisfy FT-BIN by violating DEP-μ.

In order to capture the fact that fortis consonants are moraic in coda, it is necessary to include the concept of Weight-by-Position as a constraint, which is ranked below FT-BIN (this crucial ranking will be illustrated in subsequent sections).

(26) WEIGHT BY POSITION (WBYP) (Hayes, 1989)

Coda consonants are moraic

(27) Fortis coda consonants: FT-BIN >> WBYP, DEP-μ

/ $ba_{\mu}k$ / 'Tlacolula'	FT-BIN	WBYP	DEP-μ
a. $ba_{\mu}k$	*!	*	
b. $ba_{\mu\mu}k$		*!	*
c. ☞ $ba_{\mu}k_{\mu}$			*
/ $ba_{\mu}g$ / 'cow'			
d. $ba_{\mu}x$	*!	*	
e. ☹ $ba_{\mu\mu}x$		*!	*
f. ☞ $ba_{\mu}x_{\mu}$			*

In (27), candidate (b) satisfies minimality but violates WBYP. The winning candidate (c) satisfies both minimality and WBYP, violating only DEP-μ. This ranking is still insufficient to account for words with lenis coda consonants. In tableau (25) above there is a tie between candidates (e) and (f). Vowels are always long before lenis consonants in prominent syllables. It follows then that these consonants are not able to bear a mora on their own, and vowels lengthen to satisfy minimality. In order to capture this, Arellanes (2009, p. 348) proposes a constraint to ban lenis consonants from being moraic, adapted in (28).[40] This constraint is highly ranked along with FT-BIN, accounting correctly for candidates with lenis consonants in coda.

[40] *L⇔μ (Arellanes 2009: 348)
'Los segmentos lenis no pueden constituir moras de modo autónomo'
("Lenis consonants cannot be moraic autonomously' [*Translation mine*].)

(28) *Lenis-μ (adapted from Arellanes, 2009, p. 348)
If lenis then non-moraic

(29) Lenis coda consonants: FT-BIN, *Lenis-μ >> WBYP, DEP-μ

/ $ba_{\mu}g$ / 'cow'	FT-BIN	*Lenis-μ	WBYP	DEP-μ
a. $ba_{\mu}x$	*!		*	
b. ☞ $ba_{\mu\mu}x$			*	*
c. $ba_{\mu}x_{\mu}$		*!		*

Candidate (a), the faithful one, violates minimality. Candidate (c) satisfies minimality, but the moraic lenis consonant incurs a fatal violation of *Lenis-μ. Candidate (c) wins because it only violates the low-ranked WBYP and DEP-μ.

To conclude, I repeat below the statements of (30), which summarize the prosodic analysis for Quiaviní Zapotec monosyllables.

(30) Quiaviní Zapotec minimality and moraicity (from above)

a. Minimal Prosodic Word = bimoraic foot (FT-BIN)
b. Lenis consonants are non-moraic (*Lenis-μ)
c. Vowels lengthen before lenis C
d. Fortis consonants are moraic in coda (WBYP)

3.3 Morphology: Root prominence

Prominence or stress in a language is based on the syntagmatic comparison among syllables at the word (and phrase) level; i.e. a syllable is prominent in relation to non-prominent ones. In Quiaviní Zapotec, the majority of native roots are monosyllabic, but the addition of affixes as well as disyllabic or longer loanword roots (~20% of the lexicon) allows us to make such syntagmatic comparison, which is the focus of the Chapter. This section in particular shows the root (final) syllable prominence in this language, instantiated by increased duration[41], and the ability to bear all phonological contrasts.

In Quiaviní Zapotec, neither prefixes nor suffixes are ever stressed. In addition, affixes are never as complex, prosodically and segmentally, as prominent (root) syllables. Starting with examples with prefixes, the most common forms are inflected verbs and derived nouns forms.

(31) / ka-[ʐṵn·j][42] / → [ka.ˈʐ ṵ ɲː] ‘(someone) is running’
PROG-run

(32) / ka-[kwan·j] / → [ka.ˈkwa̰ ɲː] ‘(someone) wakes up (somebody)’
PROG-run

(33) / ba-[gidj] / → [baˈgiːdʲ] ‘butterfly’
ANIM-skin

Examples above show that in all words formed by prefix+root, the root is a heavy syllable (by means of a bimoraic vowel or a moraic fortis coda consonant).

(34) / ka-[ba̤b] / → [ka.ˈba̤ːɸ] ‘(it) is itching’
PROG-itch

(35) *[ka.ˈba̤ɸ] ‘(it) is itching’

In order to show that Quiaviní Zapotec prominence pays attention to morphological domains, examples with the diminutive suffix and clitics demonstrate that stress is not simply word-final; in these examples, stress is still located on the root syllable (vowel length in relationship to the diminutive suffix and clitics will be discussed in the next section).

(36) / [ba̰t]-eˀ / → [ˈba̰.teʔ] ‘little skunk’
skunk-DIM

[41] Chávez-Peón (2008) investigates the phonetic cues to stress in Quiaviní Zapotec. The study compares pitch, intensity and duration in prominent versus non-prominent syllables; results show that duration is the main acoustic correlate of Quiaviní Zapotec stress.
[42] Roots are marked with square brackets.

(37) / ɾ-[ka̰z]=aˀ / → [ˈɾka̰ː.zaʔ] ‘I want’
HAB-to want-1S

(38) / w-[ba̰nˑj]=i̤ / → [ˈwba̰ ɲː i̤] ‘He (that one) wakes up’
PERF-to wake up-3S.DISTAL

(39) / ka-[gje̤t]=rɨŋ / →[kaˈgje̤trɨŋ] ‘They are playing’
PROG-to play-3P.PROX

All in all, the data above illustrate that affixes have no effect on stress location.

Compounds illustrate the final root (morphological) prominence. When two roots are attached to form a compound, prominence is located on the second root.

(40) / tsɨ / → [tsɨː] ‘ten’
(41) / tjop / → [tjopː] ‘two’
(42) / tsɨ(b)-[tjop] / → [tsɨb.ˈtjopː] ‘twelve’
(43) *[ˈtsɨːbtjopː]

The word / tsɨ / ‘ten’ is stressed on its own; however, when it forms the first part of the compound / tsɨ(b)-tjop / ‘twelve’, it is no longer stressed and, therefore, the vowel does not lengthen. This can be shown with compound verbs as well.

(44) / ɾ-[gwḛ] / → [ɾgwḛː] ‘speaks (a language)’
HAB-speak
(45) / ɾ-[gwḛ]-[zak] / → [ɾgwḛˈzakː] ‘speaks (a language) well’
HAB-speak-good

(46) *[ˈɾgwḛːzakː]
(47) *[ɾgwḛːˈzak]

The vowel of the verb / ɾ-gwḛ / ‘speaks (a language)’ is long when it is stressed, but when it forms the compound / ɾ-[gwḛ]-[zak] / ‘speaks (a language) well’, the stress is on the last syllable / zak /; thus, the vowel / ḛ / is short. (The vowel in the syllable / zak /

is not long because it is followed by a fortis consonant.) Compound verbs are very common in Quiaviní Zapotec (there are many entries in the dictionary of Munro and Lopez (1999)).

(48) / ɾ-[inj]-[dja̤g] / → [ɾin.ˈdja̤ːg] ‘hears’
HAB-to go-ear

(49) / ɾ-[za-lˑo̤] / → [ɾza.ˈlo̤ː] ‘starts, begins’
HAB-?-face

Finally, although all native roots seem to be monosyllabic, for several words it is not possible to establish the etymology (indicated by the question marks). These words, whether monomorphemic or not, show prominence in the last syllable.

(50) / ba-[nˑṵa] / → [ba.ˈnṵˑa̰] ‘scorpion’
ANIM-?

(51) / b-[ud]-[geɾ] / → [bud.ˈgeːɾ] ‘segment, section of fruit’
?ANIM-?-?

(52) / gi-[tseinj] / → [gi.ˈtseˑiɲ] ‘cricket’
?skin-?

(53) / [damgḛs] / → [dam.ˈgḛs] ‘type of black and white grasshopper with orange spots’

(54) / [laba̰] / → [la.ˈba̰ː] ‘root’

Finally, some loanwords are clear examples of polysyllabic roots with final syllable prominence, as shown in (55). (See loanword phonology below, §3.4, for more details.)

(55) Polysyllabic loanwords

Spanish		Quiaviní Zapotec		
a. [naˈβaxa]	→	[naˈβaxː]	‘pocket knife’	(<Sp. *navaja*)
b. [konˈxuan]	→	[kon.ˈxuanː]	‘musical group’	(< Sp. *conjunto*)
c. [koɾaˈson]	→	[ko.ɾa.ˈsonː]	‘heart’	(< Sp. *corazón*)
d. [kaˈnela]	→	[kaˈneːl]	‘cinnamon’	(<Sp. *canela*)
e. [benˈtana]	→	[ben.ˈtaːn]	‘window’	(< Sp. *ventana*)

In addition to prosodic characteristics, cross-linguistically, prosodic heads may display segmental and featural contrasts not found in non-prominent positions. In other words, clusters of information tend to occupy salient positions (see Beckman, 1998; Michael J. Kenstowicz, 1994, 1996a; Paul Valiant de Lacy, 2002; Paul de Lacy, 2006; Zoll, 1998, 2004). This is the case in Quiaviní Zapotec, where particular distributional properties differentiate prominent versus non-prominent syllables, as noted by Munro and Lopez (1999). Many of these properties were described in the phonotactics section of Chapter 1; I repeat them here in the context of Quiaviní Zapotec prominence.

Beginning with segmental properties, all consonants may appear in singleton onsets and most of them in singleton codas (as outlined in Chapter 1). More importantly, all licit consonant clusters occur in prominent syllables, and rarely in non-prominent ones. With respect to vowels, all six Quiaviní Zapotec vowel types, / a e o i u ɨ /, may bear stress (i.e. constitute prominent syllables). Diphthongs,[43] predominantly, and derived long vowels, exclusively, are found in prominent syllables.

One of the over-arching themes of this study is voice quality. In terms of metrical structure, all Quiaviní Zapotec phonation types appear in both unstressed and stressed syllables. However, non-modal vowels are considerably more common in prominent positions (see restrictions and combination forms described in Munro & Lopez, 1999).

The interaction between stress and tone shows more distributional evidence for prominence in Quiaviní Zapotec. This language has four tones: two levels (high and low) and two contours (rising and falling). All four tones may appear in prominent syllables,

[43] The only diphthongs in unstressed syllables may be found in compounds, with roots that appear as the non-head.

whereas only level tones seemed to be found in non-prominent syllables.[44] In other words, stress constrains the complexity of tone, restricting contours to stressed syllables.

In brief, prominent syllables in Quiaviní Zapotec are characterized by the ability to bear all phonological contrasts.

(56) and (57) below summarize the segmental, tonal, and voice quality properties that are restricted, or statistically restricted, to prominent syllables (non-prominent syllables have no exclusive properties), which illustrates the crucial fact that Quiaviní Zapotec restricts a considerable amount of phonological complexity to prominent positions.

(56) Exclusive properties of prominent syllables

i. (Derived) long vowels
ii. Contrastive contour tones (rising and falling)

(57) Near exclusive properties of prominent syllables

i. Non-modal vowels
ii. Diphthongs
iii. Consonant clusters (both in onset and coda)

Based on the observations above, Quiaviní Zapotec prominence patterns illustrate two cross-linguistic properties of stress: *culminativity* and *demarcativity*. The former consists of having a single prosodic peak for a morphological or syntactic constituent (stem, word, phrase). The latter concerns how stress tends to be placed near the edges of constituents. Quiaviní Zapotec shows *culminativity* in that there is only one prominent syllable per word, and *demarcativity* in that the (final) root syllable is always prominent.

[44] The analysis of tone outside stressed syllables (roots) is still inconclusive, but it seems fairly restricted. Surface contour tones appear to be non-contrastive in unstressed syllables.

3.3.1 *Foot type: Trochaic rhythm*

In accounting for the metrical structure of Quiaviní Zapotec, a necessary step is to establish its rhythmic type of feet (iambic or trochaic). As shown above, words may be morphologically complex and present different stress patterns, e.g. S, Sw (with a suffix), wS (with or without a prefix).[45] I start this section by presenting examples of root plus suffix in more detail, as these types of words may be the only cases of light stressed syllables. Having established the durational patterns of these words, I consider the different word-stress patterns in Quiaviní Zapotec and evaluate different foot-type possibilities, suggesting a trochaic analysis.

As demonstrated in §3.2.1, lenis consonants are always short, independent of their syllabic position. In contrast, the analysis of monosyllables showed that fortis consonants are long (moraic) in coda position. This generalization, however, is different when the diminutive suffix or clitics are added to monosyllabic roots (see morphosyntactic section in Chapter 1): Fortis obstruent codas resyllabify as onsets, surfacing as short segments; on the other hand, fortis sonorant segments still surface as long, ambisyllabic consonants (see formal analysis in §3.3.3). Consider the examples in (58-61), monosyllabic nouns and their affixed forms with the diminutive suffix /-e^ʔ/.

[45] S = stressed syllable; w = weak / unstressed syllable.

(58) *Fortis obstruent coda*

a.	/ tʃat /	→ [tʃa$_{μ}$t$_{μ}$]	‘kiss’	Bimoraic root syllable
b.	/ tʃat-e^{ʔ} /	→ [ˈtʃa$_{μ}$.te$^{ʔ}_{μ}$]	‘little kiss’	*Monomoraic root syllable*
c.		*tʃa$_{μ}$t$_{μ}$e$^{ʔ}_{μ}$		
d.		*tʃa$_{μμ}$.te$^{ʔ}_{μ}$		

(59) *Lenis obstruent coda*

a.	/ dad /	→ [da$_{μμ}$ð]	‘father’	Bimoraic root syllable
b.	/ dad-e^{ʔ} /	→ [ˈdaː$_{μμ}$.ðe$^{ʔ}_{μ}$]	‘daddy’	Bimoraic root syllable

(60) *Fortis sonorant coda*

a.	/ bḛlˑ /	→ [bḛ̀$_{μ}$l$_{μ}$]	‘snake’	Bimoraic root syllable
b.	/ bḛlˑ-e^{ʔ} /	→ [ˈbḛ̀$_{μ}$l$_{μ}$e$^{ʔ}_{μ}$]	‘little snake’	Bimoraic root syllable

(61) *Lenis sonorant coda*

a.	/ nan /	→ [na$_{μμ}$n]	‘mother’	Bimoraic root syllable
b.	/ nan-e^{ʔ} /	→ [ˈna$_{μμ}$.ne$^{ʔ}_{μ}$]	‘mommy’	Bimoraic root syllable

These duration patterns were initially detected using data from by-ear transcription from 4 different speakers with several words, followed by phonetic measurements. One male speaker, TiuC, produced five words with fortis obstruent in coda position, combined with the same words in their clitisized forms. Each word was recorded three times in isolation in careful speech.

Table 19. Vowel and consonant duration (ms): roots and clitisized forms (TiuC)

Rhyme type	V	C	Prediction
VO$_{fortis}$	103	230	VC:
plus clitic	98	113	VCV
VO$_{lenis}$	209	80	V:C
plus clitic	148	61	V:CV
VR$_{fortis}$	91	146	VC:
plus clitic	84	126	VC:V
VR$_{lenis}$	184	72	V:C
plus clitic	133	54	V:CV

From the values above, short vowels average 94 ms and long vowels 168 ms, whereas the mean for short consonants is 75 ms and 167 for long consonants.[46] (Similar ratios have been observed in languages with contrastive vowel and consonant length, e.g. Tamil (Maddieson, 1984); Swedish (Thorén, 2005).) In fortis obstruent-final roots, vowels are short with or without a clitic, whereas fortis obstruent consonants are long in coda, but short in the clitisized form. In lenis-final roots (both obstruents and sonorants), vowels are long and consonants short with or without a clitic. Finally, in fortis sonorant-final roots vowels are short and consonants long regardless of the type of prosodic word. These results support the analysis above (58-61) in terms of vowel and consonant duration for monosyllables and clitisized forms; Sw words may be formed by two light syllables, LL, or heavy and light, HL.

Having established the duration of vowels and consonants in monosyllables and clitisized words, let us move on to the discussion of foot type in Quiaviní Zapotec. All words in this language contain only one prominent syllable (*culminativity* property), and thus I will assume one foot per word. Consider the word types in Thorén (2005), which are by far the most common in Quiaviní Zapotec. (The previous section illustrated actual examples of these types of words.)

(62) Word stress patterns and syllable weight type

Stress pattern	*Syllable weight type*
a. S	H
b. wS	LH
c. Sw	HL, LL

A theory of rhythmic units or feet assumes the following universal inventory (McCarthy and Prince 1986, Hayes 1987, 1995, Kager 1993, 1999, p. 147):

[46] Results for the same speaker, TiuC, from the fortis/lenis experiment (§3.2.1) show smaller values but similar ratios (the difference possibly derives from the use of carrier phrase and stimuli vs. words produced in isolation, at a lower speech rate).

(63) Foot inventory [47]

a. *Syllabic trochee* (quantity-insensitive): (**σ**σ)
b. *Moraic trochee* (quantity-sensitive): (**L**L) (**H**)
c. *Iamb* (quantity-sensitive) (L**L**) (**H**) (L**H**)

In light of this foot inventory, there are three possible analyses to account for rhythmic type of feet in Quiaviní Zapotec: monosyllabic feet (heavy syllables, regardless of the specific rhythm type), iambs or trochees. Monosyllabic feet, where only the stressed syllable (root) is part of the foot (regardless of the word type), accounts for all the data except for Sw words with light stressed syllable (e.g. [ˈtʃa_{μ}.$te^{ʔ}_{\mu}$] 'little kiss'). These words would be parsed as (L)L and they would not satisfy Quiaviní Zapotec minimality (FT-BIN), crucial in accounting for monosyllables and the vowel lengthening pattern. In addition, this account would leave us with a considerable number of unparsed syllables.

The iambic analysis accounts for all wS type words, which surface as LH syllables, forming the cross-linguistic preferred iamb: (LH) (see Kager, 1993; Bruce Hayes, 1995 among others). Lengthening, commonly found in iambic systems (iambic/trochaic law, Bolton, 1894; Hayes, 1995; cf. Kager, 1993), might also support this analysis. In addition to length, the segmental complexity described in final syllables of non-compound uninflected native words (Munro & Lopez, 1999, p. 3) suggests that wS is basic, leading most directly to the idea that the basic foot is iambic. However, the iambic rhythm fails to account for words of the syllable weight type LL. A degenerate iamb like (L)L violates minimality, and parsing these words as (L**L**) would imply the clitic is stressed, which is clearly not the case. (Other problems arise with the formal analysis of iambs as we will see below.)

Finally, the trochaic rhythm as moraic trochees accounts for monosyllables and wS words, leaving the initial unstressed syllable unparsed; it is the most fitting analysis for Sw words, parsing them either as moraic trochees, (**H**)L and (**L**L), or as syllabic ones (**H**L). The most crucial data then, are cases of Sw words with LL syllables, for which both the monosyllabic feet and iambic approaches are inadequate.

[47] A trochaic rhythm entails left foot prominence (either syllabic or moraic), whereas an iambic rhythm demands right foot prominence (always moraic). In this notation, 'L' stands for a light syllable (one mora) and 'H' for a heavy syllable (two moras). The head of the foot, the stressed syllable, is marked in boldface.

Additional internal evidence supports a trochaic rhythm for Quiaviní Zapotec. In the previous section I showed that stressed syllables in Quiaviní Zapotec (roots) display more segmental and featural contrasts than unstressed syllables. We also find differences comparing final unstressed syllables (diminutive suffix and clitics) with initial unstressed syllables. The former bears tone (probably restricted to level tones) and all non-modal phonations, whereas the latter may not be specified for tone,[48] and shows extremely reduced contrasts with respect to non-modal phonation. Caldecott (2009) shows phonological and phonetic differences between parsed versus unparsed syllables in St'át'imcets (Lillooet Salish), with the former being longer and with higher pitch values, as well as having phonological properties absent in unparsed syllables (e.g. glottalization). These differences parallel those found in Quiaviní Zapotec, in favor of trochaic foot parsing.

An interesting issue is that of the acquisition of foot type in Quiaviní Zapotec. If the child is faced with data where there are not overwhelming reasons for choosing one analysis over another, which does the child identify as the correct pattern? In response to this question Stemberger and Lee (2007) and Stemberger, Chávez-Peón and Lee (2008) show that Quiaviní Zapotec children acquire Sw outputs before wS outputs. The high frequency of the diminutive and pronominal clitics, along with the arguments above seem to facilitate the child choosing a trochaic pattern over an iambic one.

In summary, three arguments suggest a trochaic analysis in Quiaviní Zapotec: First, the ability to account for all types of words, particularly Sw words with stressed light syllable (**L**L); second, the phonological properties carried by the diminutive and clitics over initial unstressed syllables (tone and phonation contrasts); and third, acquisition data where Sw is favored over wS.

The following two subsections account formally for the prominence patterns outlined in this and the previous section.

[48] From my preliminary observations, it seems that initial unstressed syllables in dysillabic roots and prefixes have a phonetic mid tone. In terms of acquisition of Quiaviní Zapotec, J. Stemberger (personal communication, March 15, 2010) has observed that the pitch of these syllables is highly variable. The status of tone outside the root requires further investigation.

3.3.2 Prefixes, compounds and complex roots: Foot alignment

The previous section presented the morphology of Quiaviní Zapotec in relationship to the prominence pattern. This subsection analyzes all root-final words, including prefixed roots, compounds and disyllabic roots, leaving the formal account of the diminutive and suffixes for the next section. The goal is to formalize the stress pattern in this language, integrating the proposed Quiaviní Zapotec foot structure.

Disyllabic words present additional problems for the formal analysis of section 3.2.3. The constraints discussed so far are not sufficient to lead to the observed pronunciation. Consider the tableaus (64) and (65), showing a prefixed root and a compound, respectively.

(64) Prefix + root: /ba-gid^{j}/ → [baˈgiːd^{j}] 'butterfly'

/ ba$_{\mu}$-[gi$_{\mu}$dj] /	FT-BIN	*Lenis -μ	WBYP	DEP-μ
a. ☞ (ba$_{\mu}$ˈgi$_{\mu}$d^{j})			*	
b. ☞ (ˈba$_{\mu}$gi$_{\mu}$d^{j})			*	
c. ☹ ba$_{\mu}$(ˈgi$_{\mu\mu}$d^{j})			*	*!
d. (ba$_{\mu}$ˈgi$_{\mu\mu}$d^{j})			*	*!
e. ba$_{\mu}$(ˈgi$_{\mu}$d$^{j}_{\mu}$)		*!		*
f. ba$_{\mu}$(ˈgi$_{\mu}$d^{j})	*!		*	

(65) Compound: / ɾ-gwḛ-zak / → [ɾgwḛ.ˈzakː] 'speaks (a language) well'

/ɾ-[gwḛ$_{\mu}$]-[za$_{\mu}$k] /	FT-BIN	*Lenis -μ	WBYP	DEP-μ
a. (ɾgwḛ$_{\mu}$ˈza$_{\mu}$k)			*!	
b. ☞ ɾgwḛ$_{\mu}$(ˈza$_{\mu}$k$_{\mu}$)				*
c. ☞ (ɾgwḛ$_{\mu}$ˈza$_{\mu}$k$_{\mu}$)				*
d. ☞ (ˈɾgwḛ$_{\mu}$za$_{\mu}$k$_{\mu}$)				*
e. ɾgwḛ$_{\mu}$(ˈza$_{\mu\mu}$k)			*!	*

Minimality is no longer an issue for this type of word; except for (64f), all candidates satisfy FT-BIN under moraic or syllabic analysis. The problem is the location of stress, and the syllable weight of the stressed syllable. This constraint-based grammar is insufficient to decide whether stress is word-initial or located in the root-final syllable (64b & 65d). In addition, no constraint regulates the parsing into feet (64a&b vs. the actual output 64c; and 65b vs. 65c&d). In short, this account is not enough to explain the prominence pattern of Quiaviní Zapotec. (From these examples, however, we do see now that WBYP >> DEP-μ (65a vs. 65b)).

This ranking will be equally insufficient for inflected verbs (e.g. / ka-zṳnˑj / → [ka.ˈzṳɲː] '(someone) is running') or disyllabic or longer roots (e.g. / ɡji-tseinj /→ [ɡʲi.ˈtseˑiɲ] 'cricket'). In all these cases, the final syllable is heavy. The Stress-to-Weight Principle (SWP), which states that every stressed syllable is heavy, seems a likely way to account for Quiaviní Zapotec prominence pattern. However, the previous section showed that root-final fortis obstruents surface with a light prominent syllable once a suffix or clitic is added (see formal analysis in the next section).

(66) / lat-eˀ / → [ˈla$_{\mu}$.teˀ$_{\mu}$] 'little can'
can-DIM

Since minimality is not enough and SWP by itself cannot account for morphologically complex words in Quiaviní Zapotec, the explanation seems to need to rely on the alignment of the root and stress. In metrical structure, this can be attained by means of alignment of the head of the foot with the right edge of the root. Following the format of 'Generalized Alignment' (McCarthy & Prince, 1993), the constraint is formulated in (67). (I will show that this constraint is also adequate for capturing loanword phonology in §3.5.)

(67) ALIGN (Hd(Ft), R, Root, R) (ALIGN-R)
'For every stressed syllable (= head of a foot) there must be some root such that the right edge of that syllable matches the right edge of the root'

The "head of the foot" automatically means the stressed syllable (not the stressed mora), because syllables are the next level down from feet in the prosodic hierarchy. As we will see in the next section, to refer to the head of the foot instead of the foot itself (i.e. the right edge of the foot) is crucial in accounting for cases like (66) above, where the foot includes the suffix: (ˈla$_{\mu}$.teˀ$_{\mu}$) 'little can', as shown in the previous section. The undominated constraint ALIGN-R will eliminate candidates with initial stress (64b & 65d).[49]

In arguing that OT constraints are categorical, McCarthy (2003) proposes different ways of assessing alignment constraints, such as Align-by-segment, Align-by-syllable, Align-by-foot, among others (see also Horwood, 2008, p. 8). Along these lines, the alignment constraint proposed in (67) evaluates candidates in the form of Align-by-syllable, that is, the head of the foot must be the rightmost syllable of the root, and not necessarily the precise segmental edge of the root. This is important as some root-final coda consonants resyllabify when a clitic is added (e.g. /dad/ → [daːθ], but /dad+eˀ/ → [daː.ðeˀ]); in these cases the consonant would not be part of the stressed syllable, but no violation of ALIGN-R would be incurred as the rightmost syllable of the root is stressed (these cases are evaluated in the next section). This subtle issue of determining prosodic boundaries is not exclusive to Quiaviní Zapotec, but common cross-linguistically, particularly in languages where a morphological domain (e.g. the root) is prosodically salient.

In addition to the alignment of stress, the previous section established trochaic rhythm as the most appropriate for Quiaviní Zapotec, formalized in (68).

(68) RHTYPE=T (TROCHEE) (Kager, 1999, p. 172)
Feet have initial prominence

As a result of the undominated constraints ALIGN-R and TROCHEE some syllables of the output candidates will be left unparsed, violating the low ranked constraint PARSE-σ.

(69) PARSE-σ
Every syllable must belong to some foot. (No syllable may be left unparsed)

[49] With respect to example (65d), although both syllables are roots the Align-R constraint refers to the first root in the derivation.

With these revisions, the summary tableaus below demonstrate how the interaction of ALIGN-R and the foot type constraint TROCHEE correctly derives the Quiaviní Zapotec prominence pattern.

(70) Complex words: lenis coda (ALIGN-R & TROCHEE)

/ba$_{\mu}$-[gi$_{\mu}$dj] /	FT-BIN	ALIGN-R	TROCHEE	*Lenis-μ	WBYP	DEP-μ	PARSE-σ
a. (ba$_{\mu}$ˈgi$_{\mu}$d^{j})			*!		*		
b. (ˈba$_{\mu}$gi$_{\mu}$d^{j})		*!			*		
c.☞ ba$_{\mu}$(ˈgi$_{\mu\mu}$d^{j})					*	*	*
d. (ba$_{\mu}$ˈgi$_{\mu\mu}$d^{j})			*!		*	*	
e. ba$_{\mu}$(ˈgi$_{\mu}$d$^{j}_{\mu}$)				*!		*	*
f. ba$_{\mu}$(ˈgi$_{\mu}$d^{j})	*!				*		*

(71) Complex words: fortis coda (ALIGN-R & TROCHEE)

/ɾ-[gwḛ$_{\mu}$]-[za$_{\mu}$k] /	FT-BIN	ALIGN-R	TROCHEE	*Lenis -μ	WBYP	DEP-μ	PARSE-σ
a. (ɾgwḛ$_{\mu}$ˈza$_{\mu}$k)			*!		*		
b.☞ ɾgwḛ$_{\mu}$(ˈza$_{\mu}$k$_{\mu}$)						*	*
c. (ɾgwḛ$_{\mu}$ˈza$_{\mu}$k$_{\mu}$)			*!			*	
d. (ˈɾgwḛ$_{\mu}$za$_{\mu}$k)		*!			*		
e. ɾgwḛ$_{\mu}$(ˈza$_{\mu\mu}$k)					*!	*	*

This analysis adequately explains all words where the root is word-final. I turn now to the analysis of words with final unstressed syllables.

3.3.3 Diminutive suffix and clitics: Faithfulness to the base

This section continues the morphological analysis of prominence in Quiaviní Zapotec, focusing on the diminutive suffix and clitics. The goal is to account for the additional prosodic phenomena found with elements within the constraint-based Quiaviní Zapotec grammar.

Section 3.3.1 illustrated the special behavior of root final fortis segments once the diminutive suffix or a clitic is added. Fortis obstruent codas resyllabify as onsets, surfacing as short segments, whereas fortis sonorant segments still surface as long, ambisyllabic consonants. In contrast, roots with lenis consonants in the coda, both obstruents and sonorants, always surface as bimoraic in their suffixed or clitisized forms. The examples below, repeated from §3.3.1, illustrate these patterns.

(72) *Fortis obstruent coda*

a. / tʃat / → [tʃa$_{\mu}$t$_{\mu}$] 'kiss'

b. / tʃat-e^{ʔ} / → [ˈtʃa$_{\mu}$.te$^{ʔ}{}_{\mu}$] 'little kiss'

(73) *Fortis sonorant coda*

a. / bḛl· / → [bḛ̀$_{\mu}$l$_{\mu}$] 'snake'

b. / bḛl·-e^{ʔ} / → [ˈbḛ̀$_{\mu}$l$_{\mu}$e$^{ʔ}{}_{\mu}$] 'little snake'

(74) *Lenis obstruent/sonorant coda*

a. / dad / → [da$_{\mu\mu}$ð] 'father'

b. / dad-e^{ʔ} / → [ˈdaː$_{\mu\mu}$.ðe$^{ʔ}{}_{\mu}$] 'daddy'

c. / nan / → [na$_{\mu\mu}$n] 'mother'

d. / nan-e^{ʔ} / → [ˈna$_{\mu\mu}$.ne$^{ʔ}{}_{\mu}$] 'mommy'

Under this analysis, the generalization is that all the roots maintain their bimoraicity in their suffixed form, except roots with fortis obstruent in coda. Considering the formal account of the previous section, the differences between the base and the suffixed or clitized forms are not reflected in the current ranking, illustrated below. (Since parsing is not decisive in selecting the optimal output, candidates are left unparsed. I will come back to this issue at the end of the section.)

(75) Root with fortis obstruent coda + suffix (or clitic)

/ [tʃa$_{\mu}$t]-e$^{ʔ}{}_{\mu}$/	FT-BIN	ALIGN-R	TROCHEE	*Lenis-μ	WBYP	DEP-μ	PARSE-σ
a. ☞ (ˈtʃa$_{\mu}$.te$^{ʔ}{}_{\mu}$)							
b. (ˈtʃa$_{\mu}$t$_{\mu}$e$^{ʔ}{}_{\mu}$)						*!	
c. (ˈtʃa$_{\mu\mu}$.te$^{ʔ}{}_{\mu}$)						*!	

(76) Root with fortis sonorant coda + suffix (or clitic)

/[bḛ$_{\mu}$l·]-e$^{ʔ}_{\mu}$/	FT-BIN	ALIGN-R	TROCHEE	*Lenis-μ	WBYP	DEP-μ	PARSE-σ
a. ☞ (ˈbḛ$_{\mu}$le$^{ʔ}_{\mu}$)							
b. ☹ (ˈbḛ$_{\mu}$l$_{\mu}$e$^{ʔ}_{\mu}$)						*!	
c. (ˈbḛ$_{\mu\mu}$le$^{ʔ}_{\mu}$)						*!	

(77) Root with lenis sonorant (or obstruent) coda + suffix (or clitic)

/[na$_{\mu}$n]-e$^{ʔ}_{\mu}$ /	FT-BIN	ALIGN-R	TROCHEE	*Lenis-μ	WBYP	DEP-μ	PARSE-σ
a. ☞ (ˈna$_{\mu}$.ne$^{ʔ}_{\mu}$)							
b. (ˈna$_{\mu}$.n$_{\mu}$e$^{ʔ}_{\mu}$)				*!		*	
c. ☹ (ˈna$_{\mu\mu}$.ne$^{ʔ}_{\mu}$)						*!	

The formal analysis of this behavior does not rely on purely phonological facts; it is necessary to refer to prosodic morphology. One possible explanation relies on the moraic correspondence between the stand-alone root form ("the base") and its derived forms ("affixed form"), in combination with the likelihood that segments bear syllable weight. This is a case of paradigm uniformity (Kurylowicz, 1945), formally treated as an Output-to-Output (OO) correspondence within OT (Benua, 1995; Kenstowicz, 1996).

The notion of OO-correspondence corresponds to the maximization of phonological identity between morphologically related output forms, as portrayed in the following diagram (Benua, 1995; Kager, 1999, pp. 263, 275).

(78) Basic Model of stem-based affixation

BA-Identity

Base ⇔ Affixed form

IO Faithfulness ⇕

Input

The base is a freestanding output form of the language, compositionally related to its derived counterpart (the affixed form). That is, "the base contains a proper subset of the grammatical (semantic, morphological) features of the derived form." (Kager, 1999, p. 281). (On the extension of Correspondence Theory (McCarthy & Prince, 1995) to relations between surface forms within a paradigm: the Base (B) and the Affixed form (A), see Benua (1995) and Urbanczyk (1996).)

As a starting point, I adopt the analysis of Arellanes (2009) accounting for similar data in San Pablo Güilá Zapotec. He proposes an interaction between the universal hierarchy of moraic elements in (79) and the OO-correspondence constraint in (80), which forces the Base-Affixed form correspondents to have the same moraic content.

(79) Universal hierarchy of moraic elements (cf. Morén 1997, 2003)
*μ/O >> *μ/R >> *μ/V

This universal hierarchy penalizes moraic segments based on their sonority, preferring moraic vowels over moraic sonorants, and moraic sonorants over moraic obstruents.

(80) MAX-μ-BA[50] (Arellanes, 2009, p. 365) *preliminary*
'Every mora in the base (B) has a correspondent in the affixed form (A)'

For this constraint, the base in Quiaviní Zapotec would be the unsuffixed or unclitisized content words (in the case of verbs, it implies the presence of an aspectual prefix, see §1.4.5). The crucial ranking for these constraints is in (81).

(81) MAX-μ-BA and the moraic hierarchy ranking
*μ/O >> MAX-μ-BA >> *μ/R >> *μ/V

Within the global current ranking, the ranking in (81) is located between the contraints WBYP and DEP-μ. On the one hand, moraic faithfulness to the base (MAX-μ-BA) outranks the penalty against inserting moras (DEP-μ); on the other hand, the moraic status of fortis obstruents in coda position (e.g. as in monosyllables like [$za_{\mu}k_{\mu}$] 'good') implies that WBYP >> *μ/O.

[50] Arellanes (2009: 365):
MAX-μ-BCLI
'Las moras de una base (B) tienen un correspondiente en su forma clitizada (CLI)'

(82) Root with fortis coda obstruent + suffix (MAX-μ-BA)

/[tʃa$_{\mu}$t] -e$^{ʔ}_{\mu}$/ Base: tʃa$_{\mu}$t$_{\mu}$	FT-BIN	ALIGN-R	TROCHEE	*Lenis-μ	WBYP	*μ/O	MAX-μ-BA	*μ/R	*μ/V	DEP-μ	PARSE-σ
a. ☞ (ˈtʃa$_{\mu}$.te$^{ʔ}_{\mu}$)							*		**		
b. (ˈtʃa$_{\mu}$t$_{\mu}$e$^{ʔ}_{\mu}$)						*!			**	*	

(83) Root fortis coda sonorant + suffix (MAX-μ-BA)

/[bḛ$_{\mu}$lˑ] -e$^{ʔ}_{\mu}$/ Base: (bḛ$_{\mu}$l$_{\mu}$)	FT-BIN	ALIGN-R	TROCHEE	*Lenis-μ	WBYP	*μ/O	MAX-μ-BA	*μ/R	*μ/V	DEP-μ	PARSE-σ
a. (ˈbḛ̀$_{\mu}$.le$^{ʔ}_{\mu}$)							*!		**		
b. ☞ (ˈbḛ̀$_{\mu}$l$_{\mu}$e$^{ʔ}_{\mu}$)								*	**	*	

(84) Root lenis coda (same for obstruents & sonorants) + suffix (MAX-μ-BA)

/[da$_{\mu}$d] -e$^{ʔ}_{\mu}$/ Base: da$_{\mu\mu}$d	FT-BIN	ALIGN-R	TROCHEE	*Lenis-μ	WBYP	*μ/O	MAX-μ-BA	*μ/R	*μ/V	DEP-μ	PARSE-σ
a.(ˈda$_{\mu}$.ðe$^{ʔ}_{\mu}$)							*!		**		
b.☞ (ˈda$_{\mu\mu}$.ðe$^{ʔ}_{\mu}$)									***	*	

This correctly accounts for the length of vowels and sonorants, which is not due to minimality anymore, but to the base correspondence in the affixed form. However, there is another candidate we must consider within suffixed or clitized forms with root-final fortis obstruents: a candidate with a long vowel. The importance of this candidate derives from the significant preference for heavy syllables in Quiaviní Zapotec prominent positions.

(85) Root with fortis coda obstruent + suffix (MAX-μ-BA)

/[tʃa$_{\mu}$t]-eʔ$_{\mu}$/ Base: tʃa$_{\mu}$t$_{\mu}$	FT-BIN	ALIGN-R	TROCHEE	*Lenis-μ	WBYP	*μ/O	MAX-μ-BA	*μ/R	*μ/V	DEP-μ	PARSE-σ
a.☹ (ˈtʃa$_{\mu}$.teʔ$_{\mu}$)							*!		**		
b. (ˈtʃa$_{\mu}$t$_{\mu}$eʔ$_{\mu}$)						*!			**	*	*
c. ☞ (ˈtʃa$_{\mu\mu}$.teʔ$_{\mu}$)									***	*	*

Candidate c. is faithful to the moras of the base (although now both moras are with the vowel) and follows the tendency of prominent syllables to be heavy. Nonetheless, it is the incorrect output. In order to account for this fact, the moraic faithfulness to the base must be encoded as IDENTITY instead of MAXIMALITY, as formalized in (86).

(86) WEIGHT-IDENT-BA (WT-IDENT-BA) (Kager, 1999, pp. 269, 271; Benua, 1995)
'Base-Affixed form correspondent segments have the same moraic content.'

This constraint establishes correspondence relations between Base and the Affixed form with regard to the moraic content associated with segments. Based on this revision, I consider more candidates in the tableaus below (particularly in terms of foot possibilities), conclusive for the suffix analysis.

(87) Root with fortis coda obstruent + suffix (WT-IDENT-BA)

/[tʃa$_{\mu}$t]-eʔ$_{\mu}$/ Base: tʃa$_{\mu}$tː$_{\mu}$	FT-BIN	ALIGN-R	TROCHEE	*Lenis-μ	WBYP	*μ/O	WT-IDENT-BA	*μ/R	*μ/V	DEP-μ	PARSE-σ
a. ☞ (ˈtʃa$_{\mu}$.teʔ$_{\mu}$)							*		**		
b.(ˈtʃa$_{\mu}$tː$_{\mu}$)eʔ$_{\mu}$						*!			**	*	*
c.(ˈtʃa$_{\mu\mu}$).teʔ$_{\mu}$							*		***!	*	*
d.(ˈtʃa$_{\mu}$).teʔ$_{\mu}$	*!								**		*
e.(ˈtʃa$_{\mu}$t$_{\mu}$eʔ$_{\mu}$)						*!			**	*	
f.(ˈtʃa$_{\mu\mu}$)t$_{\mu}$eʔ$_{\mu}$						*!	*		***	**	*

The moraicity of fortis obstruents in coda position responds to minimality and the constraint WBYP, which outranks *μ/O. In turn, *μ/O outranks WT-IDENT-BA, as illustrated in (87), thus the moraicity of the obstruent does not carry over to the suffixed form. In contrast, WT-IDENT-BA outranks *μ/R and *μ/V, accounting for the paradigm uniformity between the base and the affixed form for roots with lenis and fortis sonorant codas.

(88) Root fortis coda sonorant + suffix (WT-IDENT-BA)

/[bḛ$_{\mu}$lˑ]-eʔ$_{\mu}$/ ‘snake’ Base: bḛ$_{\mu}$l$_{\mu}$	FT-BIN	ALIGN-R	TROCHEE	*Lenis-μ	WBYP	*μ/O	WT-IDENT-BA	*μ/R	*μ/V	DEP-μ	PARSE-σ
a.(ˈbḛ$_{\mu}$.leʔ$_{\mu}$)							*!		**		
b.(ˈbḛ$_{\mu}$l$_{\mu}$)eʔ$_{\mu}$								*	**	*	*!
c.(ˈbḛ$_{\mu\mu}$).leʔ$_{\mu}$							*!		***	*	*
d.(ˈbḛ$_{\mu}$).leʔ$_{\mu}$	*!						*		**		*
e. ☞ (ˈbḛ$_{\mu}$l$_{\mu}$eʔ$_{\mu}$)								*	**	*	
f.(ˈbḛ$_{\mu\mu}$)l$_{\mu}$eʔ$_{\mu}$							*!	*	***	**	*

(89) Root lenis coda (same for obstruents & sonorants) + suffix (WT-IDENT-BA)

/[da$_{\mu}$d]-eʔ$_{\mu}$/ Base: da$_{\mu\mu}$d	FT-BIN	ALIGN-R	TROCHEE	*Lenis-μ	WBYP	*μ/O	WT-IDENT-BA	*μ/R	*μ/V	DEP-μ	PARSE-σ
a.(ˈda$_{\mu}$.ðeʔ$_{\mu}$)							*!		**		
b.(ˈda$_{\mu}$ð$_{\mu}$)eʔ$_{\mu}$				*!		*	*		**	*	*
c.(ˈda$_{\mu\mu}$).ðeʔ$_{\mu}$									***	*	*!
d. ☞ (ˈda$_{\mu\mu}$.ðeʔ$_{\mu}$)									***	*	
e.(ˈda$_{\mu}$).ðeʔ$_{\mu}$	*!						*		**		*
f.(ˈda$_{\mu}$ð$_{\mu}$eʔ$_{\mu}$)				*!		*	*		**	*	
g.(ˈda$_{\mu\mu}$)ð$_{\mu}$eʔ$_{\mu}$				*!		*			***	**	*

The final issue worth noting is parsing in relation to the trochaic rhythm, exemplifying the emergence of the unmarked. The issue is relevant for root-final fortis sonorant and root-final lenis obstruent suffixed forms. Compare, in particular, candidates (88b) (ˈbḛ$_{\mu}$l$_{\mu}$)eʔ$_{\mu}$, a moraic trochee with the final syllable unparsed, vs. (88e) (ˈbḛ$_{\mu}$l$_{\mu}$eʔ$_{\mu}$), an uneven syllabic trochee (**H**L). The low ranked constraint PARSE-σ becomes visibly active, favoring the optimal candidate (88e) over (88b). The syllabic trochee (88e), unmarked with respect to PARSE-σ, emerges as optimal, even though the presence of

PARSE-σ in the grammar is generally hidden. The same condition is observed in (89), where candidate (89d) wins over (89c). This shows that this constraint-based grammar favors parsing over the presence of uneven trochees (cf. GROUPING HARMONY, Elias Ulloa, p. 85; Kager, 1993; Hayes, 1995).

To sum up, this section added suffixes to the prominence analysis of Quiaviní Zapotec, demonstrating the correspondence between the base and its affixed form, where a division among segments and their likehood to be moraic is found.

3.4 Loanword phonology

In adapting a non-native word, the challenge for a speaker is to try to be faithful to the source while obeying her/his own language-specific restrictions. Several conflicts may emerge in this process due to the segmental inventory, phonotactics, prosodic domains, and so forth. Quiaviní Zapotec has been in continuous contact with Spanish for over 400 years; as a result, the language has borrowed heavily from Spanish. These loanwords provide valuable evidence with respect to Quiaviní Zapotec prosodic prominence. As such, the goal of this section is to apply the prosodic and formal analysis of native words to loanword phonology.

The examples and description are based on Munro and Lopez (1999), Munro et al. (2008) and Chávez-Peón (2006). (See also Stemberger & Lee, 2008, with respect to the acquisition of loanwords.)

(90) Spanish loanwords

Spanish		Quiaviní Zapotec		
a. [ˈlata]	→	[latː]	‘tin can’	(< Sp. *lata*)
b. [ˈbeto]	→	[betː]	‘Alberto’	(< Sp. *Beto* < *Alberto*)
c. [koɾaˈson]	→	[ko.ɾa.ˈsonː]	‘heart’	(< Sp. *corazón*)
d. [ˈlado]	→	[laːd]	‘side’	(< Sp. *lado*)
e. [ˈpedɾo]	→	[beːd]	‘Pedro’	(< Sp. *Pedro*)
f. [benˈtana]	→	[ben.ˈtaːn]	‘window’	(< Sp. *ventana*)

The borrowing process, exemplified with the words above, has the following characteristics (first described by Munro & Lopez, 1999):

(91) Loanword adaptation

a. Unstressed Spanish final vowels in open syllables are consistently deleted.
b. Stressed Spanish vowels are always maintained and retain their quality.
c. Stressed syllables of Spanish words are borrowed into Zapotec as the prominent syllable of the word.

These generalizations are observed in the examples above and apply to all loanwords in Quiaviní Zapotec without exception. The fact that unstressed final vowels in open syllables are routinely dropped follows the prominence pattern of Quiaviní Zapotec, as the prosodic head of a word, that is, the prominent or stressed syllable, must be the last one within the root. In the previous sections about root prominence, this pattern was attained by the foot-root alignment constraint ALIGN-R. This constraint, in combination with the trochaic rhythm (RHTYPE=TROCHEE), is essential in the analysis of loanwords. See (94) and (95) below.

With respect to the Zapotec segmental assimilation of the consonants in loanword phonology, Pamela Munro (personal communication, March 2005) notices that lenis coda consonants are preceded by prominent (stressed) long vowels, whereas fortis consonants by prominent short vowels.[51] More examples of this pattern are provided below and its prosodic relevance has already been discussed in the section on moraicity and

[51] Recall from §2.2 that in Munro and Lopez (1999), these short vowels are analyzed as checked vowels, but reanalyzed here as modal short vowels instead.

minimality. In order to form bimoraic feet, fortis consonants are moraic in coda and contribute to syllable weight, whereas lenis consonants are not moraic and, thus the vowel lengthens to become bimoraic. (92) and (93) illustrate these patterns.

(92) Short V + fortis C

	Spanish		Quiaviní Zapotec		
a.	[ˈbloke]	→	[blokː]	'cement block'	(<Sp. *bloque*)
b.	[ˈalto]	→	[alˑt]	'tall'	(<Sp. *alto*)

(93) Long V + lenis C

	Spanish		Quiaviní Zapotec		
a.	[ˈxuɣo]	→	[xuːɣ̊]	'juice'	(<Sp. *jugo*)
b.	[kaˈnela]	→	[kaˈneːl]	'cinnamon'	(<Sp. *canela*)

The adaptation of Spanish obstruents is based on voicing: Spanish voiceless obstruents are adapted as fortis consonants, whereas voiced obstruents are adapted as lenis consonants. The adaptation of sonorants into the fortis or lenis classes is less clear, since there is no "preliminary" distinction in Spanish among sonorants. The adaptation seems to rely more heavily on Spanish phonetic vowel duration (see Chávez-Peón 2006 for more details). The following tableaus show the formal analysis of loanwords.

(94) Loanwords (polysyllabic): fortis consonants[52]

/ma$_\mu$'tɾa$_\mu$ka$_\mu$/[53] 'bull roarer'	FT-BIN	TROCHEE	ALIGN-R	*Lenis-μ	WBYP	*μ/O	*μ/R	*μ/V	DEP-μ	PARSE-σ
a. ma$_\mu$('tɾa$_\mu$ka$_\mu$)			*!					***		*
b. ma$_\mu$(tɾa$_\mu$'ka$_\mu$)		*!						***		*
c. ma$_\mu$('tɾa$_\mu$k)	*!	*!			*			**		
d. (ma$_\mu$'tɾa$_\mu$k)		*!			*			**		
e. ('ma$_\mu$tɾa$_\mu$k)			*!		*			**		
f. ☞ ma$_\mu$('tɾa$_\mu$k$_\mu$)						*		**		
g. ma$_\mu$('tɾa$_{\mu\mu}$k)					*!			***		
h. (ma$_\mu$'tɾa$_\mu$k$_\mu$)		*!				*		**		

(95) Loanwords (polysyllabic): lenis consonants

/be$_\mu$n'ta$_\mu$na$_\mu$/ 'window'	FT-BIN	TROCHEE	ALIGN-R	*Lenis-μ	WBYP	*μ/O	*μ/R	*μ/V	DEP-μ	PARSE-σ
a.be$_\mu$n('ta$_\mu$na$_\mu$)			*!		*			***		*
b.be$_\mu$n(ta$_\mu$'na$_\mu$)		*!			*			***		*
c. be$_\mu$n('ta$_\mu$n)	*!				**			**		
d. (be$_\mu$n'ta$_\mu$n)		*!			**			**		
e. ('be$_\mu$nta$_\mu$n)			*!		**			**		
f. be$_\mu$n('ta$_\mu$n$_\mu$)				*!	*		*	**		
g. ☞ be$_\mu$n('ta$_{\mu\mu}$n)					**			***		
h. (be$_\mu$n'ta$_{\mu\mu}$n)		*!	*!		**			***		

Quiaviní Zapotec preserves the original stressed Spanish vowel as the prominent syllable and deletes any potential syllabic nucleus that follows (but see below). This deletion, however, applies only in final open syllables. If the final unstressed vowel is in

[52] I leave out from these tableaus the constraint WT-IDENT-BA, since it is vacuously satisfied for all loanwords as they are analyzed as an Input-Output correspondence, not an Output-Output one (i.e. there is no Base or Affixed form to evaluate).
[53] Presumably the UR is not synchronically the Spanish form, but the aim here is to show the process for the first step in adapting a loanword. Diachronically one could think of the Spanish output form as the input for Zapotec speakers, this input is evaluated by the grammar and an optimal candidate surfaces. This new "incorporated" output could presumably become the new stored input for this word. The details of this implementation, however, fall beyond the scope of this study.

a closed syllable (as is the case for a minority of words in Spanish), the vowel and the coda are maintained (96a). When the Spanish word has antepenultimate stress, the penultimate unstressed vowel is also maintained (96b).

(96) Loanwords: Non-final prominent roots

	Spanish		Quiaviní Zapotec		
a.	[ˈfasil]	→	[ˈfas̤i̤lʲ]	'easy'	(<Sp. *fácil*)
b.	[ˈbaskula]	→	[ˈbaskwalː]	'scale'	(<Sp. *báscula*)

These types of words show that it is more important to be faithful to the original prosodic head than to shift the stress to the final syllable (i.e. Quiaviní Zapotec grammar is faithful to the original prosodic head of the Spanish word). Faithfulness to the location of stress between one string and another (be it input-output or, output-output) can be obtained via IDENT-HEAD, as defined below.[54]

(97) IDENT-HEAD (Plag, 1998, p. 203)
The prosodic head of the input is the prosodic head of the output
(= no stress shift).

As a consequence, the type of words in (96) is the only instance that violate the alignment of the head of the foot with the right edge of the root, thus the small change in the ranking IDENT-HEAD >> ALIGN-R.

Moreover, Quiaviní Zapotec grammar shows that it is more important to preserve consonants than vowels. While final unstressed vowels are always deleted in open syllables, consonants in unstressed (final and penultimate) syllables are preserved (see examples in 96). Formally, this consonant-retention is obtained by ranking MAX-C over MAX-V.[55]

(98) MAX-C
Input consonants must have output correspondents ('No consonant deletion')

[54] Variations of this constraint include, e.g. MAX/IDENT-Stress (M. Kenstowicz, 2007).
[55] On the relative importance of faithfulness to C versus V in loanwords, this is true in other cases also, such as Cantonese (Yip, 2006), where MIMIC-TONE(STRESS), MIMIC-CONS >> MIMIC-VOWEL >> MIMIC-LENGTH.

(99) MAX-V

Input vowels must have output correspondents (‘No vowel deletion’)

(100) Non-final prominent loanwords (IDENT-HEAD, MAX-C >> ALIGN-R >> MAX-V)

/ˈfa$_\mu$si$_\mu$l/ ‘easy’	FT-BIN	TROCHEE	IDENT-HEAD	MAX-C	*Lenis-μ	ALIGN-R	WBYP	*μ/O	WT-IDENT-BA	*μ/R	*μ/V	DEP-μ	PARSE-σ	MAX-V
a. ☞ (ˈfa$_\mu$si$_\mu$l)						*	*				**			
b.fa$_\mu$(ˈsi$_{\mu\mu}$l)			*!				*				***	*	*	
c. (fa$_\mu$s$_\mu$)				*!				*			*			*
d.(ˈfa$_{\mu\mu}$)si$_\mu$l						*	*				***!	*	*	
/ˈba$_\mu$s ku$_\mu$l·a$_\mu$/ ‘scale’														
a. ☞ (ˈba$_\mu$s$_\mu$) (kwa$_\mu$l$_\mu$)						*		*		*	**			*
b. (ba$_\mu$s$_\mu$) (ˈkwa$_\mu$l$_\mu$)			*!					*		*	**			*
c. (ba$_\mu$s$_\mu$)				*!*				*			*			**

In turn, the faithfulness to the input’s prosodic head (IDENT-HEAD) also rejects the possibility of shifting stress in loanwords, for instance, a hypothetical output /ben'tana/ → [benta'naː] ‘window’. Such candidates would satisfy both ALIGN-R and TROCHEE, but would violate IDENT-HEAD.

Finally, the last descriptive fact that impacts the theoretical analysis involves loanwords with a complex coda formed by lenis consonants. As the examples below illustrate, vowels are short in these words.

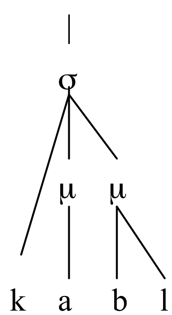
(101) Loanwords: lenis complex coda

	Spanish		Quiaviní Zapotec		
a.	['kable]	→	[kabl]	‘insulated wire’	(< Sp. *cable*)
b.	['kwadɾa]	→	[kwadɾ]	‘(city) block’	(< Sp. *cuadra*)
c.	['sjempɾe]	→	[sjemɾ]	‘always’	(< Sp. *siempre*)

I have proposed (§3.3) that the minimal word in this language is a bimoraic foot, and that lenis consonants are not moraic. Accordingly, words with complex lenis codas seem monomoraic at first glance. Nonetheless, following Arellanes (2009), a possible analysis is that although a lenis consonant cannot be moraic on its own, it can share a mora; therefore, in order to satisfy minimality lenis coda clusters contribute a mora. Cross-linguistically, it is common to ban long vowels before coda clusters (e.g. in Scandinavian languages, Kristoffersen, 2000). This is also the case in Quiaviní Zapotec. The moraic representation is below.

(102) Moraic representation of Quiaviní Zapotec words

a. Foot



‘wire’

This explanation seems a more adequate solution than to assume that these words are sub-minimal prosodic words in Quiaviní Zapotec, and correlates with the duration of these segments.[56] Formally, then, we need a slight rectification on the *Lenis−μ constraint. As originally proposed in Arellanes (2009, p. 348), the word “autonomously” reflects the fact that a single lenis consonant cannot be moraic on its own, but as a cluster it can share a mora.

(103) *Lenis−μ

If lenis then non-*autonomously* moraic (adapted from Arellanes, 2009, p. 348)

This final modification neither affects the analyses of previous cases nor changes the proposed constraint ranking.

[56] Vowels are short followed by coda clusters; in turn, each of these lenis consonants is short.

3.5 Summary and conclusions

This Chapter analyzed the metrical constituency of Quiaviní Zapotec in terms of the prosodic hierarchy (PrWd – Foot – Syll – Mora), accounting for the prominence pattern in this language. I have argued that the minimal prosodic word consists of a bimoraic foot. In monosyllables, this is satisfied in one of two ways. First, if the syllable is open, or closed by a lenis consonant, the vowel is lengthened, and becomes bimoraic. Second, if the coda consonant is fortis, it contributes a mora. Valley Zapotec is unique in that both fortis coda sonorants and obstruents are moraic. This claim was tested acoustically in a production study with significant results that clearly suggest that differences between lenis and fortis consonants in codas reflect prosodic contrasts in terms of moraicity, thus enriching the typology of syllable weight.

In disyllabic and longer words, Quiaviní Zapotec displays a trochaic metrical pattern at the moraic and syllabic level. Further, in accordance with Munro and Lopez (1999), stress is demarcative, with the root-final syllable consistently carrying prominence.[57]

(104) Metrical properties of Quiaviní Zapotec

a. *Culminative*	one prominent syllable per word
b. *Demarcative*	root-final syllables are prominent
c. *Rhythmic*	trochaic
d. *Quantity-sensitive*	(moraic) trochees (**L**L) (**H**)

The metrical structure of Quiaviní Zapotec presented in this chapter was particularly illustrated with items with modal voice (mostly with high tone). Nonetheless, the principles outlined here hold for all the phonation types and tones in the language. This chapter sets the basis for the prominence pattern in Quiaviní Zapotec and will be taken as foundational to understand subsequent phonological patterns in the language: tone and phonation type.

[57] Only a few exceptions (<10 dictionary entries) are found in loanwords.

Chapter 4:

Tone in Quiaviní Zapotec

4.1 Introduction

Tone (the use of pitch to distinguish lexical or grammatical meaning) occurs in many languages in of the world; according to Yip (2002, p. 1), 60~70 percent of the world's languages are tonal. Hyman (2006, p. 229) defines a tonal language as follows: "A language with tone is one in which an indication of pitch enters into the lexical realisation of at least some morphemes." With respect to Otomanguean languages, which include Amuzgo, Chatino, Chinantec, Mazatec, Mixtec, Zapotec, among other linguistic groups,[58] the contrastive use of tone is so consistent that it has been considered to be a genetic feature (Rensch, 1976; Suárez, 1983). Nonetheless, the phonological patterns and tonal inventories are very diverse across languages in the family.

Also within the Otomanguean stock, practically all Zapotec languages have been analyzed as tonal.[59] Valley Zapotec variants spoken in communities neighboring on San Lucas Quiaviní, such as Santa del Valle Zapotec (Rojas, 2010), San Pablo Güilá Zapotec (López Cruz, 1997, Arellanes, 2003), and San Juan Guelavía Zapotec (Jones & Knudson,

[58] See INALI's catalogue (National Institute of Indigenous Languages in Mexico): http://www.inali.gob.mx/catalogo2007/mapa.html#5.

[59] According to Jaeger and Van Valin (1982, p. 127) "all Zapotecan languages are tone languages".

1977), have been reported to use tone contrastively.[60] In Quiaviní Zapotec, Munro and Lopez (1999) recognize four different tone melodies, including two level tones, high and low, and two contour tones, rising and falling. Based on these facts, we would expect tone to be contrastive in Quiaviní Zapotec.

However, in the most complete work to date on this language, Munro and Lopez (1999) make the controversial claim that tone is predictable from phonation types. They state that "tone melodies on Quiaviní Zapotec vowel complexes [syllable nuclei] are derived from the number and phonation type of the vowels in the complex and its phonological environment rather than representing primary contrasts" (Munro & Lopez, 1999, p. 3).

Their proposal implies that for there to be a pitch difference, there must be a phonation type difference. This is in contrast to the natural tendency in tonal languages of carrying lexical contrasts within modal voice. This is a testable prediction that rests upon particular items in the Munro and Lopez (1999) description of Quiaviní Zapotec. This chapter instrumentally evaluates the categorization of some words in Munro and Lopez' (1999) analysis, that are claimed to have non-modal voice. The prediction is that if there is a phonologically distinctive four-way tonal contrast in Quiaviní Zapotec, it ought to appear with modal voice. The ultimate goal of the chapter is to establish the phonological status of tone in Quiaviní Zapotec.

Section §4.2 presents an overview of the phonation type mechanisms found in the languages of the world. The phonetic properties considered in subsequent sections are presented here. Sections §4.3, §4.4, and §4.5 analyze potential cases of modal low, rising and falling tone items, respectively. The chapter concludes with a summary of the findings and a reanalysis of the Quiaviní Zapotec tonal inventory, arguing that all four tones occur in modal voice. The implications of tone as contrastive in Quiaviní Zapotec, including an analysis of their tone-bearing units and the phonological representation of tone, are investigated in the next chapter.

[60] It is important to mention that, despite the differences among these variants and Quiaviní Zapotec, there is a high degree of intelligibility among them.

4.1.1 *Phonetic properties associated with phonation types*

In order to establish what modal voice is and is not, this section provides a brief overview of the phonetic properties associated with phonation types. The phonetic properties described in this section serve as background to the acoustic descriptions and phonetic experiments of all the following sections.

Phonation types refer to the manner in which vocal folds vibrate. Modal voice is the standard vibration type. The vocal folds are adducted along their full length and with a suitable degree of tension to allow vibration in a rhythmic manner, opening and closing at regular intervals of time. Breathy voice or murmur is where the folds are held partly apart while the vibration continues, and creaky voice or laryngealization is where the folds are held stiffly and vibration is partially inhibited. The different ways the vocal cords vibrate, or do not vibrate at all, create a variety of phonation types (Ladefoged, 1971; Catford, 1977; Laver, 1980). As suggested by Ladefoged (1971; see also Catford, 1964), these various glottal states may be represented in the form of a phonation continuum, "[…] defined in terms of the aperture between the arytenoid cartilages, ranging from voiceless (furthest apart), through breathy voiced, to regular, modal voicing, and then through creaky voice to glottal closure (closest together)." (Gordon & Ladefoged, 2001, p. 384). This is schematically represented in the following figure.

	Most open	◄──────	──────	──────►	Most closed
Phonation type	Voiceless	Breathy	Modal	Creaky	Glottal closure

Figure 10. Continuum of phonation types (Ladefoged, 1971)

The following unambiguous examples of breathy, modal and creaky vowels in Quiaviní Zapotec exemplify some of the phonation types mentioned above.

(1) Phonation types: modal, breathy and creaky

a. Modal: / be / ˩ → [bèː ~ βèː] ‘mesquite bean’
b. Breathy / be̤ / ˩ → [bè̤ː ~ βe̤͡e̤ː] ‘mold (growth)’
c. Creaky / bḛ / ˩ → [bḛ̀ː ~ βe͡ḛ] ‘Tanivet (*X:ta'isy Dàany Bèèe'*)’

Phonetic properties associated with phonation types include differences in periodicity, fundamental frequency, spectral tilt, duration and intensity.

Periodicity among different phonation types is illustrated in the following figure, showing waveforms of Quiaviní Zapotec vowels.

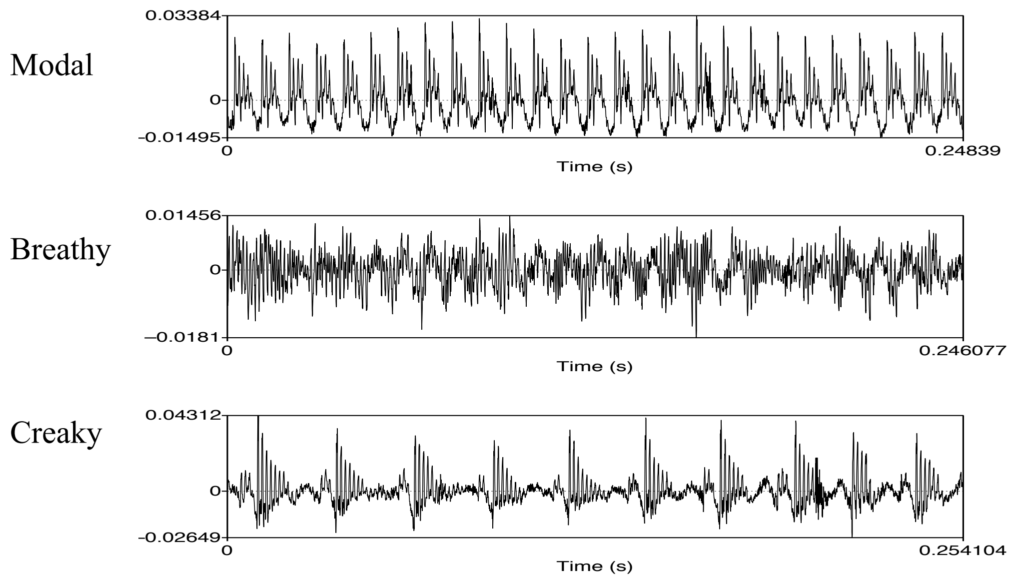


Figure 11. Waveforms of voice qualities: modal, breathy and creaky voices.

Jitter is an effective calculation for measuring the periodicity of the signal. Jitter corresponds to measurements of the variation in the duration of adjacent pulses. This parameter has been used to establish differences in phonation types (e.g. Gordon & Ladefoged, 2001; Ladefoged, Maddieson, & Jackson, 1988). As shown above, adjacent pulses vary less during modal vowels than during non-modal vowels, especially creaky ones, typically characterized by irregularly spaced pulses.

Another reliable way to measure phonation is spectral tilt, defined as “the degree to which intensity drops off as frequency increases” (Gordon & Ladefoged, 2001, p. 15).

Subtracting the amplitude of a higher frequency harmonic from the amplitude of the fundamental frequency (also called the first harmonic) yields a largely positive value for breathy vowels, a smaller positive value for modal vowels, and a negative value for creaky vowels. Spectral tilt has been a reliable measure of phonation in numerous languages such as Jalapa Mazatec, Gujarati, Kedang and Hmong (as reviewed by Gordon & Ladefoged, 2001).

There are different ways to characterize spectral tilt. Primarily, the difference between the amplitudes of the first and second harmonics (H1-H2), which correlates with the percentage of a glottal vibration cycle during which the glottis is open (i.e. *open quotient*, Holmberg et al. 1995), has been used to distinguish between modal and breathy phonation. However, other studies have made use of the relationship between H1 (first harmonic) and harmonics exciting higher formants, which correlates with the abruptness of the closure of the vocal folds. These measurements include: H1-F3 (Stevens & Hanson, 1995), H1-F1 or H1-F2 (Ladefoged, 1983; Blankenship, 2002) and the average of H1-H2 compared to F1 (Stevens, 1988). Other studies have used the relationship of higher formants to lower ones such as F2-F3 (Klatt & Klatt, 1990). First and second formants (F1 and F2) are commonly referred to as A1 and A2, as it is the harmonic with the highest amplitude within the formant that is considered.

Duration and intensity may also play a role in distinguishing modal versus non-modal phonation. Non-modal vowels tend to have lower intensity and longer duration compared to modal vowels, e.g. Hupa for intensity (Gordon, 1998), and Jalapa Mazatec for duration (Silverman, Blankenship, Kirk, & Ladefoged, 1995; Silverman, 1997b).

4.2 Experiment 1: Low tone with modal voice

Munro and Lopez (1999) recognize Quiaviní Zapotec as a tonal language with four tones (high, low, falling and rising); however, they state that tones do not represent primary contrasts, but melodies derived from voice qualities. By contrast, a prototypical tonal language would use its tonal inventory distinctively within modal voice. This chapter reconsiders some vowel patterns described in Munro and Lopez (1999) by examining contrasts in Quiaviní Zapotec. In this section I investigate the case of low tone. I argue that the low tone vowel pattern *àa* has modal voice.

Munro and Lopez (1999) present the following Quiaviní Zapotec vowel patterns with low tone:

Table 20. Munro and Lopez (1999: 4) low tone vowel patterns

Pattern	Combination[61]	Examples	Tone
ah	*ah* (same)	*zah* ‘grease’	low
ahah	*ah*	*bihih* ‘air’	low
àa	*àa* (same)	*bòo* ‘charcoal’	low

The first two have breathy voice and will be analyzed in chapter 6, which examines non-modal phonation. The pattern *àa* is of crucial interest to this chapter. According to the orthography, it appears to represent / a̰a /; however, this is more an orthographic convention rather than a phonological representation. The authors maintain “the vowel complex we write as creaky vowel followed by plain vowel is suspicious. […] We have considered the idea that àa […] should be represented as a sequence of two creaky vowels, but in fact the degree of creakiness of this vowel is (perceptually and instrumentally) considerably less than any other sequences […] that include creaky vowels (p. 5).” The suspicious status of this vowel pattern makes it a clear candidate to look for the expression of low tone within modal voice.

[61] Recall from Chapter 1, that according to Munro and Lopez (1999) many Valley Zapotec words shorten to simpler combination forms in some contexts (e.g. when suffixes are added to them).

4.2.1 Acoustic description: Modal-L

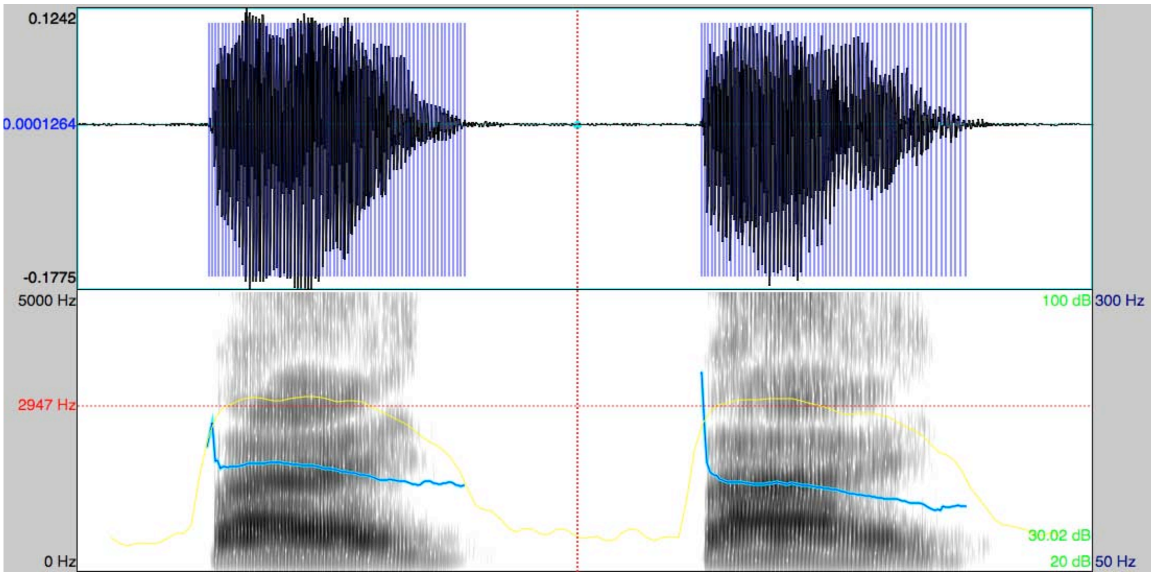
The purpose of this section is to describe the acoustic characteristics of low-tone items with the vowel pattern *àa* (Munro & Lopez, 1999). In order to clearly see the voice quality and pitch of items with this vowel pattern, I compare them with the unambiguous modal-H pattern. Consider the contrastive sets in (2).[62]

(2) Modal voice minimal pairs: High vs. Low tones [63]

a. / dan^{j} /	˥	'harm'	vs.	/ dan^{j} /	˩	'mountain'
b. / ʒi /	˥	'tomorrow'	vs.	/ ʒi /	˩	'quite'
a. / nda /	˥	'bitter'	vs.	/ nda /	˩	'sensitive'
d. / lad /	˥	'side'	vs.	/ lad /	˩	'between'

Figure 12 shows the waveform and the spectrogram of /danj/ ˥ 'harm' (*daany*) on the left, and /danj/ ˩ (*dàany*)[64] 'mountain' on the right, by male speaker TiuR. The spectrogram frequency range is 0-5000 Hz (on the left) and the pitch frequency (blue line) on the range of 50-300 Hz.

[62] A contrastive set is defined by Pike (1947, p. 161) as "a group of tone sequence patterns, in some particular position, which differ only by one tone in the same relative place in the sequence".
[63] For these examples, no phonetic transcription is included, as it does not add any information with respect to the issue at hand; all these examples surface with long vowels.
[64] Since the voice quality of *modal-L* is in question I present these items with my hypothetical phonological transcription, followed by the dictionary's orthography (Munro & Lopez, 1999).



d a : j ɲ d a : j ɲ

Figure 12. Waveform and spectrogram of / danj / ˥ ‘harm’ (*daany*) on the left, and / danj / ˩ (*dàany*) ‘mountain’ on the right, by male speaker TiuR.

Beginning with a pitch evaluation, the high-tone word / danj / ˥ ‘harm’ has a pitch of 143 Hz during the vowel, whereas the pitch for the low-tone word / danj / ˩ ‘mountain’ averages 123 Hz. (High-tone items for this speaker average 155 Hz whereas low-tone items average 121 Hz.) In both cases, the pitch is stable and relatively flat throughout the vowel. It starts to lower with the glide and the consonant. Most tokens with high or low tone have a slight pitch lowering (more noticeable for low tone) towards the end of the vowel if the syllable is open, or closed by an obstruent. If followed by a sonorant coda, the pitch is maintained if the sonorant is fortis, but normally drops if it is lenis. The next chapter discusses in detail the type of coda consonant and its relevance with respect to tone.

According to Rietveld and Gussenhoven (1985), pitch differences of 1.5 semitones (about 10 Hz) can reliably be interpreted as prominence differences. Mambila (Connell, 2000), for instance, has four level tones and they are spaced an average of 10 Hz apart. In a language like Quiaviní Zapotec with only two level tones, my prediction is to find a more spacious separation between tones. Based on the examples illustrated above, the difference between high and low tone is more than 20 Hz. Quiaviní Zapotec, then, looks like a tonal language in terms of its pitch characteristics.

With respect to voice quality, the periodicity of the sounds in Figure 12 (a correlate of modal voice) is clear throughout both examples. In turn, the spectrograms are clear and with no signs of laryngealization in the case of the low tone (e.g. no strong or weak "trillization" (Pike, 1947, p. 21) during the vowel). Although non-modal phonation is normally associated with lowering of the fundamental frequency, the contrastive use of low tone with modal voice within a tonal system is prototypical, and this parameter on its own (pitch at the acoustic level) is not enough to determine voice quality in a tonal language.

As reviewed above (§4.2), non-modal vowels may be of longer duration than modal vowels. In Quiaviní Zapotec, however, length plays an important role in the prosody (Chapter 3). Short vowels appear before fortis consonants and long vowels before lenis consonants or in open syllables. Both the high and low tone examples in Figure 12 have long vowels: 323 ms and 360 ms, respectively, including the glide. Finally, intensity levels are very similar: 60 dB for the modal-H token, and 67 dB for the modal-L. Further examples by a different speaker are provided in Figure 13.

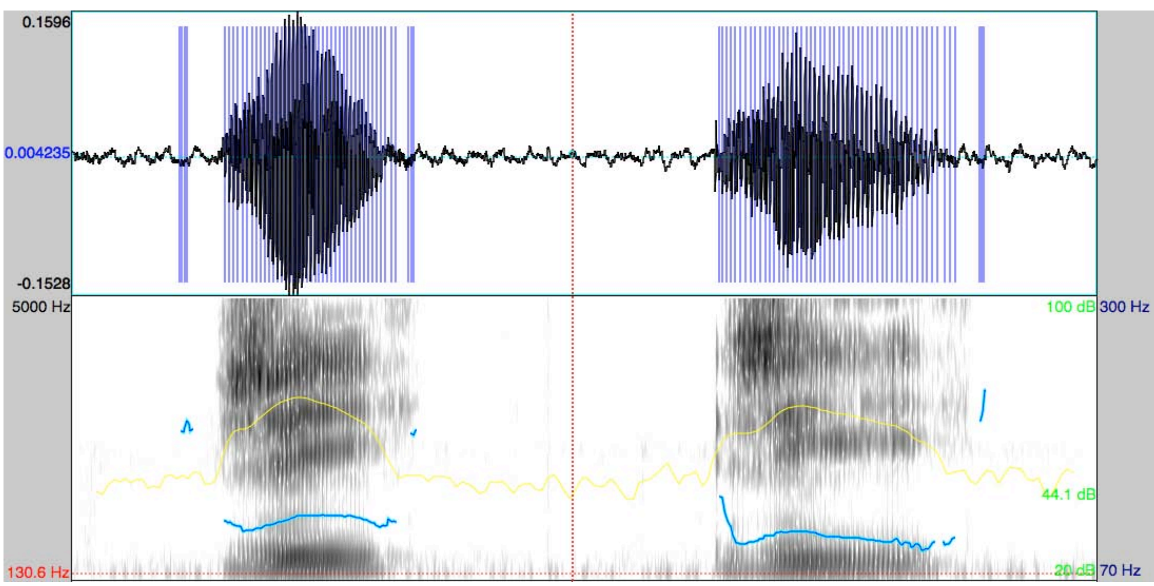


Figure 13. Waveform and spectrogram of / ʒi / ˥ 'tomorrow' (*zhii*), on the left, and / ʒi / ˩ (*zhìi*) 'quite', on the right, by male speaker TiuC.

Pitch for / ʒi / ˥ 'tomorrow' averages 122 Hz, whereas for / ʒi / ˥ 'quite' it is 106 Hz. Both measurements are within the averages of level tones for this speaker. The high tone word shows brief rising that can be taken as a phonetic preparation for the phonological expression of high tone; it goes from 115 Hz to 124 Hz at the highest pitch value. Then, after about 100 ms of flat pitch, it lowers towards the end of the word. The pitch in the low tone word is stable and relatively flat during the first 100 ms, then it starts to lower, a common tendency with low-tone items in this language.

In terms of phonation type, the glottal pulses of both sounds are regular and the spectrograms show clear formant frequencies in both examples. Towards the end of the low-tone example, we notice some weakening of the formant frequencies, correlated with a drop in intensity. This may be an utterance-final effect. Overall intensity for the modal-H token is 69 dB, and a slightly lower value of 66 dB for the modal-L one. Finally, although the low-tone item has a longer vowel, both are well within the range of long vowels at 238 ms (modal-H) and 276 ms (modal-L).

In summary, based on the acoustic description from above (§4.2), items with the vowel pattern *àa* appear to have modal voice. In order to confirm this analysis, I conducted a phonetic experiment to instrumentally and statistically test the phonation type of items that I anticipatorily called modal-L.

4.2.2 Phonetic experiment: Modal-L

This section consists of a phonetic experiment that examines the voice quality of items with the vowel pattern *àa*, originally analyzed in Munro and Lopez (1999) as having some amount of creakiness (tension in the vocal folds) and compares them with unambiguous cases of modal voice (high-tone items) and unambiguous cases of creaky voice (low-tone items).

The hypothesis of this study is that Quiaviní Zapotec uses tone contrastively, with the specific prediction that low tone is used with modal voice. Accordingly, the vowel pattern *àa* is tentatively called modal-L.

In order to test this prediction, the phonetic parameters I considered are periodicity (jitter), spectral tilt, duration and intensity. The first two are considered primary since both have been reliable parameters in distinguishing different voice qualities in several languages (see §4.1.1 above). Specifically, spectral tilt has already been applied successfully to illustrate modal voice (high tone), as well as unambiguous creaky and breathy voice in Quiaviní Zapotec (Gordon & Ladefoged, 2001, pp. 15-17; Ladefoged, 2003, pp. 178-181). Duration and intensity may also play a role in distinguishing modal from non-modal phonation (§4.1.1). Nonetheless, in this study they are considered secondary parameters due to the mixed results from previous studies. Gordon and Ladefoged (2001, p. 18) report no durational differences among breathy, modal and creaky vowels in Quiaviní Zapotec (although the sample analyzed is small and numbers are not reported). On the other hand, Chávez-Peón (2008) found that breathy vowels were longer than modal ones. Also in this study, intensity values were slightly higher for modal vowels versus breathy ones.

4.2.2.1 Methods

Subjects: Two native speakers of Quiaviní Zapotec participated in the study: 1 female speaker (LiaL, 35), and 1 male speaker (TiuC, 40).

Stimuli: This experiment considered as control cases the unambiguous modal voice of the modal-H tokens, and the unambiguous creaky voice quality of creaky-L tokens.[65] These control cases were compared with each other, and with the voice quality of the modal-L tokens.

(3) Stimuli groups

1. Modal-H	control: modal voice
2. Modal-L	*under investigation*
3. Creaky-L	control: creaky voice

[65] I agree with Munro and Lopez (1999) on the voice quality of the control cases considered in this experiment; for creaky vowels, however, the cases considered to have low tone are reported to have falling tone in Munro and Lopez (1999). (See Chapter 6 for the analysis of tone in non-modal vowels.)

The actual stimuli consisted of four words for each group. All of these words have long vowels (open syllables or lenis coda), because (a) the longer duration in these environments allows a better comparison of the voice quality, and (b), most of the (near) minimal pairs that I have identified have these syllabic characteristics.

Table 21. Stimuli: low tone experiment

		dictionary	gloss
Modal -H	1	*daany*	'harm'
	2	*ndaa*	'bitter'
	3	*daad*	'dice'
	4	*bdaa*	'shadow'
Modal-L	5	*dàany*	'mountain'
	6	*ndàa*	'sensible'
	7	*nàan*	'thick'
	8	*bdàan*	'soot'
Creaky-L	9	*gàà'*	'nine'
	10	*bàà'*	'tomb'
	11	*làà'z*	'heart, center'
	12	*yàà'n*	'corncob'

All of these words were recorded in the following carrier phrase:

(4) Carrier phrase

[ɾiː ɾa ______ ɾuk] 'There are _____ here'

(orthography: *rii ra* ______ *ru'c*)

This particular carrier phrase was used because it contains only modal voice vowels, thus avoiding any possible contextual influence from non-modal voice. Four repetitions of each phrase were collected based on a randomized list, for a total of 96 tokens (4 modal-H + 4 modal-L + 4 creaky-L = 12 x 4 repetitions x 2 speakers = 96 tokens). The stimuli were recorded using a Marantz 660 solid-state recorder and a Countryman lapel microphone (phantom power). Measurements were done in Praat for Mac (version 5.1.07; Boersma & Weenink, 2009); results were compiled in Excel 2004 for Mac; and statistics were run in JMP IN 5.1 for Mac (two-tailed unequal variance t-tests).

Measurements: Periodicity was calculated by jitter, measuring the variation in duration of glottal cycles. The measures of jitter considered in this study are *ppq5* and *ddp*:[66]

(5) Jitter (ppq5) (*Praat manual*: jitter)
This is the five-point Period Perturbation Quotient, the average absolute difference between a period and the average of it and its four closest neighbors, divided by the average period.[67]

(6) Jitter (ddp) (*Praat manual*: jitter)
This is the average absolute difference between consecutive differences between consecutive periods, divided by the average period.

Jitter (ppq5) was chosen, as it is the least dependent calculation on pitch. In order to have an additional jitter reference, Jitter (ddp) was also considered. This is Praat's original 'Get jitter' function, and probably the most common calculation in the literature.

Since jitter measures the variation in duration of glottal cycles, changes in pitch will show variation in duration of these cycles. In other words, rising and falling contours may influence jitter values. For this reason measurements were not taken for the whole vowel, but during a specific portion: six glottal pulses at the center of the vowel (the minimum required by jitter (ppq5) are 5 pulses). By measuring jitter at the center of the vowel we also avoid effects of the preceding and following consonants, or effects of final lowering at the end of the phrase.

Spectral tilt measurements include H1-H2 and H1-A1,[68] defined as follows:

(7) H1-H2 (open quotient):
Difference in dB between the first and second harmonics in the Fourier spectrum. Used to estimate the proportion of a cycle in which the glottis is open (Ni Chasaide & Gobi, 1997).

(8) H1-A1 (spectral slope):
Difference in dB between the first harmonic and the most prominent harmonic in the F1 region (Kirk et al., 1993).

[66] Other jitter calculations include: *local, local absolute,* and *rap*.
[67] The Multi-Dimensional Voice Program (MDVP), a standard software tool for quantitative acoustic assessment of voice quality, calls this parameter *PPQ*, and gives 0.840% as a threshold for pathology (that is, in languages without phonemic laryngealization).
[68] A1 corresponds to the amplitude of the harmonic within the first formant (F1) that has the greatest amplitude.

Measurements were obtained from FFT spectra at specific points during the vowel duration. Since non-modal phonation may be localized to a portion of the vowel (a pattern observed in Otomanguean languages, e.g. Jalapa Mazatec in Silverman et al. 1995, Blankenship 1997), the measures H1-H2 and H1-A1 were taken at five evenly spaced intervals distributed from the onset to the offset of the vowel.[69] Figure 14 illustrates this procedure.[70]

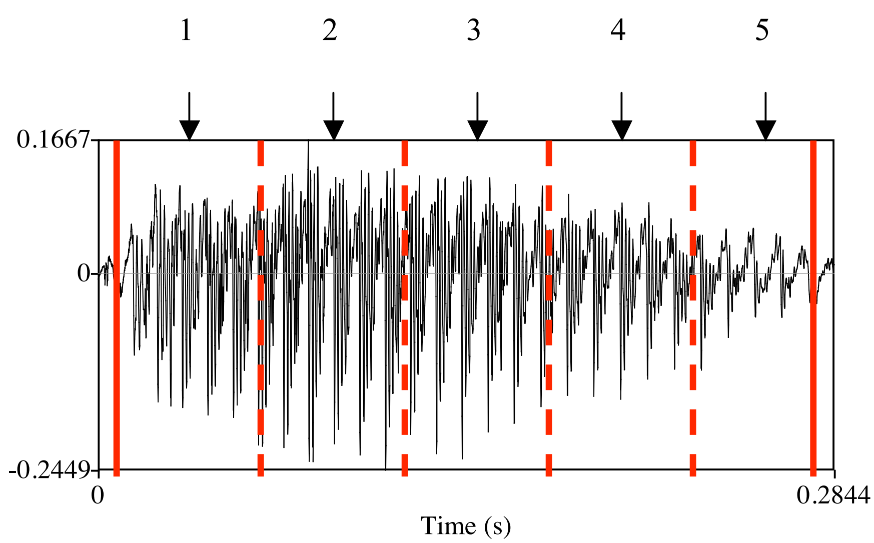


Figure 14. Spectral tilt measurements were taken at five evenly spaced intervals distributed from the onset to the offset of the vowel (Solid lines in the extremes indicate onset and offset of the vowel; dashed lines divide the intervals; and the arrows indicate the points were the measurements were taken).

Finally, each vowel was measured for duration (ms; total timing of vowel) and intensity (dB; average within vowel duration).

[69] Based on House (1961) and Gordon (2004), the duration of each vowel was measured from the waveform in conjunction with a wide band spectrogram. The onset and offset of the second formant served as the beginning and end points, respectively, of each duration measurement. Duration criteria also included the initiation and cessation of voicing, and F1 and F2 transitions.

[70] I thank Christian DiCanio for sharing the Praat script 'Get_spectral_tilt' to obtain these measurements (See DiCanio, 2008).

4.2.2.2 Results

Beginning with jitter results, Figure 15 shows the mean results for both jitter (ppq5) and jitter (ddp) for TiuC and LiaL. Tables following each figure present the means and standard deviations, as well as the statistical analysis results.

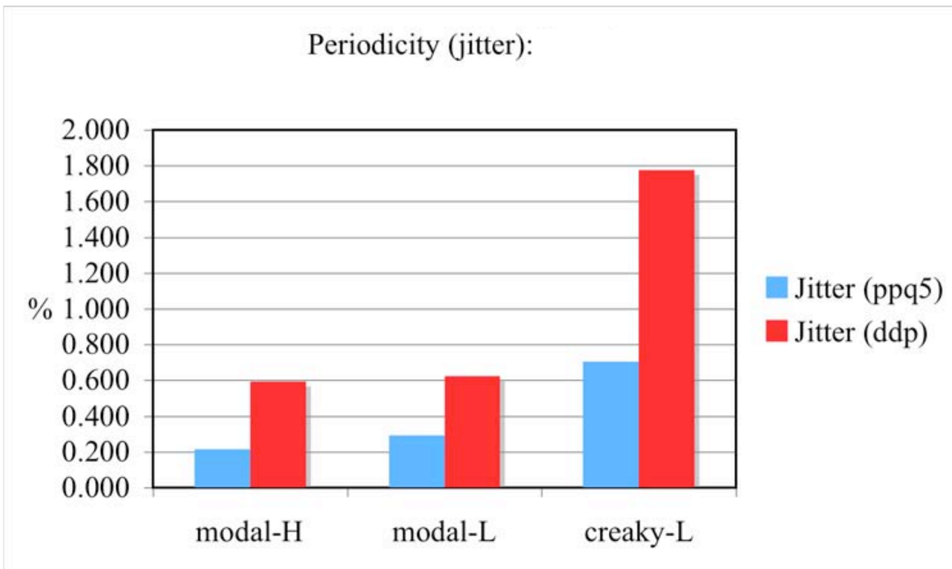


Figure 15. Jitter (ppq5 & ddp) mean results (TiuC).

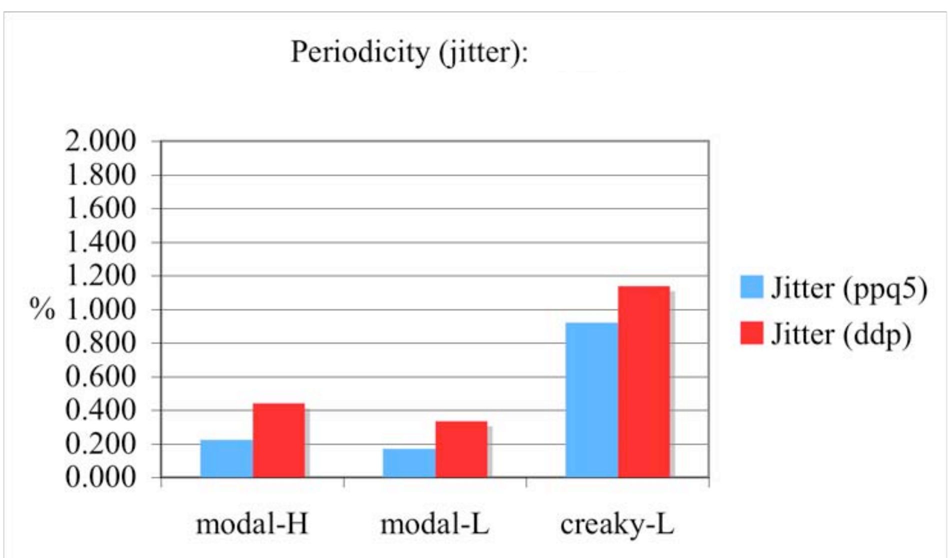


Figure 16. Jitter (ppq5 & ddp) mean results (LiaL).

Table 22. Periodicity (jitter): Mean and standard deviation (LiaL & TiuC)

		LiaL		TiuC	
		Jitter (ppq5)	Jitter (ddp)	Jitter (ppq5)	Jitter (ddp)
modal-H	Mean	0.224%	0.443%	0.217%	0.596%
	SD	0.111	0.298	0.126	0.423
modal-L	Mean	0.172%	0.337%	0.295%	0.624%
	SD	0.267	0.131	0.208	0.285
creaky-L	Mean	0.921%	1.141%	0.706%	1.777%
	SD	0.639	0.619	0.392	1.500

Table 23. Jitter results: Probability values from t-test (LiaL & TiuC)[71]

	LiaL		TiuC	
	Jitter (ppq5)	Jitter (ddp)	Jitter (ppq5)	Jitter (ddp)
modal-H vs. creaky-L	**<0.001**	**0.003**	**<0.001**	**0.007**
modal-H vs. modal-L	0.206	0.215	0.212	0.830
modal-L vs. creaky-L	**<0.001**	**0.020**	**0.001**	**0.008**

For both types of jitter, modal-H and modal-L are grouped together. Results for the male speaker show slightly higher jitter in modal-L tokens than modal-H, but the reverse is observe in the results for the female speakers. There are no significant differences between modal-H and modal-L. Creaky-L is statistically different.

Spectral tilt: I provide below a figure with the average plot results for spectral tilt H1-H2 for both subjects. Although the male speaker has lower average values, both speakers show the same tendency, and thus it is possible to combine their results in the same graph. The figure is followed by the results of the female speaker (LiaL) and another table with the corresponding t-test results. I then present results and statistics for the male speaker (TiuC).

Figure 17 shows that at the first two intervals, all three types of vowels exhibit similar patterns. By the third interval creaky-L tokens start to be noticeably different, and at intervals 4 and 5, all creaky-L numbers are negative, for both subjects (Tables 24 and 27). The modal-L tokens from the female speaker (LiaL) show lower spectral tilt values

[71] According to standard conventions, results above 0.12 are considered not significant (ns.); results between 0.12 and 0.05 are marginally significant; finally, any value below 0.05 is statistically significant.

than modal-H ones; whereas the male speaker (TiuC) shows more similar values for both modal-L and modal-H tokens. As expected, modal-H versus creaky-L as well as modal-L vs. creaky-L show significant differences for both subjects at intervals 3, 4 and 5. Unexpectedly, differences between modal-H and modal-L were significant for the female speaker in all intervals except the first one. For the male speaker, however, H1-H2 was higher (less creaky-like) for modal-L than for modal-H during the third and fourth intervals, and practically identical during the second and last measurement points.

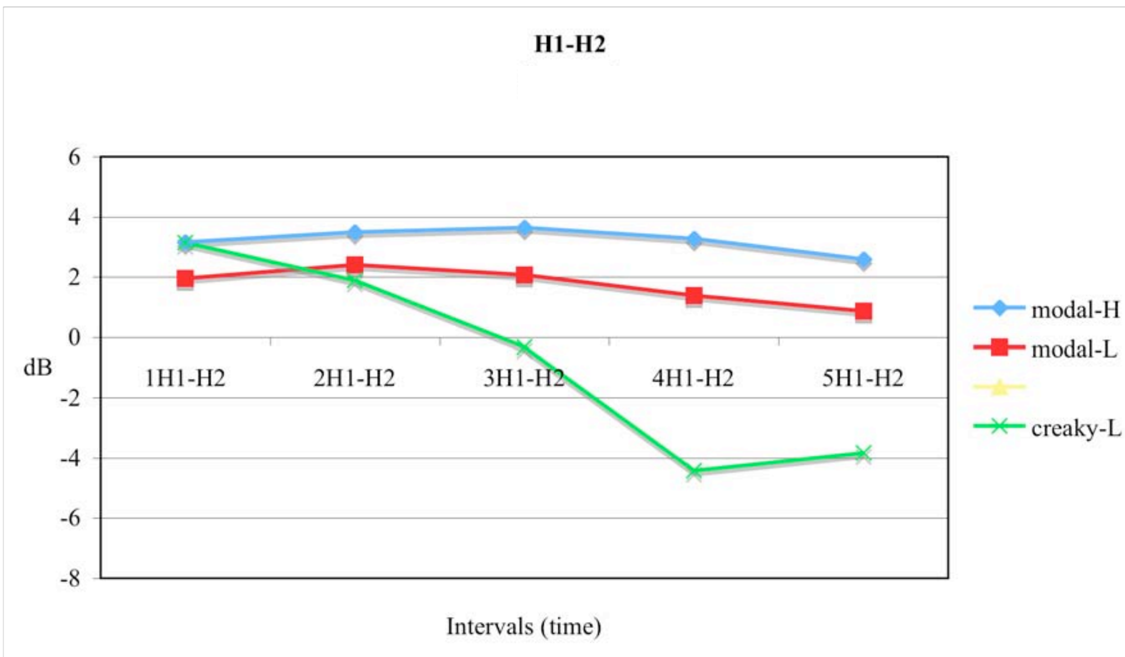


Figure 17. H1-H2 plot for mean results of both speakers.

Table 24. H1-H2 results: Mean and standard deviation (LiaL)

		1H1-H2	2H1-H2	3H1-H2	4H1-H2	5H1-H2
modal - H	Mean	6.34	7.14	7.36	6.93	5.23
	SD	2.23	2.07	2.46	2.60	3.41
modal - L	Mean	4.40	4.93	4.12	2.80	1.79
	SD	3.17	3.11	3.50	3.66	3.79
creaky - L	Mean	6.73	4.83	1.64	-3.66	-3.09
	SD	3.04	3.90	2.96	4.64	4.22

Table 25. H1-H2 results: Probability values from t-test (LiaL)

	1H1-H2	2H1-H2	3H1-H2	4H1-H2	5H1-H2
modal-H vs. creaky-L	0.683	**0.048**	**<0.001**	**<0.001**	**<0.001**
modal-H vs. modal-L	0.055	**0.025**	**0.005**	**0.001**	**0.011**
modal-L vs. creaky-L	**0.042**	0.940	**0.038**	**<0.001**	**<0.001**

Table 26. H1-H2 results: Mean and standard deviation (TiuC)

		1H1-H2	2H1-H2	3H1-H2	4H1-H2	5H1-H2
modal - H	Mean	-0.05	-0.15	-0.08	-0.36	-0.06
	SD	0.74	0.95	0.88	0.92	0.75
modal - L	Mean	-0.49	-0.11	0.02	-0.02	-0.07
	SD	0.77	0.46	0.68	0.54	0.61
creaky - L	Mean	-0.47	-1.05	-2.28	-5.17	-4.59
	SD	1.06	1.09	3.35	6.83	5.55

Table 27. H1-H2 results: Probability values from t-test (TiuC)

	1H1-H2	2H1-H2	3H1-H2	4H1-H2	5H1-H2
modal-H vs. creaky-L	0.202	**0.018**	**0.021**	**0.013**	**0.005**
modal-H vs. modal-L	0.108	0.901	0.714	0.201	0.960
modal-L vs. creaky-L	0.956	**0.004**	**0.015**	**0.008**	**0.005**

With respect to the H1-A1 spectral tilt measure, all results were as predicted for both speakers. Modal-H and modal-L have similar results, i.e., spectral tilt values are not consistent with greater creakiness on modal-L tokens. Results cluster together in comparison with creaky-L, with statistically significant differences at intervals 3, 4 and 5.

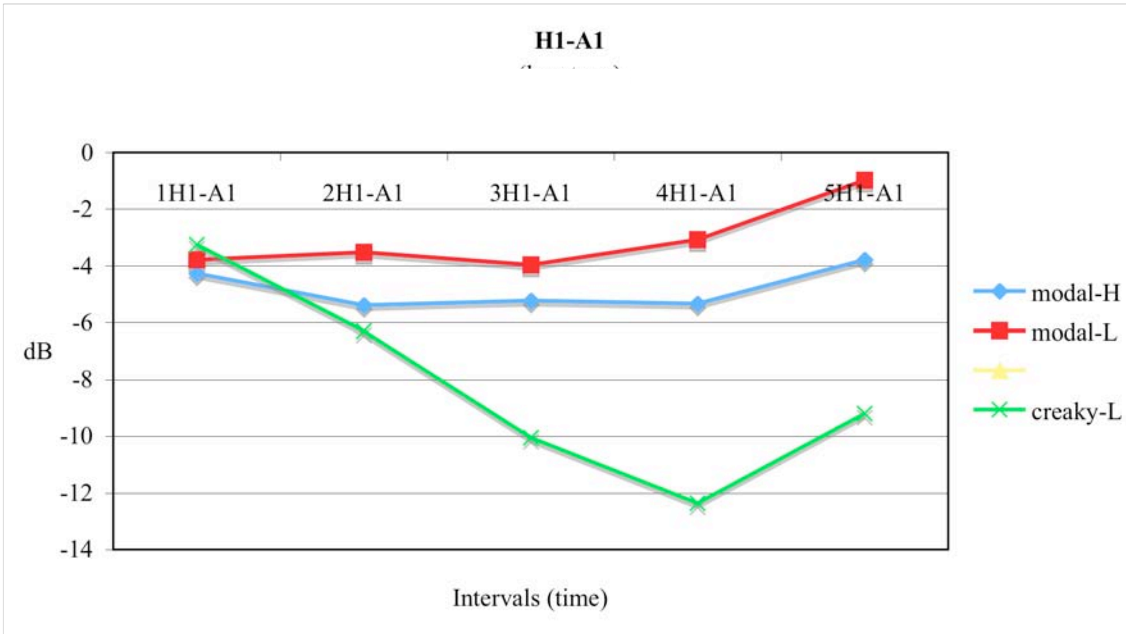


Figure 18. H1-A1 plot for mean results of both speakers.

Table 28. H1-A1 results: Mean and standard deviation (LiaL)

		1H1-A1	2H1-A1	3H1-A1	4H1-A1	5H1-A1
modal-H	Mean	-3.01	-3.51	-3.04	-3.06	-2.91
	SD	4.77	3.70	3.62	3.59	3.70
modal-L	Mean	-0.42	-0.19	-1.06	-0.60	0.33
	SD	5.09	5.06	3.08	3.81	5.55
creaky-L	Mean	-2.14	-3.86	-8.68	-13.67	-9.64
	SD	3.59	4.54	3.80	4.95	5.66

Table 29. H1-A1 results: Probability values from t-test (LiaL)

	1H1-A1	2H1-A1	3H1-A1	4H1-A1	5H1-A1
modal-H vs. creaky-L	0.563	0.810	**<0.001**	**<0.001**	**<0.001**
modal-H vs. modal-L	0.147	**0.043**	0.106	0.07	0.062
modal-L vs. creaky-L	0.278	**0.038**	**<0.001**	**<0.001**	**<0.001**

Table 30. H1-A1 results: Mean and standard deviation (TiuC)

		1H1-A1	2H1-A1	3H1-A1	4H1-A1	5H1-A1
modal - H	Mean	-5.53	-7.27	-7.43	-7.62	-4.68
	SD	3.43	4.67	3.58	4.16	5.38
modal - L	Mean	-7.17	-6.86	-6.88	-5.57	-2.28
	SD	3.10	2.45	2.80	2.74	2.27
creaky - L	Mean	-4.39	-8.74	-11.43	-11.08	-8.77
	SD	4.88	3.08	4.57	6.12	3.95

Table 31. H1-A1 results: Probability values from t-test (TiuC)

	1H1-A1	2H1-A1	3H1-A1	4H1-A1	5H1-A1
modal-H vs. creaky-L	0.451	0.302	**0.010**	0.073	**0.020**
modal-H vs. modal-L	0.165	0.762	0.635	0.110	0.115
modal-L vs. creaky-L	0.065	0.067	**0.002**	**0.003**	**<.001**

Duration and *intensity* results are presented in the following tables. Tables 32 and 34 present averages and standard deviation, Tables 33 and 35 statistical results (t-test). Neither duration nor intensity yields significant differences among the items in consideration. (The only significant result was the difference in intensity between modal-L vs. creaky-L for female speaker LiaL; modal-H vs. modal-L was marginally significant.) These parameters were not even reliable between the control cases modal-H and creaky-L. In short, all the vowels in the study have similar duration and intensity values.

Table 32. Duration and intensity results: Mean and standard deviation (LiaL)

		Duration (ms)	Intensity (dB)
modal-H	Mean	235	69.62
	SD	35.84	2.55
modal-L	Mean	230	67.5
	SD	33.29	3.75
creaky-L	Mean	225	69.87
	SD	32.07	2.70

Table 33. Duration and intensity results: Probability values from t-test (LiaL)

	Duration	Intensity
modal-H vs. creaky-L	0.40	0.78
modal-H vs. modal-L	0.67	0.07
modal-L vs. creaky-L	0.67	**0.04**

Table 34. Duration and intensity results: Mean and standard deviation (TiuC)

		Duration (ms)	Intensity (dB)
modal-H	Mean	195	72.81
	SD	22.98	4.02
modal-L	Mean	185	71.88
	SD	11.83	2.36
creaky-L	Mean	194	70.69
	SD	19.98	3.03

Table 35. Duration and intensity results: Probability values from t-test (TiuC)

	Duration	Intensity
modal-H vs. creaky-L	0.858	0.102
modal-H vs. modal-L	0.133	0.429
modal-L vs. creaky-L	0.147	0.226

4.2.2.3 Discussion

Results for both jitter and spectral tilt show that while some of the small non-significant differences are consistent with very light laryngealization in modal-L tokens, others suggest the reverse (less laryngealization than modal-H). This is exactly as expected if both vowel types are equally modal. Let us discuss these parameters in more detail.

Periodicity (jitter) results clearly confirm the modal voice quality of the modal-L items in question. Measures of jitter (ppq5 and ddp) establish creaky-L items as having clear aperiodicity, as opposed to modal-H and modal-L, which show periodicity in their signal with no statistical difference between them. This experiment demonstrates the effectiveness of jitter as an acoustic parameter in the distinction of phonation types. To my knowledge, this experiment is the first one that uses jitter in the description of Otomanguean languages.

Spectral tilt. Beginning with the comparison between modal-H versus creaky-L, spectral tilt results indicate modal voice at the beginning of these vowels. All measurements (H1-H2 and H1-A1) are similar in both subjects at intervals 1 and 2. From interval 3 to 5 (and from interval 2 in H1-H2), the differences between modal-H and creaky-L are statistically significant. As expected, creakiness in creaky-L tokens is found from the middle towards the end of the vowel. Overall, this confirms that the amplitude differences H1-H2 and H1-A1 serve as an indicator of phonation types in the language. More specifically, the second and higher harmonics (A1) have greater energy relative to that of the fundamental (F0) in creaky phonation, whereas the difference is smaller in modal phonation.

As for the case under investigation, modal-L versus the modal-H control, results show that it is possible to group them as cases of modal voice. According to the hypothesis, we expect modal-L to have spectral tilt results within a modal phonation range, and this is, in fact, what was obtained. For both subjects, none of the results were statistically different when comparing the prototypical modal phonation with modal-L tokens, with the exception of H1-H2 for the female subject, LiaL. With respect to this difference, modal-L results still show positive numbers, which is expected for modal phonation when comparing H1-H2. Put in other words, within a spectral tilt modal range we may expect differences, and in this case the differences can be attributed to tone and gender. Supporting this reasoning, spectral tilt has also been used as an effective indicator of stressed syllables versus non-stressed (for English, see Laver, 1994, Campbell & Beckman, 1997; for Spanish, see Ortega-Llebaria & Prieto, 2007); since stress is typically associated with high pitch in non-tonal languages, this may also explain the differences between modal-H and modal-L in Quiaviní Zapotec. As for speaker differences, the female speaker produced notably different pitch for each type of tone; thus, this is reflected in the spectral tilt results. Pitch (tone) differences were more subtle in the case of male speaker TiuC.

Finally, with respect to the comparison between modal-L (the case under investigation) versus control creaky-L, the tendency for both subjects in all parameters is for modal-L to pattern with creaky-L during the first two intervals, but statistically differ for intervals 3, 4 and 5. This is basically the same pattern found for modal-H versus creaky-L, that is, all three patterns together at first.

Recapitulating, I mentioned in the introduction that the pattern analyzed here as modal-L was analyzed in Munro and Lopez (1999) as having some amount of laryngealization, being probably somewhere in between modal and creaky voice, maybe tense voice. Let us consider this in more detail in light of the results of the experiment.

With respect to modal-L, results demonstrated that these tokens do not have creaky voice, and, more importantly, the results also rule out the possibility of attributing tense voice to modal-L items. Studies analyzing tense (or pressed) voice (DiCanio, 2009; Tejada, 2009) show that this type of phonation tends to pattern with creaky voice, with slightly less negative numbers for the different spectral tilt measurements, and with considerably different values to those of modal voice. This was not the case in Quiaviní Zapotec modal-L tokens. (See also the analysis of creaky vowels with high tone in Quiaviní Zapotec as cases of tense voice in Chapter 6.)

The last parameters considered in this study were *duration* and *intensity*. They yield no significant results in comparing the control cases: modal-H vs. creaky-L. For female speaker LiaL, the difference between modal-H vs. modal-L was marginally significant, and that of modal-L vs. creaky-L was significant. The latter difference would be in line with the prediction of the experiment; however, the lack of significant differences between the control cases diminishes the assessment of any other dissimilarity. No significant results were obtained for the male speaker.

With respect to duration, I mentioned above that Gordon and Ladefoged (2001) report no duration differences between modal, creaky and breathy vowels in Quiaviní Zapotec. In addition, duration plays an important role in the prosodic pattern in this language (see previous chapter); hence, phonation types seem to be subordinated to prosody. With respect to intensity, which was measured for the overall duration of the vowel, perhaps measurements at specific points throughout the vowel (intervals) could have shown significant variation. All in all, it seems that neither duration nor intensity are useful parameters to distinguish modal vs. laryngealized vowels in Quiaviní Zapotec.

In summary, the following conclusions can be drawn from the results of this phonetic experiment. First, jitter and spectral tilt results confirm the modal voice quality of modal-L tokens, as they pattern with modal-H for most of the parameters in both subjects. Whenever the results were significantly different (H1-H2 for LiaL), results are still within the modal phonation range and the differences can be attributed to pitch.

Second, the modal voice control (modal-H), as well as the modal voice case under investigation (modal-L), are significantly different from the creaky voice control (creaky-

L) at the intervals 3, 4 and 5, i.e. at the middle and second part of the vowel production, which is the part where the creakiness is mainly manifested.

Third, tone and non-modal voice are sequenced: based on the above results, we can confirm that laryngealization is found towards the second half of the vowel in Quiaviní Zapotec creaky vowels with low tone (similar phonetic characteristics are found for creaky-F examples; see Chapter 6 for more details).

According to Yip (2002, p. 25) "two contrastive surface tones is the minimum necessary to earn the name of 'tone language' ". This section confirms two distinctive tone categories in Quiaviní Zapotec, the level tones high (˥) and low (˩), and thus, corroborates the hypothesis of the study, that Quiaviní Zapotec uses tone contrastively. In turn, there is a partial confirmation of the prediction that if there is a four-way tonal contrast in Quiaviní Zapotec, it ought to appear with modal voice.

Having established the contrastive use of tone in Quiaviní Zapotec for the two level tones, the next two sections evaluate the possibility of contour tones occurring with modal voice in this language.

4.3 Experiment 2: Rising tone with modal voice

Rising tone in Quiaviní Zapotec is reported in Munro and Lopez (1999) with the vowel patterns in Table 36.

Table 36. Munro and Lopez (1999, p. 4) rising tone vowel patterns

	Pattern	Combination	Examples	Tone
1	***a'a***	*a'a* (same)	*gyi'izh* 'city person'	rising
2	***a'aa***	*a'a*	*chi'iinnzh* 'bedbug'	rising
3	***àaa***	*a'a*	*nnàaan* 'mother'	rising
4	***àaa'***	*a'a*	*rsìii'lly* 'morning'	rising

According to Pam Munro (p.c.) *a'a* is an orthographic convention for rising tone items with a certain amount of non-modal phonation. Additionally, Munro and Lopez (1999, p. 32) note that "the brief glottal gesture interrupting a checked vowel preceding another vowel at the beginning of a vowel complex can be difficult to perceive. The glottal stop is clearer in vowel complexes where the checked vowel is flanked by other vowels."[72] Other reasons to define these patterns this way include the native-speaker intuition of one of the authors (Felipe Lopez), as well as the comparison with cognates in other Zapotec languages. Notice that all of the vowel patterns in Table 36 are reduced to the first one, *a'a*, in their combination forms.[73] The vowel pattern *a'a* is the most frequent in rising tone items.

In my fieldwork experience, the voice quality of these tokens varies slightly among speakers, but is predominantly modal. Women always produce them with modal voice, whereas for some male speakers, their low pitch range may cause it to sound as if they were produced with some tension in the vocal folds at the beginning. Acoustically, however, I can detect only modal voice in rising-tone tokens, as shown in the acoustic description below.

In the search of the four-way tonal contrast with modal voice in this language, the purpose of this section is to establish the voice quality of items with rising tone in Quiaviní Zapotec. Towards this goal, I follow the same structure as in the previous section. First, I present a preliminary acoustic description of rising-tone items, then a phonetic experiment that instrumentally examines their phonation.

4.3.1 Acoustic description: Modal-R

This section describes the acoustic characteristics of rising-tone items with the vowel pattern *a'a* (Munro & Lopez, 1999), with the purpose of demonstrating the contour shape of these lexical items, as well as evaluating their voice quality. Consider the following (near) minimal pairs.

[72] In agreement with these authors, these latter vowel patterns, including for example *àa'ah* and *àa'ah*, are analyzed here as interrupted vowels (see Chapter 6, §6.5).
[73] Combination forms are shortened realizations of some vowel patterns when endings are added to them, or in compounds (see Munro & Lopez, 1999; and Munro et al, 2008).

(9) Modal voice (near) minimal pairs: High vs. Rising tones

a. / ʧan / ˥ ‘Feliciano’ vs. / ʧan / ˩˥ ‘respectful greeting’
b. / dad / ˥ ‘dice’ vs. / dad / ˩˥ ‘father’
c. / ʒjet / ˥ ‘little’ vs. / ʒjet / ˩˥ ‘cat’
d. / ʒi / ˥ ‘tomorrow’ vs. / ʃi / ˩˥ ‘what (ellip.)’

(10) Modal voice (near) minimal pairs: Low vs. Rising tones

a. / danj / ˩ ‘mountain’ vs. / bdanj / ˩˥ ‘type of traditional dress’
b. / nan / ˩ ‘thick (liquids)’ vs. / nˑan / ˩˥ ‘mother’
c. / nda / ˩ ‘sensitive’ vs. / dad / ˩˥ ‘father’
d. / nla / ˩ ‘greedy’ vs. / nlas / ˩˥ ‘extremely thin’

The first contour tone to be analyzed within modal vowels is the rising tone. The distribution of this tone is not restricted segmentally; fortis and lenis consonants may appear both in onset and coda position. Rising tone may also appear in open syllables, but the number of lexical items of this type is small. The following figure illustrates the realization of rising tone in Quiavini Zapotec.

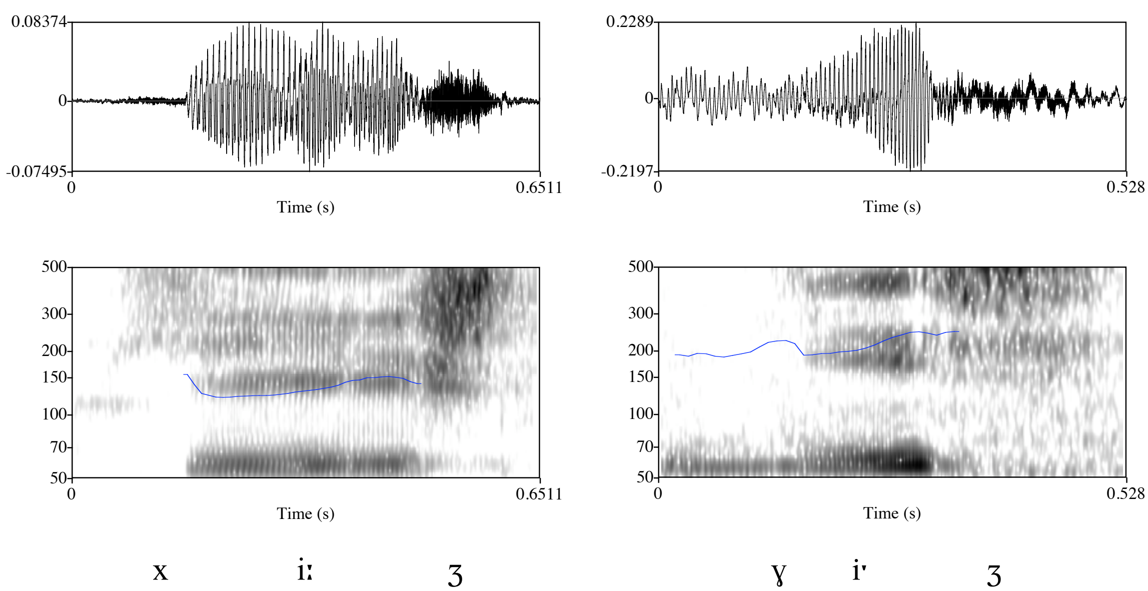


Figure 19. Waveform and spectrogram of / giʒ / ˩˥ ‘city person’, by male speaker TiuR and female speaker LiaB.

The spectrograms above illustrate rising tone with the word / giʒ / ˩˥ ‘city person’ in both male and female speech. The pitch of the former goes from 121 Hz to 151 Hz, whereas the female’s token starts at 190 and finishes at 245 Hz.

Overall results for rising tone for TiuR average a gliding curve of 121-144 Hz, whereas LiaB results show 198-226 Hz. These numbers are very similar to the individual correspondents of low and high tone. Finally, as the figures above show, the contour of the rising tone tends to be located in the second half or towards the end of the vowel.

With respect to the voice quality, my analysis of lexical items with the rising tone indicated no laryngealization (either creakiness or a glottal closure). As shown in the figure above, neither pitch nor intensity is interrupted during the vowel duration, as expected with a checked (interrupted) vowel (see §6.5 in Chapter 6).

4.3.2 Phonetic experiment: Modal-R

As mentioned above, the vowel pattern *a’a* was originally analyzed (Munro and Lopez 1999) as having some amount of laryngealization. In contrast, the acoustic description in the preceding section provides evidence for the re-categorization of rising-tone items as modal-R. In order to test this hypothesis, rising-tone items are acoustically analyzed. These items were part of the recordings made for the evaluation of the modal-L (*àa*) items previously presented. As such, the characteristics of the analysis are the same: modal-R tokens are compared with unambiguous cases of modal voice (high-tone items) and unambiguous cases of creaky voice (low-tone items). The hypotheses and predictions are the same for the analysis of the whole chapter. The phonetic parameters considered in this section are periodicity (jitter) and spectral tilt. Since duration and intensity showed no significant results in the evaluation of modal-L in the previous section, they are not included here.

4.3.2.1 Methods

The methodology of this experiment is the same as that of the previous section for low tone, with the addition of the following rising tone items.

Table 37. Stimuli (partial): rising-tone experiment

Modal-R	1	*da'ad*	'father'
	2	*na'an*	'mother'
	3	*cha'an*	'respectful greeting'
	4	*zhya'ab*	'bad, evil'

As shown in Table 36, the four rising-tone vowel patterns described in Munro and Lopez (1999) may be reduced to the most common pattern *a'a*. For this reason all the modal-R items are of this type. As before, four tokens of each item were recorded by Quiaviní Zapotec native speakers LiaL (female) and TiuC (male), in the same carrier sentence and under the same conditions of the previous experiment (§4.2.2).

4.3.2.2 Results

Figures 20 and 21 show the average results for jitter (ppq5 & ddp) for modal-H and creaky-L of the previous section, along with the results for the items in question in this section: modal-R. For both speakers, we observe that modal-R is different from creaky-L, and how it patterns with the other two modal items. This is confirmed statistically, presented in Tables 38 and 39.

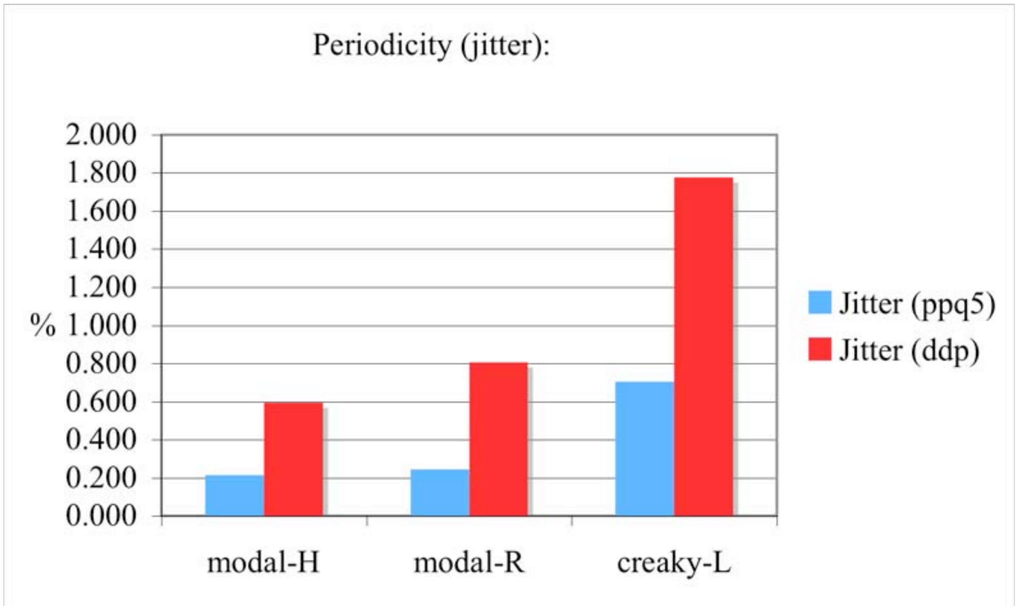


Figure 20. Jitter (ppq5 and ddp) mean results (TiuC).

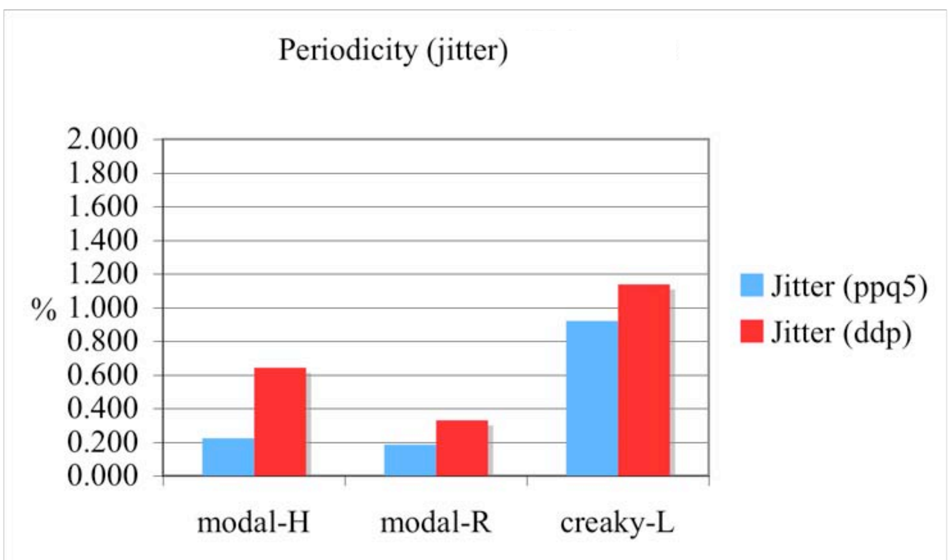


Figure 21. Jitter (ppq5 and ddp) mean results (LiaL).

Table 38. Periodicity (jitter): Mean and standard deviation (LiaL and TiuC)

		LiaL		TiuC	
		Jitter (ppq5)	Jitter (ddp)	Jitter (ppq5)	Jitter (ddp)
modal-H	Mean	0.224%	0.443%	0.217%	0.596%
	SD	0.111	0.298	0.126	0.423
modal-R	Mean	0.188%	0.332	0.246%	0.808%
	SD	0.118	0.091	0.129	0.351
creaky-L	Mean	0.921%	1.141%	0.706%	1.777%
	SD	0.639	0.619	0.392	1.500

Table 39. Jitter results: Probability values from t-test (LiaL and TiuC)

	LiaL		TuC	
	Jitter (ppq5)	Jitter (ddp)	Jitter (ppq5)	Jitter (ddp)
modal-H vs. creaky-L	**<0.001**	**0.003**	**<0.001**	**0.007**
modal-H vs. modal-R	0.124	0.315	0.520	0.133
modal-R vs. creaky-L	**<0.001**	**0.020**	**<0.001**	**0.022**

As regards spectral tilt results, modal-R is within the range of modal voice (with triangles in yellow in the figure below) reporting positive values by female speaker LiaL, although significantly different from modal-H, and values around zero for male speaker TiuC. Both speakers' results were statistically different between modal-R and creaky-L.

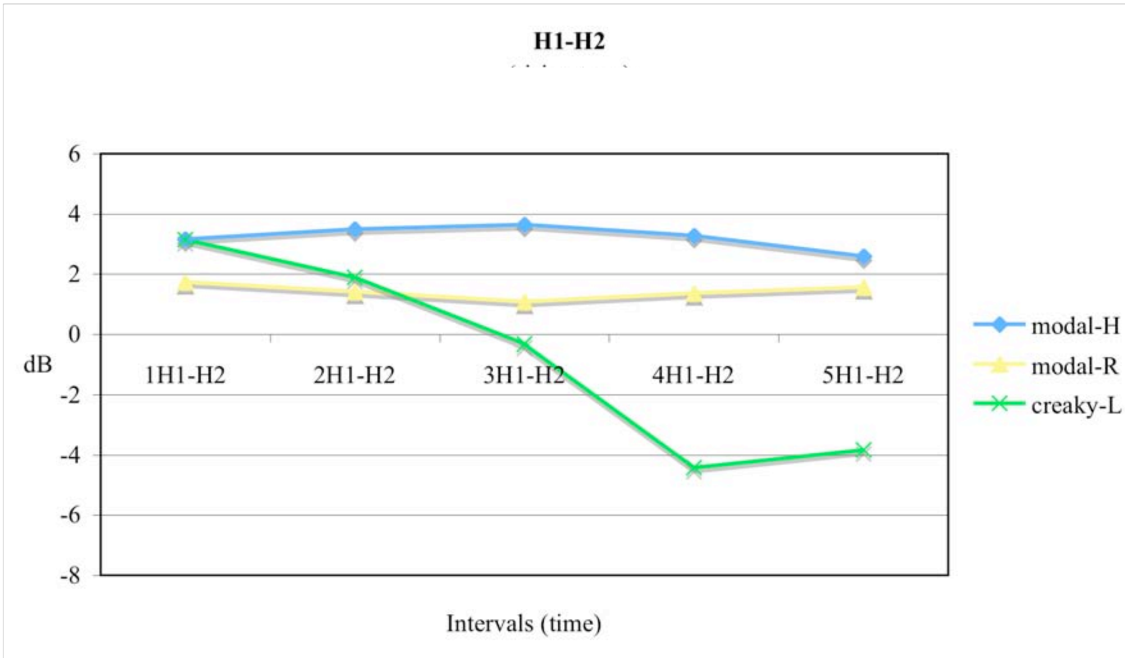


Figure 22. H1-H2 plot for mean results of both speakers.

Table 40. H1-H2 results: Mean and standard deviation (LiaL)

		1H1-H2	2H1-H2	3H1-H2	4H1-H2	5H1-H2
modal - H	Mean	6.34	7.14	7.36	6.93	5.23
	SD	2.23	2.07	2.46	2.60	3.41
modal - R	Mean	3.75	3.14	2.75	3.06	2.79
	SD	3.99	3.53	3.88	3.38	2.82
creaky - L	Mean	6.73	4.83	1.64	-3.66	-3.09
	SD	3.04	3.90	2.96	4.64	4.22

Table 41. H1-H2 results: Probability values from t-test (LiaL)

	1H1-H2	2H1-H2	3H1-H2	4H1-H2	5H1-H2
modal-H vs. creaky-L	0.683	**0.048**	**<0.001**	**<0.001**	**<0.001**
modal-H vs. modal-R	0.0325	**<0.001**	**<0.001**	**0.0011**	**0.0355**
modal-R vs. creaky-L	0.0243	0.2091	0.3698	**<0.001**	**<0.001**

Table 42. H1-H2 results: Mean and standard deviation (TiuC)

		1H1-H2	2H1-H2	3H1-H2	4H1-H2	5H1-H2
modal - H	Mean	-0.05	-0.15	-0.08	-0.36	-0.06
	SD	0.74	0.95	0.88	0.92	0.75
modal - R	Mean	-0.27	-0.32	-0.59	-0.34	0.33
	SD	0.93	0.92	1.16	1.74	1.43
creaky - L	Mean	-0.47	-1.05	-2.28	-5.17	-4.59
	SD	1.06	1.09	3.35	6.83	5.55

Table 43. H1-H2 results: Probability values from t-test (TiuC)

	1H1-H2	2H1-H2	3H1-H2	4H1-H2	5H1-H2
modal-H vs. creaky-L	0.202	**0.018**	**0.021**	**0.013**	**0.005**
modal-H vs. modal-R	0.449	0.595	0.176	0.965	0.345
modal-R vs. creaky-L	0.586	**0.050**	**0.071**	**0.013**	**0.003**

H1-A1 results are parallel to H1-H2. Rising tone items pattern with modal-H and L (no significant differences), and are statistically different from creaky-L from intervals 3 to 5 for both speakers.

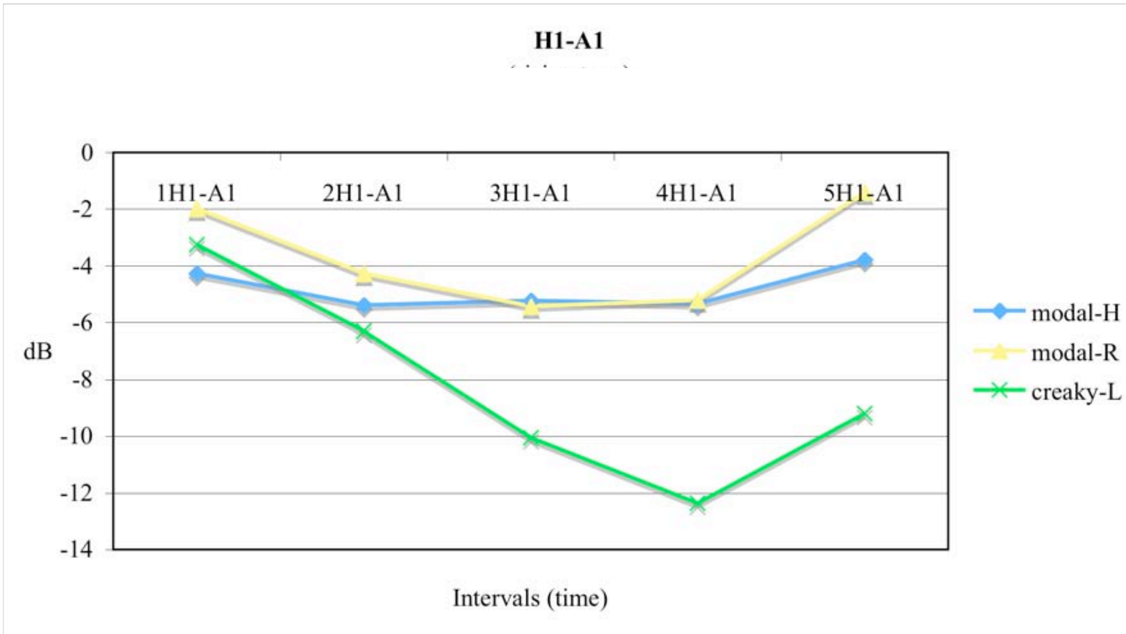


Figure 23. H1-A1 plot for mean results of both speakers.

Table 44. H1-A1 results: Mean and standard deviation (LiaL)

		1H1-A1	2H1-A1	3H1-A1	4H1-A1	5H1-A1
modal-H	Mean	-3.01	-3.51	-3.04	-3.06	-2.91
	SD	4.77	3.70	3.62	3.59	3.70
modal-R	Mean	-0.63	-3.40	-4.35	-3.83	-1.60
	SD	5.45	4.16	4.19	4.48	5.55
creaky-L	Mean	-2.14	-3.86	-8.68	-13.67	-9.64
	SD	3.59	4.54	3.80	4.95	5.66

Table 45. H1-A1 results: Probability values from t-test (LiaL)

	1H1-A1	2H1-A1	3H1-A1	4H1-A1	5H1-A1
modal-H vs. creaky-L	0.563	0.810	**<0.001**	**<0.001**	**<0.001**
modal-H vs. modal-R	0.199	0.936	0.350	0.592	0.437
modal-R vs. creaky-L	0.365	0.763	**0.004**	**<0.001**	**<0.001**

Table 46. H1-A1 results: Mean and standard deviation (TiuC)

		1H1-A1	2H1-A1	3H1-A1	4H1-A1	5H1-A1
modal - H	Mean	-5.53	-7.27	-7.43	-7.62	-4.68
	SD	3.43	4.67	3.58	4.16	5.38
modal - R	Mean	-3.30	-5.14	-6.49	-6.60	-1.22
	SD	3.07	3.20	2.91	3.21	4.17
creaky - L	Mean	-4.39	-8.74	-11.43	-11.08	-8.77
	SD	4.88	3.08	4.57	6.12	3.95

Table 47. H1-A1 results: Probability values from t-test (TiuC)

	1H1-A1	2H1-A1	3H1-A1	4H1-A1	5H1-A1
modal-H vs. creaky-L	0.451	0.302	**0.010**	0.073	**0.020**
modal-H vs. modal-R	0.062	0.145	0.420	0.442	0.051
modal-R vs. creaky-L	0.456	**0.002**	**0.001**	**0.016**	**<.001**

4.3.2.3 Discussion

As in the modal-L experiment, results for modal-R tokens show some inconsistency in the direction of both jitter and spectral tilt. While some of the small non-significant differences are consistent with very light laryngealization in modal-R tokens, others suggest the reverse tendency. Once again, this is expected if the voice quality of these vowels is modal. In more detail, jitter results clearly demonstrate the modal voice of rising tone items. Numbers and statistics are according to the expected results in this experiment. As for spectral tilt, the vowel pattern *a'a* (modal-R) showed no signs of laryngealization. Modal-R results at the middle interval were statistically different from those of creaky-L and similar to modal-H and L. The exception to this similarity was H1-H2 for LiaL, where differences can be attributed to pitch; and regardless of the difference both modal-H and R are within the range of modal voice (with positive spectral tilt values).

4.4 Experiment 3: Falling tone with modal voice

At this point, we have reanalyzed Quiaviní Zapotec as a tonal language that contrasts two level tones, high and low, and one contour tone, rising, within modal voice. I now turn to falling tone. In the 33 vowel patterns in Munro and Lopez' (1999) description 23 correspond to falling tone. There are two cases of vowel patterns with falling tone that seem to have modal voice on the basis of my fieldwork and preliminary acoustic evidence: *a'àa* and *a'aa'*. The next section offers an acoustic description of some of these items, followed by an acoustic evaluation.

4.4.1 Acoustic description: Modal-F

The following (near) minimal pairs include comparisons between falling tone items versus the other three lexical tones in Quiaviní Zapotec.

(11) Modal-Falling (near) minimal pairs

a. / aʒ /	˥˩	's/he'	vs.	/ n-ʒaʒ /	˩	'greedy'
b. / nkai /	˥˩	'dark'	vs.	/ kai /	˥	'street'
c. / -gelˑ /	˥˩	'by chance'	vs.	/ gwelˑ /	˩˥	'chance, turn'
d. / ʒilj /	˥˩	'sheep'	vs.	/ ʒilj /	˩˥	'saddle'
e. / bibj /	˥˩	'pipe (plant)'	vs.	/ n-ʒibj /	˥	'scared'

Figure 24 shows two examples of falling tone in Quiaviní Zapotec.

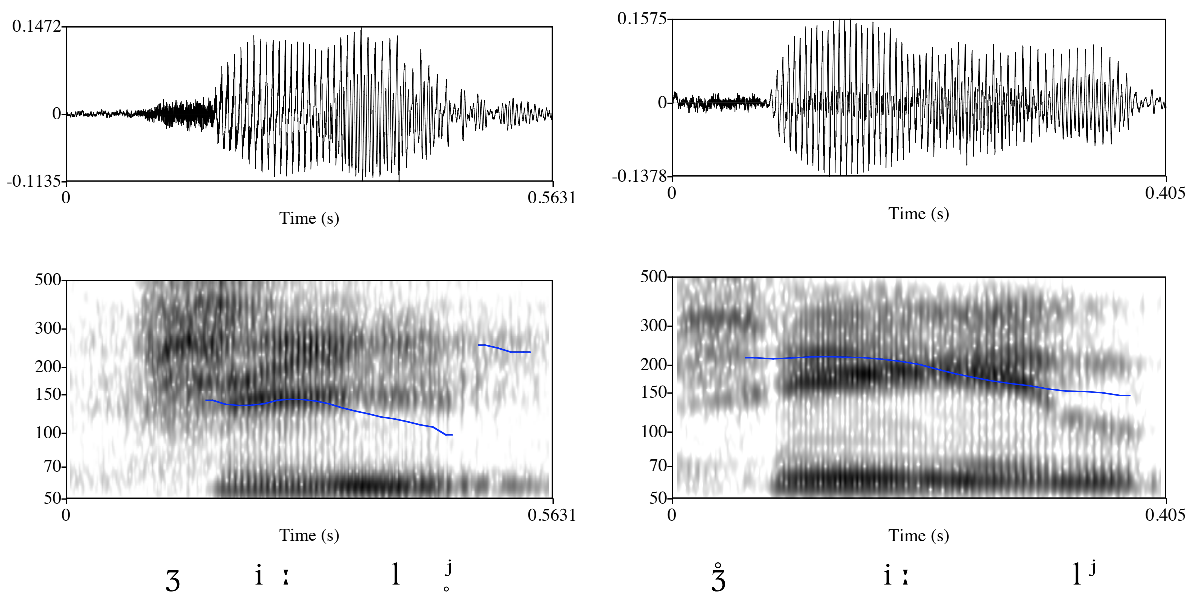


Figure 24. Waveform and spectrogram of / ʒilj / ˥˩ 'sheep', by male speaker TiuR and female speaker LiaB.

In this example, TiuR's pitch falls from 143 Hz to 117 Hz, whereas LiaB's pitch is 218-170 Hz. Overall results for falling tone for TiuR average a gliding curve of 146-116 Hz, whereas LiaB results show 220-181 Hz. The falling contour shape is distributed either along the whole vowel/rhyme or towards the second half. Additionally, the pitch of creaky-L tokens is generally lower than that of modal-F tokens (see Chapter 6, §6.4).

In terms of voice quality, the periodicity of the sounds in Figure 24 is clear throughout both examples. Likewise, the spectrograms are clear and with no signs of laryngealization, particularly compared with prototypical creaky voice (see Chapter 6, §6.4).

4.4.2 Phonetic evaluation: Modal-F

This is a post-experiment evaluation. Fewer tokens of hypothetical lexical items with modal voice and falling tone were included in the recordings for modal-L and -R tokens. Consequently, instead of conclusive experimental results, in what follows, I present a preliminary evaluation.

The following lexical items were analyzed:

Table 48. Stimuli: falling-tone evaluation

Modal-F	1	*a'àazh:*	's/he'
	2	*gue'èell*	'by chance'
	3	*nca'ài*	'dark'
	4	*zhi'ìilly*	'sheep'

Each of these items was recorded twice by female speaker LiaL, under the same conditions as the previous experiments. The jitter and spectral tilt results are presented in the following tables, in comparison with the control cases, modal-H and creaky-L tokens.

Table 49. Periodicity (jitter): Mean and standard deviation (LiaL)

		LiaL Jitter (ppq5)	Jitter (ddp)
modal-H	Mean	0.224%	0.443%
	SD	0.111	0.298
modal-F	Mean	0.325%	0.502%
	SD	0.111	0.298
creaky-L	Mean	0.921%	1.141%
	SD	0.639	0.619

As with modal-L and modal-R, modal vowels with falling tone have low jitter values, similar to those of the control case modal-H. Likewise, modal-F tokens pattern with modal voice in terms of spectral tilt throughout the five different intervals considered for H1-H2 and H1-A1. As with previous cases under investigation, the non-modal voice control case, creaky-L, departs from the positive values of modal-F from the third interval onwards.

Table 50. H1-H2 results: Mean and standard deviation (LiaL)

		1H1-H2	2H1-H2	3H1-H2	4H1-H2	5H1-H2
modal - H	Mean	6.34	7.14	7.36	6.93	5.23
	SD	2.23	2.07	2.46	2.60	3.41
modal - F	Mean	5.40	5.76	4.82	4.34	3.92
	SD	3.17	3.51	2.50	3.16	3.49
creaky - L	Mean	6.73	4.83	1.64	-3.66	-3.09
	SD	3.04	3.90	2.96	4.64	4.22

Table 51. H1-A1 results: Mean and standard deviation (LiaL)

		1H1-A1	2H1-A1	3H1-A1	4H1-A1	5H1-A1
modal-H	Mean	-3.01	-3.51	-3.04	-3.06	-2.91
	SD	4.77	3.70	3.62	3.59	3.70
modal-F	Mean	-1.42	-1.19	-1.06	-0.50	1.33
	SD	4.09	3.86	3.57	4.81	5.75
creaky-L	Mean	-2.14	-3.86	-8.68	-13.67	-9.64
	SD	3.59	4.54	3.80	4.95	5.66

The above results suggest that modal-F tokens have modal voice, and therefore, this completes the tonal inventory of modal voice in Quiaviní Zapotec.

4.5 Conclusions: Quiaviní Zapotec tonal inventory with modal voice

This final section concludes the chapter providing a complete picture of the reanalysis of tone with modal voice in Quiaviní Zapotec. The section includes comparisons of the Munro and Lopez (1999) vowel patterns, along with a final comprehensive illustration of Quiaviní Zapotec tone pitch contours for vowels with modal voice.

Table 52 summarizes the vowel patterns from the Quiaviní Zapotec dictionary considered in this chapter, in parallel with my reanalysis of these vowels. On the left, I present Munro and Lopez' (1999) orthography and tone, along with the proposed phonological transcription and tone.

Table 52. Tone in modal voice: vowel pattern reanalysis

	Munro and Lopez (1999) orthography	tone	Reanalysis phonemic	tone
1	*aa*	H	/ a /	H
2	*àa*	L	/ a /	L
3	*a'a*	R	/ a /	R
4	*a'àa, a'aa'*	F	/ a /	F

Table 53 encodes the same information as Table 52, but with actual examples instead of only with the patterns. Within the reanalysis, another column is added to present the phonetic transcription.

Table 53. Tone in modal voice: reanalysis with examples

	Munro and Lopez (1999) orthography	tone	gloss	Reanalysis phonemic	phonetic
1	*daany*	H	'harm'	/ danj / ˥	[dáːɲ]
2	*dàany*	L	'mountain'	/ danj / ˩	[dàːɲ]
3	*da'ad*	R	'father'	/ dad / ˩˥	[dǎːð]
4	*a'àazh:*	F	's/he'	/ aʐ / ˥˩	[âːʐ]

Based on the findings of this chapter, I conclude that modal voice may bear all tones in this language. The four contrastive tone categories in Quiavini Zapotec are included in the following table.

Table 54. Quiaviní Zapotec Tone and modal voice

	High	Low	Rising	Falling
Modal	√	√	√	√

Finally, the following figure schematizes the four tone melodies in Quiaviní Zapotec. Means correspond to the production of 10 tokens of each category by male speaker TiuC (§6.4). This is an illustration of the overall shape of Quiaviní Zapotec tones.

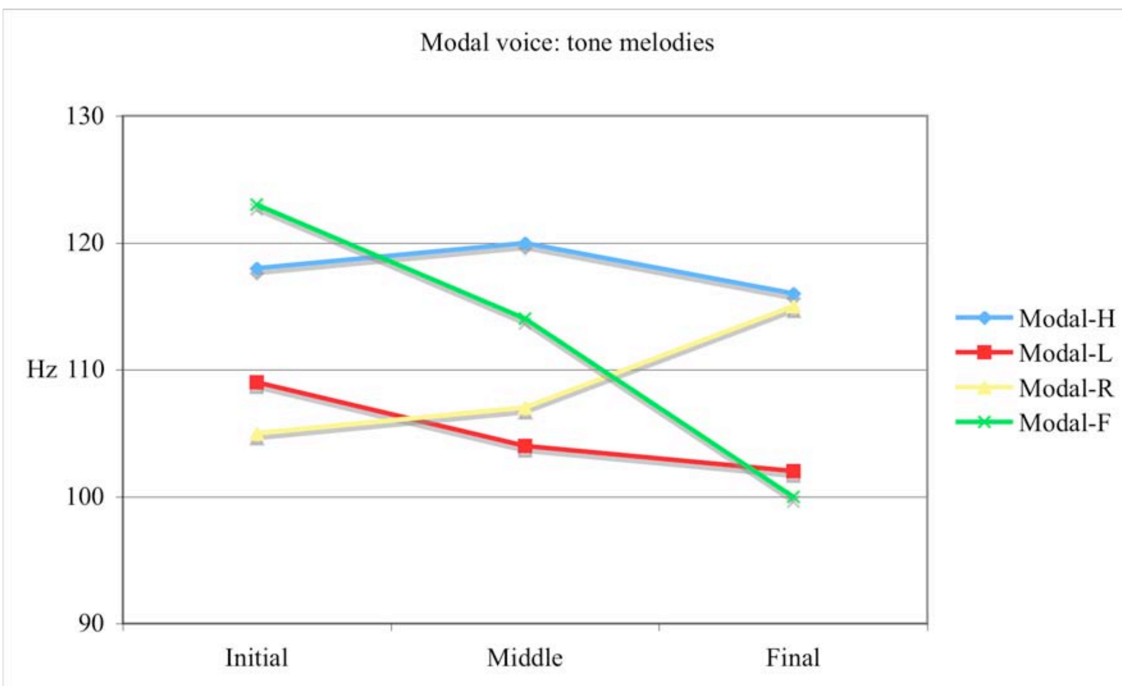


Figure 25. Pitch average contours for modal vowels (TiuC).

Having established the contrastive use of tone in Quiaviní Zapotec, with examples of all four tones on vowels with modal voice, the next chapter investigates the tone-bearing unit in Quiaviní Zapotec, as well as the phonological representation of tone.

Chapter 5:

The tone-bearing unit in Quiaviní Zapotec: Moraicity and tone

5.1 Introduction

Under non-linear phonology (e.g. Autosegmental Phonology, Goldsmith, 1976), tone is represented on a separate tier from segmental and other prosodic material. A tone is only realized on the surface if it is associated with some segment or prosodic entity such as the syllable or the mora, on which it is eventually pronounced.[74] A large amount of evidence in the literature has established the mora as the prosodic tone-bearing unit (TBU; Hyman, 1985; Pulleyblank, 1994; Jiang-King, 1999, among others). Moreover, there are languages in which the TBU is not just any mora, but those associated with vowels and sonorants only (Yip, 2002, p. 73; see Zec, 1988; and Steriade, 1991 for discussion).

Taking into account this theoretical background, I assume that the mora is the TBU in Quiaviní Zapotec. The question remains, however, of how tone is manifested at the segmental level. In the previous chapter, it has been illustrated how vowels express

[74] Except in that floating (L) tones, for example, are often taken to be realized in the form of *downstep* effects on a following (H) tone (Hyman & Schuh, 1974).

tone (being the optimal segments to do so), but Quiaviní Zapotec also has a wide variety of syllable rhymes, with the full inventory of consonants allowed in the coda. Of particular interest is the pervasive fortis/lenis distinction in the consonant inventory, a contrast that is found both in obstruents and sonorants. The goal of this section is to determine the segmental tone-bearing units in Quiaviní Zapotec, focusing on syllables with modal vowels only (in case other voice qualities may make it more difficult to isolate what is going on). Consequently, only the level tones (high and low) and rising tone will be considered, since falling tone has a restricted distribution with modal voice (i.e. few lexical items; see Chapter 4, §4.4).

Since tone associates with the mora, only moraic segments will bear tone. Among the moraic segments, vowels clearly bear tone in Quiaviní Zapotec. Coda fortis consonants are also moraic and so coda fortis sonorants could in principle bear tone phonetically, but fortis obstruents cannot bear tone phonetically due to their voicelessness. Finally, since the prosodic affiliation of segments determines their tone-bearing status, it follows that (non-moraic) lenis consonants (including sonorants) will not bear tone and that onset consonants of all sorts may not bear tone. I thus predict that fortis coda sonorants may be tone-bearing segments in Quiaviní Zapotec, along with vowels (cf. Arellanes, 2003). I now turn to the phonetic and phonological analysis of tone in Quiaviní Zapotec.

5.2 Tone-bearing segments in Quiaviní Zapotec

5.2.1 Obstruents

The phonetics of tone requires voicing and, as mentioned above, the constriction that characterizes obstruent segments makes it very difficult, and impossible in some cases, for these sounds to bear tone phonetically. Since fortis obstruents are always voiceless, the lack of voicing prevents these segments from manifesting pitch (tone), even though they are moraic in coda position. It remains to be determined whether lenis obstruents are able to bear tone in this language. Lenis obstruents are voiced intervocalically, but may devoice word-initially and word-finally. In addition, these segments are analyzed as non-moraic (Chapter 3), based on the fact that vowels followed by lenis consonants become long in order to satisfy the bimoraic requirement of the minimal word. All in all, the characteristic stricture of lenis obstruents, the inconsistency of their voicing, and their non-moraic prosodic status lead us to predict that lenis obstruents do not bear tone in Quiaviní Zapotec.

To investigate the possibility of tone with lenis obstruents, I carried out an informal acoustic investigation using the lexical items in Table 55, which include the lenis stops /b, d, g/ and lenis fricatives /z, ʒ/ in coda position. I looked for two acoustic parameters of these items: (i) voicing; and (ii) consistency with the pitch of the vowel. This is not intended to be a formal acoustic analysis. Rather, examination of the pitch contour is intended as a supplement to by-ear transcription of the tone, to give the reader an idea of what is going on with pitch during the consonants (where no tone is perceived).

Table 55. Words with lenis stops / b, d, g / and fricatives / z, ʒ /.

1	/ zʉb /	˩˥	→	[zʉːβ] ~ [zʉːɸ]	‘dried corn kernel’
2	/ ʒjab /	˩˥	→	[ʒjaːβ] ~ [ʒjaːɸ]	‘bad’
3	/ dad /	˥	→	[dað] ~ [daθ]	‘dice’
4	/ dad /	˩˥	→	[dað] ~ [daθ]	‘father’
5	/ nlˑag /	˩	→	[nlˑaːɣ] ~ [nlˑaːx]	‘wide’
6	/ lug /	˩˥	→	[luːɣ] ~ [luːx]	‘from San Lucas’
7	/ gaz /	˩	→	[gaːz] ~ [gaːs]	‘seven’
8	/ klaz /	˥	→	[klutz] ~ [kluts]	‘Nicolas a’
9	/ nɾaʒ /	˥	→	[nɾaːʒ] ~ [nɾaːʃ]	‘orange’
10	/ giʒ /	˩˥	→	[giːʒ] ~ [giːʃ]	‘city person’

Each word was produced three times in isolation by two male native speakers (TiuR, 50 years old, and TiuL, 35) for a total of 60 tokens (10 words x 3 repetitions x 2 speakers = 60).

All lenis obstruents, both stops and fricatives, demonstrated the following patterns: they were produced as voiceless or partially voiceless; when they manifested pitch, it was inconsistent, dropping for the most part, and without continuation of the trajectory of the phonological tone manifested in the vowel. These characteristics held regardless of the type of tone, confirming the prediction that lenis obstruents are not tone-bearing in Quiaviní Zapotec.

As an illustration, Figure 26 shows a vowel with rising tone before a lenis “stop” realized as a (low-amplitude) fricative, spoken by a male speaker. From the middle to the end of the vowel, the pitch rises from 125 to 144 Hz. As soon as the lenis obstruent begins, the pitch becomes inconsistent. First, it slightly drops (138 Hz), then, it stays flat, and finally it shows a small rise. The lenis obstruent does not continue the shape of the phonological tone manifested in the vowel, nor does it show any different pitch contour of its own. In addition, the characteristic allophony of lenis consonants is particularly salient in coda position; thus, different F0 patterns were obtained with different tokens of a word. Apart from the voiced fricative realizations ([ð]), common allophones for lenis plosives are voiceless fricatives ([ð̥]), where the lack of voicing prevents the expression of tone during the obstruent’s constriction.

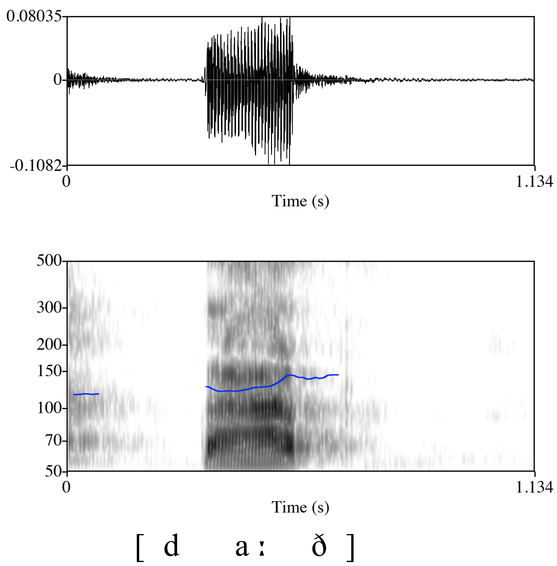


Figure 26. Waveform and spectrogram[75] of / dad / ˩˥ ‘father’, by male speaker TiuR.

Lenis (high-amplitude) fricatives show the same inconsistency; they cannot manifest tone phonetically. In Figure 27, the example of / giʒ / ˩˥ ‘city person’ illustrates the behavior of lenis fricatives in coda position. During the vowel, we observe the pitch rising, but during the transition into the fricative, the pitch drops and disappears, as voicing fades out. The fricative is practically devoiced, thus unable to manifest tone. As voicing is variable for lenis consonants in final utterance position, other examples show a little more voicing in their production. However, the pitch is not sustained, neither consistent with the tone of the vowel nor consistent across different tokens of the same vowel.

[75] As in previous sections, the spectrogram frequency is 0-5000 Hz. (except those containing alveolar fricatives which are 0-8000 Hz.), but since this chapter concerns tone, the pitch frequency is superimposed on the range of 50-500 Hz.

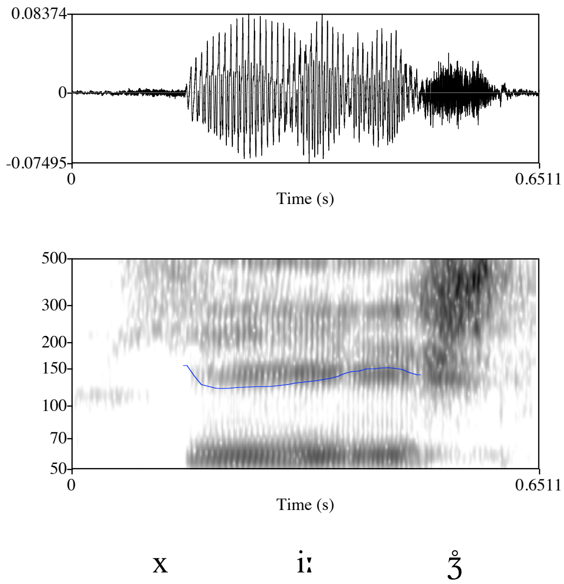


Figure 27. Waveform and spectrogram of / giʒ / ˩˥ ‘city person’, by male speaker TiuR.

5.2.2 Sonorants

In contrast to obstruents, sonorants are cross-linguistically voiced by default and have an F0 that could in principle be raised or lowered enough to realize contrastive tone. Sonorant consonants may even constitute syllable nuclei in many languages and bear tone on their own (e.g. Bantu languages, Hyman & Schuh, 1974; Nieves Chinantec (Otomanguean), P. Hernández, personal communication, August 2008). Nonetheless, sonorant consonants in Quiaviní Zapotec are never syllabic, and therefore, all syllables must have a vowel bearing tone. The question is whether in addition to the vowels moraic (fortis) sonorants bear tone and whether nonmoraic (lenis) sonorants bear tone. Since the mora is the TBU, the prediction is that only fortis coda sonorants bear tone.

In order to corroborate this prediction, I selected several lexical items with level and contour tones with both fortis and lenis sonorants in the coda (see tables below). As in the previous section, I carried out an informal acoustic investigation, examining the data with respect to: (i) voicing; and (ii) consistency with the pitch of the vowel. Once again, the examination of the pitch contour is intended as a supplement to by-ear transcription of the tone. No experimental data is reported; instead, the following sections present the results of the analysis as a phonetically informed description. (The examples with long vowels in open syllables from the previous chapter were considered the control case, as a parameter of comparison for the tonal shapes in Quiaviní Zapotec.)

The words I evaluate contain five lexical entries with fortis sonorants in coda and five with lenis sonorants, making a total of 10 words for each of the tones in consideration: high, low and rising. (Falling tone was excluded because it occurs mostly with non-modal vowels.) Within each comparison group, there is at least one item with a low vowel (/a/), and one item with a high vowel (/i/ or /u/). Two male native speakers of Quiaviní Zapotec (TiuR and TiuL) produced every word three times in isolation. In total, the words consisted of 180 tokens (5 words with a fortis coda sonorant + 5 words with a lenis coda sonorant x 3 tones x 3 repetitions x 2 speakers = 180 tokens).

Table 56. Words with high tone (sonorants)

VC$_{fortis}$				VC$_{lenis}$			
/ njanˑ / ˥	→	[njáń:]	‘Marcelo’	/ tan / ˥	→	[táːn]	‘Cayetana’
/ xalˑ / ˥	→	[xáĺː]	‘job’	/ danj / ˥	→	[dáːɲ]	‘harm’
/ belˑ / ˥	→	[béĺː]	‘Avelina’	/ bal / ˥	→	[báːl]	‘bullet’
/ nˑdenˑ / ˥	→	[ndéńː]	‘this (one)’	/ nuan / ˥	→	[núːán]	‘chirimoya’
/ n-sualˑ / ˥	→	[nsúáĺː]	‘blue’	/ banˈgual / ˥	→	[banˈgúːál]	‘old’

Table 57. Words with low tone (sonorants)

VC$_{fortis}$				VC$_{lenis}$			
/ galˑj / ˩	→	[gàl̀ːʲ]	‘twenty’	/ danj / ˩	→	[dàːɲ]	‘mountain’
/ nalˑ / ˩	→	[nàl̀ː]	‘is hung’	/ nan / ˩	→	[nàːn]	‘thick’
/ tʃonˑ / ˩	→	[tʃòǹː]	‘three’	/ bdan / ˩	→	[bdàːn]	‘soot’
/ nˑdenˑ / ˩	→	[ndèǹː]	‘that (one)’	/ bkwel / ˩	→	[bkwèːl]	‘corn husk’ (totomoztle)
/ bunˑj / ˩	→	[bùɲ̀ː]	‘person’	/ zinj / ˩	→	[zìːɲ]	‘spring (of water)’

Table 58. Words with rising tone (sonorants)

VC*fortis*				VC*lenis*			
/ damˑ / ˩˥	→	[dàḿː]	‘owl’	/ manj / ˩˥	→	[mǎːɲ]	‘animal’
/ sanˑʒ / ˩˥	→	[sàńːʒ]	‘tame’	/ nan / ˩˥	→	[nǎːn]	‘mother’
/ kanˑ / ˩˥	→	[kàńː]	‘Alejandra’	/ tʃan / ˩˥	→	[tʃǎːn]	‘respectful greeting’
/ gwelˑ / ˩˥	→	[gwèl̀ː]	‘turn, chance’	/ bjol / ˩˥	→	[bjǒːl]	‘agave flower bud’
/ tʃinˑʒ / ˩˥	→	[tʃìńːʒ]	‘bedbug’	/ ngwinj/ ˩˥	→	[ngwǐːɲ]	‘sickness’

5.2.2.1 High tone (sonorants)

I present first the characteristics of rhymes consisting of vowel plus fortis sonorant (VC*fortis*). In terms of pitch, vowels expressing high tone may show an initial period of phonetic consonant pitch perturbation (raised pitch after voiceless consonants, lowered pitch after voiced ones), followed by a pitch level that is more stable and relatively flat. The fortis sonorant continues the tonal trajectory initiated by the vowel and maintains it during the majority of its duration. This is illustrated in Figure 28.

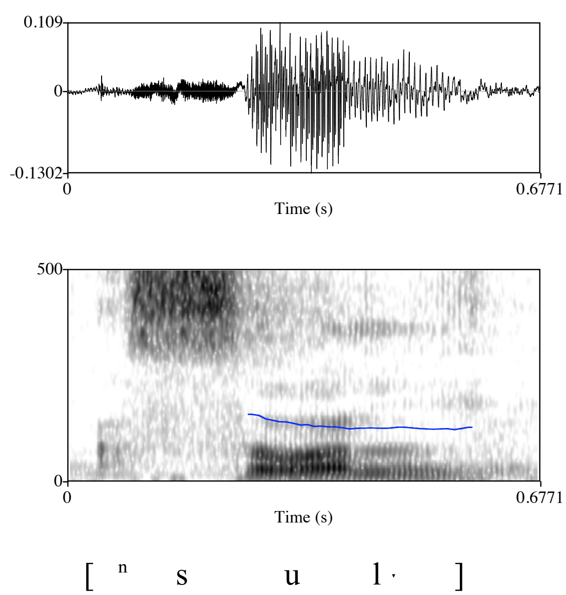
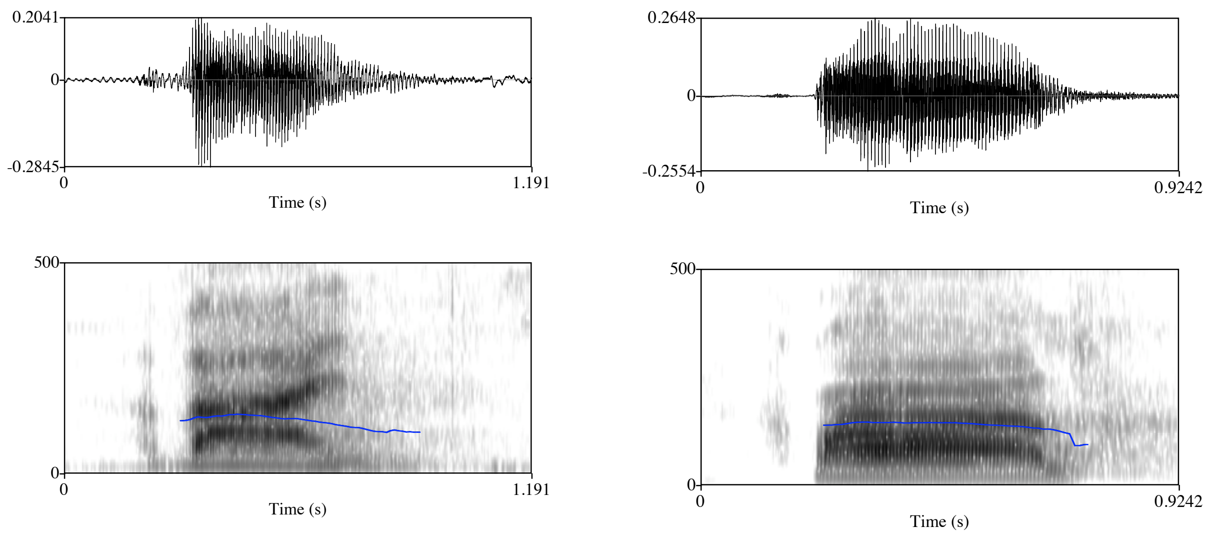


Figure 28. Waveform and spectrogram of / n-sualˑ ~ n-sulˑ / ˥ ‘blue’, by male speaker TiuR.

In contrast, in rhymes formed by a vowel plus a lenis sonorant (VC*lenis*), both the duration and the manifestation of pitch are different. Vowels are always long, whereas the lenis consonants are short. For pitch, coda consonants do not show the same continuity with the vowel as their fortis counterparts. The most common pattern is that pitch drops in these cases.



[d aː j ɲ] [b aː l]

Figure 29. Waveform and spectrogram of / dan^j / ˥ ‘harm’ and / bal / ˥ ‘bullet’, by male speaker TiuR.

Figure 29 shows two examples with a coda lenis sonorant. In the case of / dan^j / ˥ ‘harm’, after a small initial rise (due to /d/), pitch is steady during the vowel, but begins to fall with the glide and continues to fall through the nasal. Because the phonological tone is manifested during the steady state of the vowel, the nasal does not need to maintain a flat F0, thus, the pitch lowering is the expected trajectory in utterance final position. The case of the liquid in / bal / ˥ ‘bullet’ is even clearer in showing the role of lenis consonants. The pitch is clear and sustained during the vowel duration; the liquid continues the pitch trajectory for a few pitch periods and then it suddenly drops and voicing disappears. In summary, these examples suggest that lenis sonorants do not bear phonological tone whereas fortis ones do.[76]

[76] The possibility of lenis consonants bearing a L tone is rejected below.

5.2.2.2 Low tone (sonorants)

With respect to low tone, let us start with a particular example. Figure 30 shows an interesting comparison between two types of rhymes in Quiaviní Zapotec, both in terms of duration and pitch. The first one is the word / nda / ˩ 'sensitive' on its own, which consists of an open syllable, hence, with a rhyme made up of a single vowel (V). The spectrogram on the right corresponds to the same word plus the 3s clitic (child) / ＝ɨmˑ /, which forms in this case a rhyme with a vowel and a fortis sonorant (VC_{fortis}).

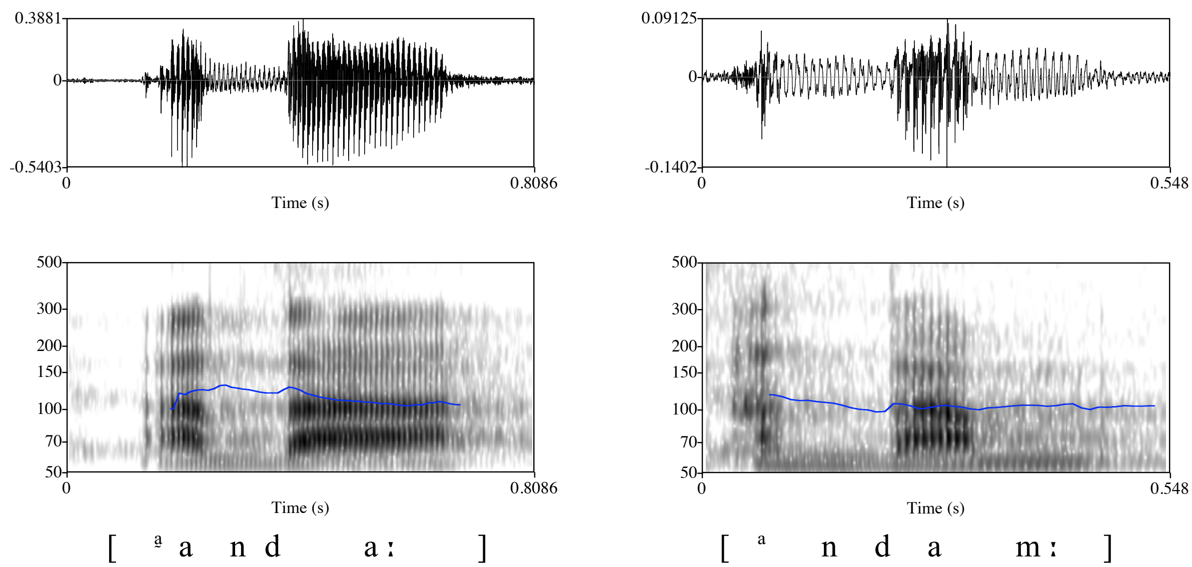


Figure 30. Waveform and spectrogram of / nda / ˩ 'sensitive', by male speaker TiuL. The first one shows the word on its own, and the second example includes the 3s clitic (child) / =ɨmˑ /.

The vowel in the first spectrogram expresses the low tone throughout its entire duration. Apart from the little phonetic perturbation at the beginning, the pitch is stable, averaging 110 Hz. The second spectrogram suggests that tone is manifested in both the vowel and the consonant. The pitch shape initiated by the vowel continues stably into the consonant for its entire duration. These characteristics exemplify the prosodic bimoraic requirement of the minimal prosodic word. In the first case, the vowel is the only segment in the rhyme, thus, it is the only prosodically active element. It is lengthened in order to satisfy minimality and tone is expressed fully. In the second case, both the vowel and the consonant are moraic and both manifest the phonological tone.[77]

For lenis sonorants, the case is the same as the one outlined above for high tone; namely, they do not show continuity with the vowel pitch. The pitch expressed in the lenis sonorants is normally irregular and commonly drops. An example is given in Figure 31, which corresponds to the word / bdan / ˩ ‘soot’. The vowel last 177 ms and averages a pitch of 136 Hz, whereas the consonant shows no pitch track and lasts ~70 ms. When I plotted the pitch by hand, the result was a lowering of about 20 Hz compared to the vowel, and with considerable irregularity.

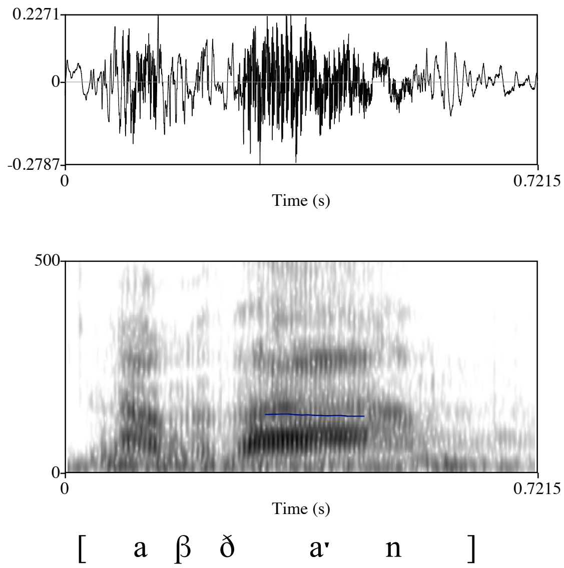


Figure 31. Waveform and spectrogram of / bdan / ˩ ‘soot’, by male speaker TiuR.

[77] This set of examples shows the complementary distribution of vowel length: long in open syllables and before lenis consonants and short with fortis coda consonants. In more detail, the difference in duration is noticeable in this example. The vowel lasts 274 ms. in the open syllable, and 89 ms. in the closed one. In the latter case, the coda compensates for the duration of the rhyme, lasting 133 ms. (for a total rhyme duration of 222 ms.).

5.2.2.3 Rising tone (sonorants)

The last type of tone to consider is the rising contour tone. It shows the same characteristics outlined above for the level tones with respect to sonorants in coda position. In addition, the rising contour tone adds crucial evidence to support the claim that fortis coda sonorants are the only tone-bearing consonants: these consonants continue the pitch trajectory of the preceding vowel, and often it is during the coda consonant that the pitch rise takes place. On the other hand, lenis sonorants normally do not show continuity with the vowel pitch.

Figure 32 provides examples of words with a vowel-fortis sonorant sequence in the rhyme. For the word on the left, / damˑ / ˩˥ ‘owl’, the pitch starts to rise only towards the end of the vowel, but the most noticeable rise occurs throughout the fortis nasal. The average pitch during the vowel portion is 108 Hz (very close to the average for low tone tokens for this speaker, 110 Hz). At the mid point of the vowel, the pitch is 106 Hz, and at the end point it has risen only to 112 Hz. From there, the nasal continues rising until 144 Hz. The rise during the vowel portion is too small on its own to be interpreted as a contour; the whole rhyme is used to create the contour tone. We observe the same characteristics for the word on the right, / tʃinˑʒ / ˩˥ ‘bedbug’. The vowel has a quite flat pitch averaging 155 Hz, and only rises slightly at the end. It is during the nasal where we find a salient rise, from 158 Hz to 205 Hz.

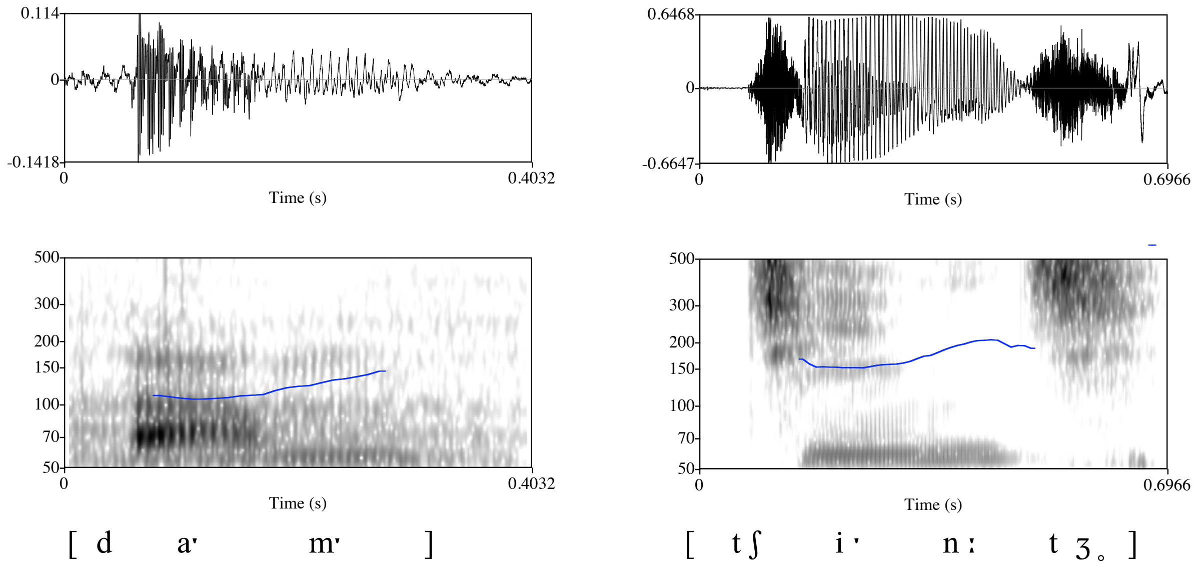


Figure 32. Waveform and spectrogram of / damˑ / ʌ 'owl', by male speaker TiuL. And waveform and spectrogram of / tʃinˑʒ / ʌ 'bedbug', by male speaker TiuR.

The hypothesis that fortis sonorants are the only consonants capable of bearing tone in Quiaviní Zapotec entails that in any other syllable without a fortis coda sonorant, only vowels will bear the tone, including contour tones. Having this consideration in mind, it seems important to compare the above case (rising tone with fortis coda sonorant) with a rhyme with a fortis obstruent to confirm that the shape of the tone is realized during the vowel production only. In the word / mes / ʌ 'table', in Figure 33, we observe that there is no manifestation of pitch during the long (more than 300 ms) obstruent coda. Instead, the realization of tone is entirely located during the vowel production, as predicted. Contrary to the vowel of / damˑ / ʌ 'owl' in Figure 32, which practically has a flat tone, the vowel in / mes / ʌ 'table' shows a clear rising contour. At the beginning, there is a 34 ms period of flat pitch of 128 Hz., and then it takes about 115ms to rise to 156 Hz.

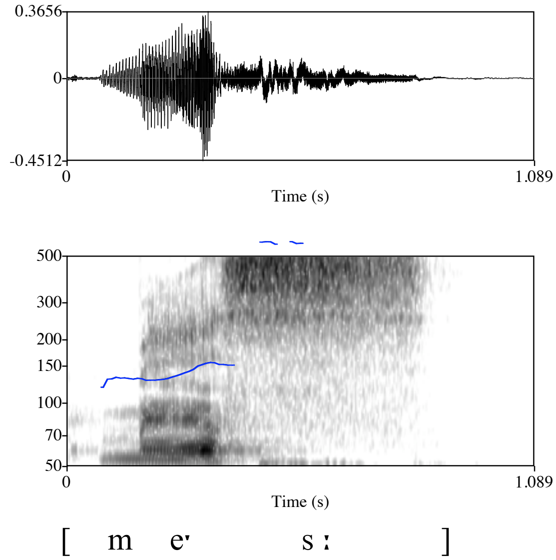


Figure 33. Waveform and spectrogram of / mes / ˩˥˩ ‘table’, by male speaker TiuR.

As demonstrated for lenis consonants in codas, either obstruents or sonorants, their duration is short and the pitch is not consistent with the vowel. Similar to Figure 27 above, in Figure 34 the vowel is long and the pitch contour takes place during its duration; during the production of the lenis coda, the trajectory of the pitch changes (drops). The change in slope is particularly abrupt in the case of the nasal.

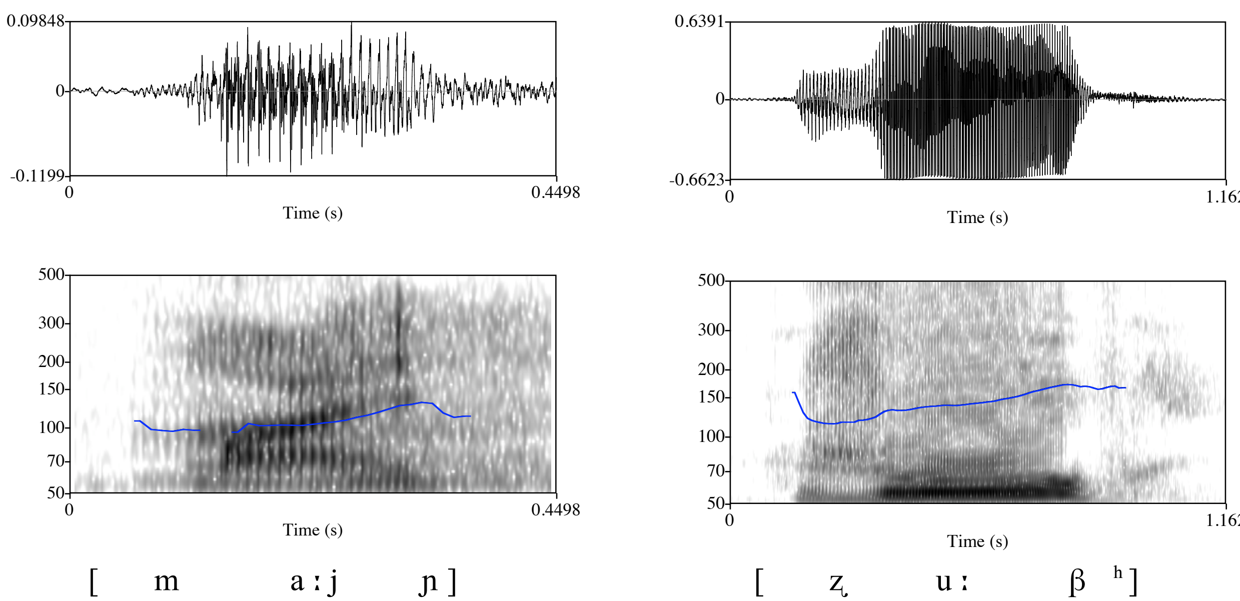


Figure 34. Waveform and spectrogram of / manj / ˩˥˩ ‘animal’, by male speaker TiuL, and waveform and spectrogram of / ʐub / ˩˥˩ ‘dried corn kernel’, by male speaker TiuL.

The examples in Figure 34, with long vowel plus lenis coda consonant, have a similar pitch pattern to that of vowel plus fortis sonorant sequences (Figure 32), where the pitch is realized in the entire rhyme. Contrastively, the shape of the rising tone is somewhat reduced in sequences of vowel plus fortis obstruent (Figure 33). There were a few tokens in which lenis sonorants continue the pitch contour started in the vowel, but it is precisely this inconsistency that demonstrates that lenis coda consonants do not bear phonological tone in Quiaviní Zapotec. Furthermore, when a H tone follows these lenis consonants, e.g. the 1st person clitic /-aˀ/, as in [z̹ǔ:βáʔ] 'my corn', then the lenis consonant shows continuation with the phonological tone manifesting a high pitch. This is consistent with the fact that lenis coda consonants do not have L tone —despite the tendency for dropping the pitch; rather, they simply show phonetic inertia to their context.

Once again, it is clear that fortis sonorants show continuity with the vowel in the expression of rising tone, whereas lenis sonorants do not.

5.2.3 Discussion

The evidence presented here supports the hypothesis that fortis coda sonorants bear tone in Quiaviní Zapotec. Nonetheless, it is necessary to discuss some aspects of this issue. In the case of level tones, although the pitch trajectory is continued during fortis sonorants, it could be argued that the vowel on its own expresses the phonological tone, and the pitch found in the coda consonant is simple phonetic inertia. However, this consistency with vowel pitch does not take place with lenis sonorants. Moreover, there are cases in which it is necessary to include the fortis sonorant as a tone-bearing unit together with the vowel. This is the case for rising contour tones, where all or most of the rise takes place during the consonant.

On the other hand, the data confirms that it is not necessary to include lenis sonorants for the expression of the phonological tone in Quiaviní Zapotec. In the cases analyzed here, lenis sonorants are short, many of them have low amplitude and weak formant frequencies, and practically all tend to cause the pitch to drop. This pitch lowering is common word-finally (words were recorded in isolation). If another word follows, lenis sonorants may have a different pitch shape. This inconsistency is crucial to support their lack of phonological tone. In the case of the level tones, the lenis sonorants rarely continue the flat or level pitch started in the vowel. In the case of rising tone, this pitch disruption is even more noticeable as the pitch lowering goes against the trajectory of the phonological tone. In brief, the pitch of lenis sonorants is not manipulated to bear tone. Vowels with lenis codas or in open syllables are long, and their duration is sufficient to clearly manifest tone.

In terms of syllable structure, the fact that vowels and some coda consonants bear tone indicates that tone may be located in the whole rhyme. The fact that some segments are not able to bear tone in coda is related to their specific articulatory characteristics and prosodic status. Obstruents (fortis and lenis) have a significant constriction and lack of formant structure. Lenis sonorants are normally short, sometimes devoiced and their formant structure is weak. These circumstances make it difficult, or even impossible, to achieve the necessary characteristics to express tone. Prosodically, although fortis obstruents are claimed to be moraic (Chapter 3), they are unable to manifest pitch due to their voicelessness. As for lenis consonants, I described them as non-moraic (Chapter 3), mainly based on their short duration. Their inability to bear phonological tone provides additional evidence for this prosodic characterization.

5.2.4 Conclusion

Table 59 summarizes the phonetic characteristics of coda segment comparison in Quiaviní Zapotec; all of them apply to the different tones analyzed here.

Table 59. Phonetic characteristics of coda segments comparison in Quiaviní Zapotec

Fortis obstruents	**Lenis obstruents**
Voiceless (no pitch)	Inconsistent voicing & pitch
Fortis sonorants	**Lenis sonorants**
Long	Short
Manipulation of pitch	Pitch drops (tendency)
Continue vowel pitch trajectory	Independent of vowel pitch
or carry latter half of pitch contour	Low amplitude and weak formant frequencies

As illustrated, there is a split between fortis and lenis sonorants, with only the former presenting the necessary phonetic characteristics to bear phonological tone. The implication of these findings is that the feature [+sonorant] is not enough for a segment to bear tone in Quiaviní Zapotec; the necessary conditions to do so are to be moraic (fortis) and [+sonorant]. This hierarchy is represented in the following table.

Table 60. Tone-bearing segments in coda in Quiaviní Zapotec

Coda type		Moraic segments		Tone-bearing coda
fortis obstruent	→	**fortis** obstruent		
lenis obstruent				
fortis sonorant	→	**fortis** sonorant	→	**fortis sonorant**
lenis sonorant				

The TBU in Quiaviní Zapotec is the mora associated with vowels and fortis sonorants in coda: these segments obligatorily express phonological tone in this language. The formal expression of this pattern in terms of a constraint-based grammar will be presented in the following section.

Finally, and as mentioned above, this section has focused on the TBU in Quiaviní Zapotec modal voice. The assumption is that the prosodic and segmental characteristics outlined in here will apply to the expression of tone in non-modal vowels (see Chapters 6 & 7).

5.3 Tone representation in Quiaviní Zapotec and formal account

Chapter 4 established the tonal inventory of Quiaviní Zapotec in modal voice, and the preceding sections of this chapter established the segmental distribution of tone, as well as how tone is implemented phonetically. The goal of this section is twofold: first, to map the phonetic characteristics previously defined onto a phonological representation, adopting moraic theory (Hyman, 1985; McCarthy & Prince, 1986; Hayes, 1989); and second, to provide a grammatical account of the patterns observed in this language. The overall analysis is presented within the framework of Optimality Theory (Prince & Smolensky, 2004 [1993]).

The analysis is restricted to monosyllabic roots (the majority in the language). However, an important comment regarding larger domains is that tone in Quiaviní Zapotec shows little or no mobility. As long as the syllable is prominent, level and contour tones remain within the root in bigger forms. Consequently, I assume that tone is underlyingly anchored to the root.

As shown in Chapter 3, vowels have one mora before fortis consonants and two moras before lenis consonants in monosyllables. A single (level) tone is linked underlyingly to the vowel, as on the left of (1). When a second mora is inserted in the output (due to minimality), tone spreads to it (1b, c & d), unless prevented by feature incompatibility (1a).

(1) Level tone configuration (T = H or L)

Input *Output*

a.
$$\begin{array}{ccccccc}
 & T & & & & T & \\
 & | & & & & | & \\
 & \mu & & & & \mu & \mu \\
 & | & & & & | & | \\
C & V & O_{fortis} & \rightarrow & C & V & O_{fortis}
\end{array}$$

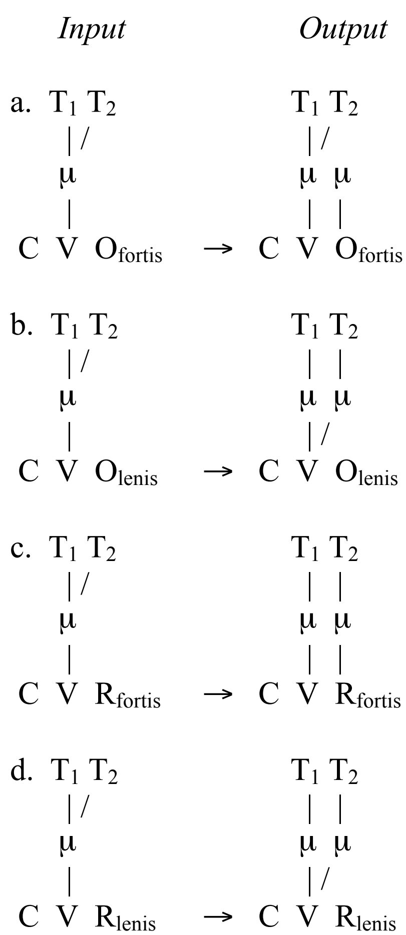
b.
$$\begin{array}{ccccccc}
 & T & & & & T & \\
 & | & & & & | & \backslash \\
 & \mu & & & & \mu & \mu \\
 & | & & & & | & / \\
C & V & O_{lenis} & \rightarrow & C & V & O_{lenis}
\end{array}$$

c.
$$\begin{array}{ccccccc}
 & T & & & & T & \\
 & | & & & & | & \backslash \\
 & \mu & & & & \mu & \mu \\
 & | & & & & | & | \\
C & V & R_{fortis} & \rightarrow & C & V & R_{fortis}
\end{array}$$

d.
$$\begin{array}{ccccccc}
 & T & & & & T & \\
 & | & & & & | & \backslash \\
 & \mu & & & & \mu & \mu \\
 & | & & & & | & / \\
C & V & R_{lenis} & \rightarrow & C & V & R_{lenis}
\end{array}$$

Contour tones are standardly analyzed as complex: HL (falling) or LH (rising) (e.g. Akinlabi, 1985; Akinlabi & Liberman, 1995). As mentioned above, based on the fact that roots with rising and falling tones are lexically contrastive, and that tones always remain within the root, I assume that the tones of the contour sequence are linked underlyingly to the only underlying mora (left part of (2)). To a certain extent this is only an assumption for convenience in monosyllables. It could be argued that only the first tone of the sequence is linked underlyingly, or neither, but regardless of this assumption, the constraint ranking presented below correctly accounts for the surface patterns as optimal outputs. Nonetheless, in most languages contour tones are bimoraic, with each tone associating with a different mora (Zhang, 2001). Quiaviní Zapotec illustrates this preference: when a second mora is inserted, the second tone links to it (2b, c & d)—except when the second mora is attached to a fortis obstruent (2a). Before fortis obstruents, Quiaviní Zapotec has a short vowel with a contour tone (two tones linked to one mora), which is typologically unusual.

(2) Contour tone configuration (T_1T_2 = LH or HL)



The above input and output representations are motivated on the basis of the phonetics-phonology mapping. Both the moraicity of segments and how tone is implemented in the phonetics of the language (timing patterns) were taken into account. Specifically, all input forms are monomoraic. It is commonly assumed that single vowels are monomoraic, long vowels bimoraic, and consonants are not moraic underlyingly except for geminates. Under an Optimality theory approach, this is not the only possibility (cf. *Richness of the base*, Prince & Smolensky, 2004 [1993]), but it is the best assumption in light of *lexicon optimization* (Prince & Smolensky, 2004 [1993];

McCarthy, 2002). As presented in Chapter 3 (§3.3), monosyllabic roots do not always surface as bimoraic; in non-prominent syllables and some suffixed words vowels are monomoraic. This variation then suggests the underlying root monomoraicity, rejecting the apparent violation of lexicon optimization in (1) and (2).

In order to formally account for the facts in (1) and (2), I present first some assumptions for the analysis. The representations in (1) and (2) assume that there are no floating tones in Quiaviní Zapotec. In addition, no tones are deleted or inserted in Quiaviní Zapotec roots.[78] This is formalized by the constraints below (cf. Pulleyblank, 1997, p. 79; Myers, 1997; Yip, 2002, p. 79).

(3) *FLOAT [79]
Every tone must be associated to some mora (TBU) (No floating tones)

(4) MAX-TONE
Input tones have output correspondents (No deletion of tones)

(5) DEP-TONE
Output tones have input correspondents (No insertion of tones)

I assume these constraints are undominated in Quiaviní Zapotec grammar. For simplicity, they are not included in the following sections.

Furthermore, as the moraicity of segments is crucial in determining their tone association, the formal account of monosyllables in Quiaviní Zapotec from Chapter 3 (§3.2.3) is included. Below, I repeat the ranking and constraint definitions.

(6) FT-BIN, *Lenis-μ >> WBYP >> DEP-μ

(7) FT-BIN
Feet are binary under moraic or syllabic analysis

(8) *Lenis-μ
If lenis then non-moraic

[78] Different tonal processes take place at the morphological level, as in verb inflection and with person clitics, among others. See Munro et al (2008).
[79] This constraint evokes the second well-formedness condition from Goldsmith (1976), which states that 'Every tone must be associated to some TBU'.

(9) WEIGHT BY POSITION (WBYP)
Coda consonants are moraic

(10) DEP-μ
Output moras have input correspondents (No insertion of moras)

5.3.1 Level tones

The first type of rhyme to consider for level tones is a short vowel followed by a fortis obstruent in coda (VO$_{\text{fortis}}$). Examples of this type of rhyme are provided below.

(11) Rhyme: VO$_{\text{fortis}}$

a. / ba$_{\mu}$k / ˥ → [bá$_{\mu}$k$_{\mu}$] ‘person from Tlacolula’
b. / me$_{\mu}$s / ˥ → [mé$_{\mu}$s$_{\mu}$] ‘professor’

Fortis obstruents, despite being moraic, are unable to bear tone; hence, their mora is unspecified for tone:

(12)
```
     H                H
     |                |
     μ                μ  μ
     |                |  |
   C V O_fortis  →  C V O_fortis
```

The restriction that obstruents cannot express tone is common cross-linguistically (Yip, 2002) and is encoded by the following markedness constraint (this constraint would also prevent tone on lenis obstruents, which at any rate are non-moraic):

(13) *[-SON][TONE][80] (Yip, 2002, p. 80)
No tones on obstruents

This constraint is undominated and outranks the markedness constraint SPECIFY T that penalizes any mora (TBU) that is not associated with a tone.

[80] Formally, "Tone" here refers to tonal autosegments in QZ (H & L).

(14) SPECIFY T (cf. Myers, 1997, pp. 861-863; Yip 2002, p. 83) [81]

A mora must be associated with a tone

(15) Fortis obstruent coda – level tone

H | /ba$_{\mu}$k/ 'tlacolula'	FT-BIN	*Lenis-μ	*[-SON][TONE]	WBYP	SPECIFY T	DEP-μ
a. H | ba$_{\mu}$k	*!			*		
b.☞ H | ba$_{\mu}$k$_{\mu}$					*	*
c. H | \\ ba$_{\mu}$k$_{\mu}$			*!			*
d. H |\\ ba$_{\mu\mu}$k				*!		*

Candidate (a), the faithful candidate, violates minimality (FT-BIN) as well as the constraint WBYP that requires coda consonants to have a mora. Candidate (b), the winning candidate, inserts a mora for the /k/ and thus satisfies WBYP. This mora does not associate with the tone, in violation of SPECIFY T, which is low ranked. Candidate (c) incurs a fatal violation of *[-SON][TONE], which penalizes tone on obstruents. Finally, candidate (d) satisfies minimality and SPECIFY T, but at the cost of fatally violating WBYP (which illustrates the crucial ranking WBYP >> SPECIFY T).

The second type of rhyme is a vowel followed by a lenis obstruent.

(16) Rhyme: VO$_{lenis}$ (level tone)

a. / da$_{\mu}$d / ˥ → [dá$_{\mu\mu}$d] 'dice'

b. / nɾa$_{\mu}$ʒ / ˥ → [nɾá$_{\mu\mu}$ʒ] 'orange'

[81] This constraint is in the spirit of the first well-formedness condition of Goldsmith (1976), which states that 'Every TBU must have a tone'.

(17)

$$\begin{array}{ccccccc}
 & \text{H} & & & & \text{H} & \\
 & | & & & & | & \backslash \\
 & \mu & & & & \mu & \mu \\
 & | & & & & | & / \\
\text{C} & \text{V} & \text{O}_{\text{lenis}} & \rightarrow & \text{C} & \text{V} & \text{O}_{\text{lenis}}
\end{array}$$

As lenis consonants are not moraic in Quiaviní Zapotec, the vowel lengthens to satisfy minimality (FT-BIN). The inserted mora is attached to the vowel and so it is allowed to link to a tone satisfying SPECIFY T. Nonetheless, this new association entails other constraint violations. Tones are preferably associated with only one mora, as stated by *LONGT.

(18) *LONGT

A tone may be associated with at most one mora

In addition, the constraint that penalizes associations that deviate from the input is DEPPATH (Pulleyblank, 1996), here formulated as DEPPATH(T). Conversely, the constraint that prevents loss of tone associations is MAXPATH(T).

(19) Tone-mora faithfulness constraints

a) DEPPATH(T)
   Any output path between a tone and an anchor (mora) must have a correspondent path in the input.

b) MAXPATH(T)
   Any input path between a tone and an anchor (mora) must have a correspondent path in the output.

(20) Lenis obstruent coda – level tone

H | / nɾa$_{\mu}$ʒ/ ‘orange’	FT-BIN	*Lenis-μ	*[-SON][T]	WBYP	SPEC T	DEP-μ	*LONGT	DEP PATH(T)	MAX PATH(T)
a. H | nɾa$_{\mu}$ʒ	*!			*					
b. ☞ H |\\ nɾa$_{\mu\mu}$ʒ				*		*	*	*	
c. H | nɾa$_{\mu\mu}$ʒ				*	*!	*			
d. H | \\ nɾa$_{\mu}$ʒ$_{\mu}$		*!	*!			*	*	*	
e. H | nɾa$_{\mu}$ʒ$_{\mu}$		*!			*	*			

The faithful candidate (a) violates the requirement of a prosodic word to form a bimoraic foot, along with WBYP. The rest of the candidates satisfy minimality by inserting a mora, in violation of DEP-μ. The optimal candidate (b) and candidate (c) violate WBYP, but the latter also violates SPECIFY T. In turn, this violation allows us to rank SPECIFY T over *LONGT and DEPPATH(T) (the latter violated by the optimal candidate). Candidates (d) and (e) are eliminated as they violate *Lenis-μ. This ranking also accounts for the remaining types of rhyme, with fortis and lenis sonorants in coda.

The third type of rhyme is a vowel followed by a fortis sonorant:

(21) Rhyme: VR$_{fortis}$ (level tone)

a. / nˑde$_{\mu}$nˑ / ˥ → [ndé$_{\mu}$ń$_{\mu}$] ‘this (one)’
b. / n-sua$_{\mu}$lˑ / ˥ → [nsúá$_{\mu}$ĺ$_{\mu}$] ‘blue’
c. / nˑde$_{\mu}$nˑ / ˩ → [ndè$_{\mu}$ǹ$_{\mu}$] ‘that (one)’
d. / bu$_{\mu}$nˑj / ˩ → [bù$_{\mu}$ ɲ̀$_{\mu}$] ‘person’

```
(22)   H                  H
       |                  | \
       μ                  μ  μ
       |                  |  |
     C V R_fortis   →   C V R_fortis
```

As in the case above, the optimal candidate incurs violations of *LONGT, DEP-μ, and DEPPATH(T), all constraints that are low-ranked, as shown in (23). (Also note that the constraint *[-SON][TONE] plays no role in evaluating these cases, and for that reason it is left out of the tableau.)

(23) Fortis sonorant coda – level tone

L | /bu$_{\mu}$n·j/ 'person'	FT-BIN	*Lenis-μ	WBYP	SPEC T	DEP-μ	*LONGT	DEP PATH(T)	MAX PATH(T)
a. L | bu$_{\mu}$ɲ	*!		*					
b. L |\\ bu$_{\mu\mu}$ɲ			*!		*	*	*	
c. L | bu$_{\mu\ \mu}$ ɲ			*!	*	*			
d. ☞ L | \\ bu$_{\mu}$ɲ$_{\mu}$					*	*	*	
e. L | bu$_{\mu}$ɲ$_{\mu}$				*!	*			

The final type of rhyme is a vowel followed by a lenis sonorant coda:

(24) Rhyme: VR$_{lenis}$ (level tone)

a. / nua$_{\mu}$n / ˥ → [nú$_{\mu}$á$_{\mu}$n] 'chirimoya'

b. / banˈgua$_{\mu}$l / ˥ → [banˈgú$_{\mu}$á$_{\mu}$l] 'old'

c. / bkwe$_{\mu}$l / ˩ → [bkwè$_{\mu\mu}$l] 'corn husk' (totomoztle)

d. / zi$_{\mu}$nj / ˩ → [zì$_{\mu\mu}$ ɲ] 'spring (of water)'

```
(25)    H                   H
        |                   | \
        μ                   μ  μ
        |                   | /
     C  V  Rlenis   →   C  V  Rlenis
```

Once again, this candidate incurs the violations of *LONGT, DEP-μ, and DEPPATH(T). The formal account for this type of rhyme is identical to that of lenis obstruents, presented in tableau (20).

5.3.2 Contour tones

Within contour tones, probably the most interesting case is that of rhymes formed by a short vowel followed by a fortis obstruent, where each segment in the rhyme has a mora, but the contour is fully realized on the vowel. As the obstruent consonant is not able to bear tone, the contour tone must then be associated entirely with the short vowel, on a single mora.

(26) Rhyme: VO$_{fortis}$ (contour tone)

a. /nga$_{\mu}$s/ ˩˥ → [ngǎ$_{\mu}$s$_{\mu}$] 'black'

b. / ʒje$_{\mu}$t / ˩˥ → [ʒjě$_{\mu}$t$_{\mu}$] 'cat'

c. /me$_{\mu}$s/ ˩˥ → [mě$_{\mu}$s$_{\mu}$] 'table'

```
(27)    L H                 L H
        | /                 | /
        μ                   μ  μ
        |                   |  |
     C  V  Ofortis  →   C  V  Ofortis
```

The mora of the coda consonant is prevented from taking the H tone by *[-SON][TONE], forcing the contour tone to associate entirely with one mora, thus violating SPECIFY TONE (as the mora in the coda is not associated with any tone). This scenario and ranking is very similar to that of a level tone with a VO_{fortis} rhyme; however, in the case of the contour tone there are two tones that require association with a mora (TBU), violating the constraint *CONTOUR, as defined in (28).

(28) *CONTOUR
A mora may be associated with at most one tone [82]

This analysis makes a clear prediction in terms of the phonetics-phonology mapping, already confirmed in §5.2 The temporal profile of the contour is different between the VO_{fortis} and the other type of rhymes. For the former, the shape of the contour tone must be expressed fully in the short vowel, and so the slope is steeper. For the remaining rhymes (with lenis obstruent, and fortis and lenis sonorant codas), the contour tone is always realized as long, with each portion of the tone associated with a mora. Consequently, the rhyme VO_{fortis} provides evidence that contour tones in Quiaviní Zapotec may be realized on short vowels, on a single mora, against the common typological tendency to have contour tones only on long vowels (Zhang, 2001; Zoll, 2004, p. 236).

[82] This is equivalent to the following formulation (and representation).

*T T ONET/M: One tone per mora (Zhang, 2001, p. 2)
\/
μ

(29) Fortis obstruent coda – contour tone [83]

LH |/ /nga$_{\mu}$s/	FT-BIN	*Lenis -μ	*[-SON] [TONE]	WBYP	SPEC T	DEP -μ	*CONTOUR	DEP PATH(T)	MAX PATH(T)
a. L H | / nga$_{\mu}$s	*!			*			*		
b. ☞ LH | / nga$_{\mu}$s$_{\mu}$					*	*	*		
c. L H | | nga$_{\mu}$s$_{\mu}$			*!			*		*	*
d. LH | | nga$_{\mu\mu}$s				*!		*		*	*

In the following three types of rhymes with contour tones, the second tone of the contour — originally associated with the underlying mora — is reassociated with the inserted mora, in violation of both DEPPATH(T) and MAXPATH(T). I present examples of the remaining types of rhymes, followed by its moraic representation and tableaus.

(30) Rhyme: VO$_{lenis}$ (contour tone)

a. / ʐu$_{\mu}$b / ˩˥ → [ʐǔ$_{\mu\mu}$b] ‘dried corn kernel’
b. / zhya$_{\mu}$b / ˩˥ → [zhyǎ$_{\mu\mu}$b] ‘bad’
c. / da$_{\mu}$d / ˩˥ → [dǎ$_{\mu\mu}$d] ‘father’
d. / gi$_{\mu}$ʒ / ˩˥ → [gǐ$_{\mu\mu}$ʒ] ‘city person’

```
(31)    L H                 L H
         | /                 |  |
        μ                   μ  μ
         |                   | /
      C  V  Olenis    →   C  V  Olenis
```

[83] Since the constraint *LONGT plays no role evaluating candidates with a contour tone, it is left out of the following tableaus for reasons of space and clarity.

(32) Rhyme: VR$_{fortis}$ (contour tone)

a. / da$_{\mu}$m· / ˩˥ → [dà$_{\mu}$ḿ$_{\mu}$] ‘owl’

b. / sa$_{\mu}$n·ʒ / ˩˥ → [sà$_{\mu}$ń$_{\mu}$ʒ] ‘tame’

c. / gwe$_{\mu}$l· / ˩˥ → [gwè$_{\mu}$1$_{\mu}$] ‘turn, chance’

d. / tʃi$_{\mu}$n·ʒ / ˩˥ → [tʃì$_{\mu}$ń$_{\mu}$ʒ] ‘bedbug’

```
(33)    L H                 L H
         |/                  |  |
        μ                   μ  μ
         |                   |  |
     C  V  Rfortis   →   C  V  Rfortis
```

(34) Rhyme: VR$_{lenis}$ (contour tone)

a. / ma$_{\mu}$nj / ˩˥ → [mǎ$_{\mu\mu}$ ɲ] ‘animal’

b. / tʃa$_{\mu}$n / ˩˥ → [tʃǎ$_{\mu\mu}$n] ‘respectful greeting’

```
(35)    L H                 L H
         |/                  |  |
        μ                   μ  μ
         |                   |/
     C  V  Rlenis    →   C  V  Rlenis
```

(36) Lenis obstruent (and sonorant) coda – contour tone (/z̧ub/ ˩˥ ‘dried corn’)

L H | / /z̧u$_\mu$b	FT-BIN	*Lenis-μ	*[-SON][T]	WBYP	SPEC T	DEP-μ	*CONTOUR	DEP PATH(T)	MAX PATH(T)
a.LH | / z̧u$_\mu$b	*!			*			*		*
b.LH | / z̧u$_\mu$b$_\mu$		*!			*	*	*		
c.☞ LH | | z̧u$_{\mu\mu}$b				*		*		*	*
d.LH | / z̧u$_{\mu\mu}$b				*	*!	*	*	*	*
e.LH | | z̧u$_\mu$b$_\mu$		*!	*!			*		*	*

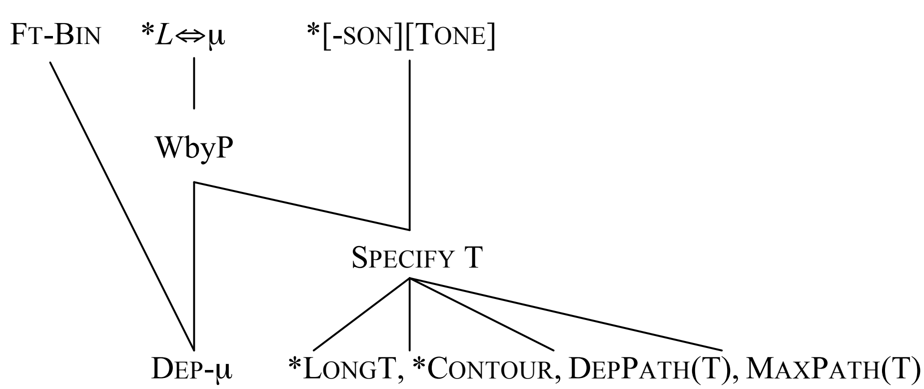
The analysis of roots with lenis obstruents and sonorants in coda is almost identical. The only difference is that a hypothetical candidate with a moraic lenis sonorant would not violate *[-SON][T], as candidate c. does in this tableau. Nonetheless, the constraint *Lenis-μ eliminates candidates with moraic lenis consonants, both obstruents and sonorants.

(37) Fortis sonorants coda – contour tone (/damˑ/ ˩˥ ‘owl’)

LH | / /da$_{\mu}$mˑ/	FT-BIN	*Lenis -μ	*[-SON] [T]	WBYP	SPEC T	DEP -μ	*CONTOUR	DEP PATH(T)	MAX PATH(T)
a. L H | / da$_{\mu}$m	*!			*			*		*
b. LH | / da$_{\mu}$m$_{\mu}$					*!	*	*		
c. LH | | da$_{\mu\mu}$m				*!		*		*	*
d. ☞ L H | | da$_{\mu}$m$_{\mu}$						*		*	*

To conclude this section, the following diagram shows the final ranking and dominance relationship among the employed constraints.

(38) Constraint dominance (TBU)



5.4 Conclusions

Relating the metrical structure analysis of Chapter 3 and the tone findings from Chapter 4, this chapter has established the association between moraicity and the tonal patterns in Quiaviní Zapotec. Assuming the mora as the tone-bearing unit (Hyman, 1985; Pulleyblank, 1994), I showed that only vowels and fortis coda sonorants bear tone in this language. This follows from the phonological analysis of fortis consonants as moraic in coda position (Chapter 3), and the typological tendency for avoiding tone on obstruents (i.e. *[-SON][TONE]), even when moraic (fortis).

These segmental restrictions lead to contour tones being associated with only one or two moras depending on the type of rhyme (cf. the typology of contour tones and the statement 'One tone per mora' (Zhang, 2001, p. 2)). The proposal was supported by acoustic data and encoded formally into an OT grammar.

In this chapter, I analyzed tone at the (monosyllabic) root level only. Polysyllabic forms, including prefixes, suffixes and clitics, raise interesting issues that need to be considered in further work. Preliminaries in this respect are presented in the concluding chapter of this dissertation.

Chapter 6:

Non-modal phonation in Quiaviní Zapotec

6.1 Introduction

Quiaviní Zapotec has a cross-linguistically uncommon four-way phonation contrast between modal /a/, breathy /a̤/, creaky /a̰/ and interrupted /aˀ/ vowels (Munro and Lopez 1999). Of particular interest is the distinction between creaky and interrupted voice, a phonetic distinction that is rarely used contrastively cross-linguistically (Ladefoged & Maddieson, 1996). I provide new phonetic and phonological evidence that supports these contrasts, and propose a novel analysis of the tone-phonation interaction in this language. Departing from Munro and Lopez (1999), Chapter 3 demonstrated that tone is used contrastively in Quiaviní Zapotec, showing that modal vowels —the default phonation type— may be associated with all four tones in this language (high, low, rising and falling). Within non-modal vowels, I propose in this chapter that breathy vowels are restricted to syllables with low and falling tones, whereas creaky and interrupted vowels appear with high, low and falling tones. That creaky and interrupted vowels can bear the same tones means that the distinction between them cannot be derived phonologically from tonal differences. The goal of this chapter is to present descriptive generalizations governing tone and non-modal phonation in Quiaviní Zapotec; theoretical consequences, such as the featural specification and phonological representation of these vowels, are addressed in Chapter 7.

I begin with a general overview of phonation types in the world's languages, focusing on typological diversity. I then dedicate a separate section to each non-modal phonation type in Quiaviní Zapotec: breathy, creaky and interrupted vowels. Issues in these analyses include the interaction between phonology and phonetics: how contrastive tone and phonation are manifested phonetically. These sections all follow the same structure. First, I provide a description of these vowels based on the tones they interact with, along with minimal pairs. Second, I present the original analysis of these vowels in Munro and Lopez (1999). Third, I compare and justify the differences between the two approaches. For the creaky and interrupted vowels sections, this comparison is accompanied by an acoustic evaluation to quantitatively validate the proposed classification. Once the properties of these types of vowels are determined, I present a further comparison of the laryngeal vowels, confirming the phonological contrast between creaky and interrupted vowels. This study finishes with a typological discussion of these findings.

6.2 Brief typology of phonation types

This section presents a cross-linguistic overview of how different languages exploit voice quality contrasts. The goal is to contextualize the typological relevance of Quiaviní Zapotec phonation types, as well as to present some preliminaries to the phonetic and phonological description of subsequent sections.

Ladefoged (1971) suggested that there might be a continuum of phonation types —the manners in which the vocal folds may vibrate— defined in terms of the aperture between the arytenoid cartilages, ranging from voiceless (furthest apart), through breathy voiced, to regular modal voicing, and then on through creaky voice to glottal closure (closest together).

	Most open	⟵		⟶	Most closed
Phonation type	Voiceless	Breathy	Modal	Creaky	Glottal closure

Figure 35. Continuum of phonation types (Ladefoged 1971)

Languages exploit different points on the continuum to manifest linguistic oppositions. The contrastive use of phonation types in vowels include two-, three- and (rarely) four-way contrasts. Two-way contrasts systems are relatively common. For instance, Hmong (Huffman, 1987) and Gujarati (Fisher-Jorgensen, 1967) make a contrast between breathy and modal voice, whereas Totonac (Alarcón, 2008) and Mundurukú (Picanço, 2005) are examples of the contrastive use of creaky and modal voice.

The three-way phonemic contrast of modal, breathy and creaky vowels has been reported for Chong (Thongkum, 1991; cf. DiCanio, 2009), Xochistlahuaca Amuzgo (Herrera, 2009) and, within the Otomanguean stock, in Jalapa Mazatec (Kirk et al., 1993), Santa Cruz Tepetotutla Chinantec (Herrera, 2009), and Santa Ana del Valle Zapotec (Esposito, 2003; Rojas, 2010), among others. (For more examples of two- and three-way phonation type contrast see the appendix of Gordon & Ladefoged, 2001.)

All of the above phonation types refer to Ladefoged's continuum, which relies on the manner in which the vocal folds vibrate. Edmonson and Esling (2006) propose the use of supra-glottal mechanisms in the expression of phonation types, which allows adding faucalized ("hollow"), harsh ("pressed") and strident ("harsh trilled") voices to the diversity of phonation types. As such, another three-way-contrast example includes Bai (Edmondson & Esling, 2006), with modal, breathy, and harsh voice.

Apart from Quiavíní Zapotec (Munro & Lopez, 1999), there exist two more cases of a four-way contrast with respect to voice qualities: in !Xóõ, Traill (1985) describes the contrastive use of modal, breathy (murmur), creaky and strident phonation types; in Dinka, Edmondson and Esling (2006) report modal, breathy, harsh and faucal voices.

The contrast between creaky /a̰/ and interrupted /aˀ/ vowels has been reported only for Zapotec languages. This contrast, which implies two degrees or variants of laryngealized vowels, was first reported in Quiavíní Zapotec (Munro & Lopez, 1999), and subsequently for Chichicapan Zapotec (Smith-Stark, 2003) and Güilá Zapotec (Arellanes 2008).

Specifically with respect to Quiaviní Zapotec, Munro and Lopez (1999) report modal, breathy, creaky and checked (interrupted) vowels. There are, however, important differences with respect to this study. Chapter 4 shows that the four Quiaviní Zapotec tones (high, low, falling and rising) may be expressed with modal voice. Taking this contrastive feature into account in the language, a revision of the vowel patterns within non-modal phonation is presented here. Moreover, Munro and Lopez (1999) argue for vowel patterns that phonologically combine different voice qualities in the same syllable nucleus. In this study, some of those combinations are claimed to be phonetic implementations of a single phonological specification for phonation. A detailed analysis and comparison is provided throughout this chapter.

Previous work on Quiaviní Zapotec phonation types also includes Gordon and Ladefoged (2001) and Ladefoged (2003), who describe the acoustic characteristics of modal, breathy and creaky phonation in this language. In those descriptions, the tone-phonation interaction is not analyzed, nor is the fourth phonation type that is described by Munro and Lopez (1999; checked vowels, called interrupted here, §6.5), nor is the possibility that tense voice is a possible variation of creaky vowels (§6.4.2).

Gender differences and rate of speech may affect the realization of phonation types. Munro, Lillehaugen and Lopez (2008) report that phonation may vary from speaker to speaker: “when men pronounce creaky vowels they sound more creaky than when women pronounce them” (p. 35); and “the amount of breathiness you hear in a vowel may vary from community to community or even from speaker to speaker. Vowels that are shown as breathy in the pronunciation guide [dictionary’s orthography] will sound a lot breathier in Tlacolula or San Lucas than in San Juan Guelavía or Santa Ana del Valle, for example. You may also notice that when women pronounce breathy vowels they sound more breathy than when men pronounce them” (p. 31). Gordon and Ladefoged (2002, p. 10) also reported noticeably creakier vowels for men and breathier vowels for women in Quiaviní Zapotec, and pointed out that gender dependent differences of this sort, particularly increased breathiness for female speakers, have also been observed in languages with allophonic rather than contrastive non-modal phonation, including English (e.g. Henton & Bladon, 1985, Klatt & Klatt, 1990, Hanson and Chuang 1999).

For Mundurukú (Tupí, Brazil), Picanço (2003, p. 37) reports that "the degree of constriction varies according to the rate of speech; in a sentence, speakers tend to produce creaky vowels with less constriction, but if the same words are pronounced in isolation, the vowels may be heavily creaky". Similar findings have been reported for Otomanguean languages, including, for example, Esposito (2003) for Santa Ana del Valle Zapotec. Throughout my personal fieldwork and phonetic analysis, these characteristics have been noticeable in Quiaviní Zapotec. I will briefly refer to these issues in the following sections; however, as mentioned elsewhere, Quiaviní Zapotec intonational patterns at sentence level are beyond the scope of this dissertation. These observations show that non-modal phonation is relative rather than absolute, similar to the linguistic analysis of tone.

In light of the cross-linguistic phonetic and phonological properties of phonation types presented here, the goal of the following sections is to characterize Quiaviní Zapotec voice qualities and understand their phonetic realization in the production of different tones.

6.3 Breathy vowels

6.3.1 Introduction

This section presents a phonetic and phonological description of breathy vowels in this language, with the goal of providing a descriptive generalization of this voice quality in Quiaviní Zapotec. Breathy voice is a phonation in which the vocal cords vibrate, as they do in normal (modal) voicing, but are held further apart, so that a larger volume of air escapes between them (see Laver 1980, Ladefoged 1971, Gordon and Ladefoged, 2002 among others). A slightly less open stage of the vocal folds is attained with slack voice, where the vocal folds vibrate more loosely than in modal voice, also with a slightly higher rate of airflow than in modal voice (Maddieson and Ladefoged

1996: 48). Breathy and slack voices may freely vary with each other allophonically. I show that breathy vowels in Quiaviní Zapotec may be associated with low and falling tones, as presented in Table 61. (The analytic and theoretical implications are discussed in the next Chapter.)

Table 61. Breathy vowels and tone interaction

	High	Low	Falling	Rising
Breathy	X	√	√	X

The following examples illustrate the contrast between breathy-L (low tone) and breathy-F (falling tone).

(1) Breathy -L
/ be̤ / ˩ → [bè̤ː ~ βe͡è̤ː] ‘mold (growth)’

(2) Breathy-F
/ beṳ / ˥˩ → [béṳ̀ ~ βéṳ̀] ‘turtle’

As the narrow phonetic transcription shows, the realization of these items normally includes a modal vowel portion followed by breathiness. As explained below, length patterns are the same for breathy-L and breathy-F lexical items. I now turn to the description of each of the breathy vowels.

6.3.2 Breathy-L

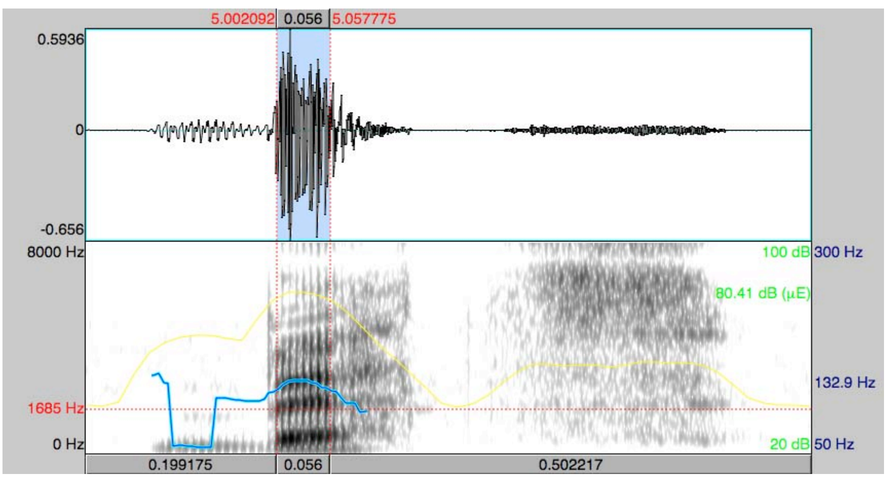
An interaction between low tone and breathiness is extremely common cross-linguistically (see Gordon and Ladefoged 2002 and references therein), and is found in Quiaviní Zapotec. Examples below include fortis and lenis coda consonants. As demonstrated in Chapter 2 and 3 with modal vowels, the coda type determines the duration of the vowel. Phonetically, fortis consonants are preceded by short vowels, whereas vowels are long before lenis consonants or in open syllables.

(3) Breathy-L examples: fortis coda consonant

a. / ta̤p / ˩ → [tà̤pː] 'four'
b. / gje̤t / ˩ → [gjè̤tː] 'squash'
c. / nˑa̤ʃ / ˩ → [nà̤ʃː] 'chocolate'
d. / na̤s / ˩ → [nà̤sː] 'the day before yesterday'

(4) Breathy-L examples: lenis coda consonant or open syllable

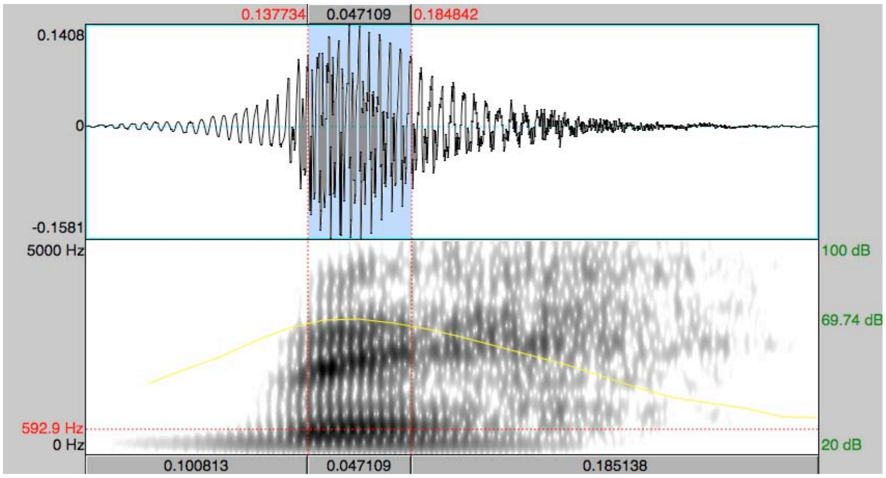
a. / ge̤i̤ʒ / ˩ → [gè̤i̤ʒ] 'town'
b. / na̤ / ˩ → [nà̤ː] 'now'[84]
c. / jṳ / ˩ → [jṳ̀ː] 'soil'



[b è e̤ e̥ t s]

Figure 36. Waveform and spectrogram of / be̤ts / ˩ → [bè̤tsː ~ βè͡e̤tsː] '(man's) brother' by male speaker TiuN.

[84] Also / na̤ / ˩ 'hard' (*nahah* 'hard' vs. *nah* 'now' in Munro & Lopez, 1999).



[β è e̤ e̥]

Figure 37. Waveform and spectrogram of / be̤ / ˩ → [bè̤ː ~ βe͡e̤ː] ‘mold (growth)’ by female speaker LiaL.

The above examples illustrate the modal-breathy-voiceless phonetic sequence as a common realization of breathy vowels. This is especially clear in the long vowel of /be̤ / ˩ ‘mold (growth)’, where the high amplitude and the periodicity of the waveform decreases as the vowels progresses and fades away. Pitch values during the modal portion are equivalent to those of modal-L items for these speakers. Cross-linguistically, non-modal vowels are commonly accompanied by modal phonation, especially at the beginning of the vowel. This is the case in both tonal and non-tonal languages (Gordon and Ladefoged 2002); however, for tonal languages this laryngeal timing is particularly important as it is during modal phonation that tone is realized, because tone is realized during modal phonation (see Silverman, 1997). As implied by examples in (3) and (4), when underlyingly breathy vowels encode breathiness and tone, modal voice is used to implement phonetically the realization of tone (see also breathy vowels with falling tone below).

In order to confirm the contrastive character of breathy vowels in Quiaviní Zapotec, the following minimal (contrast) sets consist of triplets made of modal-H, modal-L and breathy-L items.

(5) a. / ʒi / ˥ → [ʒíː] ‘tomorrow’
b. / ʒi / ˩ → [ʒìː] ‘quite’

c. / ʒi̤ / ˩ → [ʒì̤ː] ‘day’

(6) a. / gjia / ˩ → [gʲíˑá] ‘will go home’
b. / gjia / ˩ → [gʲìˑà] ‘agave root’
c. / gji̤a̤ / ˩ → [gʲì̤ˑà̤] ‘rock’

(7) a. / nʒibj / ˥ → [nʒíːbʲ] ‘scared’
b. ---
c. / nʒi̤bj/ ˩ → [nʒì̤bʲ] ‘knee’

(8) a. ---
b. / ze / ˩ → [zèː] ‘was going’
c. / ze̤ / ˩ → [zè̤ː] ‘will go’ (*zeheh* def. of rihah ‘goes’)

(9) a. / belˑ / ˥ → [bélː] ‘Abel’
b. ---
c. / be̤lˑ / ˩ → [bè̤lː] ‘fish’

(10) a. ---
b. / na / ˩ → [nàː] ‘is (copula)’
c. / na̤ / ˩ → [nà̤ː] ‘now, hard’

6.3.3 Breathy-F

The following examples illustrate breathy vowels with falling tone.

(11) Breathy-F: fortis coda consonant

a. / nje̤s / ˥˩ → [njé͡è̤sː] ‘water’[85]
b. / ba̤lˑj / ˥˩ → [bá͡à̤l̤ːʲ] ‘fire’

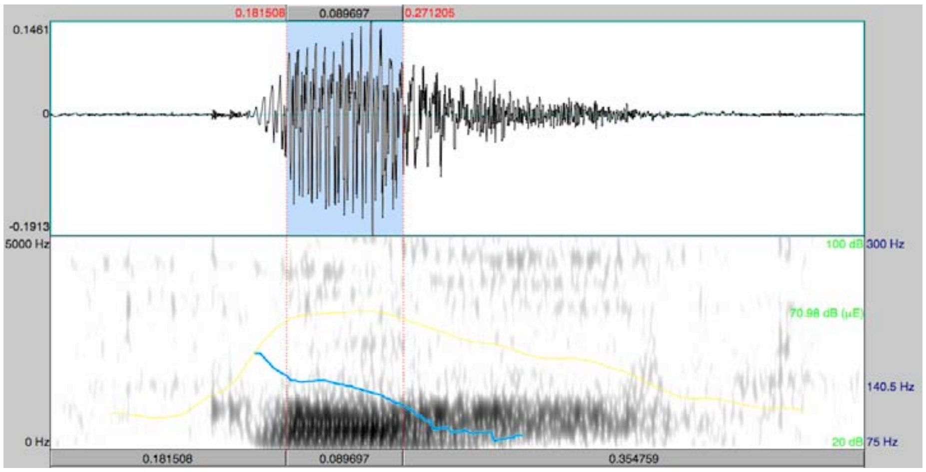
(12) Breathy-F: lenis coda consonant

a. / na̤ʒj / ˥˩ → [ná͡à̤ːʃʲ] [86] ‘wet’

---

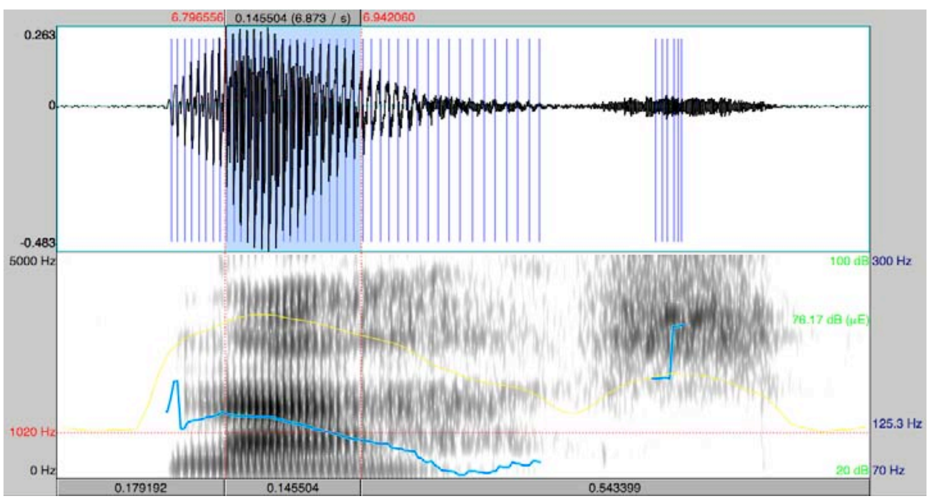
[85] One variant of this item contains a diphthong: / nie̤s / ˥˩ → [ní͡è̤s] ‘water’.
[86] Recall from Chapter 2 that lenis obstruents typically devoice word finally.

b. / ga̤l·gi̤ʒ / ˥˩ → [ga̤l·gî͡i̤ːʃ]   ‘sickness’
c. / bṳdj /   ˥˩ → [bû͡ṳːð̥ʲ]   ‘chicken’
d. / kṳb /   ˥˩ → [kû͡ṳːɸ]   ‘tejate (traditional beverage)’



[k û ṳ ɸ]

Figure 38. Waveform and spectrogram of / kṳb / ˥˩ ‘tejate’ by male speaker TiuR.



[n â a̤ː ʃ]

Figure 39. Waveform and spectrogram of / na̤ʒj / ˥˩ ‘wet’ by male speaker TiuL (Munro et al., 2008; Sound file: L3-3B)

As with breathy-L (low tone) examples, the modal-breathy voice quality sequence is also noticeable in breathy-F (falling tone) examples. During the modal portion of the vowel in Figures 38 and 39 we observe a quick rise (during the vowel in / kṳb / ˥˩ and during the nasal in / n̤a̤ʒj / ˥˩) and a slow fall, becoming breathy towards the end. The preliminary rise can be analyzed as a phonetic preparation to reach a high pitch level so that the falling tone can be adequately perceived. In Figure 39, for instance, pitch reaches 130 Hz (equivalent to modal-H for this speaker) and falls below 100 Hz during the breathy portion.

The minimal pair in (13) contrasts modal-F vs. breathy-F, whereas (14) illustrates the distinction between breathy-L vs. breathy-F.

Modal-F vs. Breathy-F:

(13) a. / beu / ˥˩ → [béù] 'moon'
b. / beṳ / ˥˩ → [béṳ̀] 'turtle'

Breathy-L vs. Breathy- F:

(14) a. / nˑa̤ʃ / ˩ → [nà̤ʃː] 'chocolate'
b. / n̤a̤ʒj / ˥˩ → [nâ͡à̤ːʃʲ] 'wet'

6.3.4 Munro and Lopez (1999): Breathy vowels

The previous sections show my analysis of breathy vowels in Quiaviní Zapotec, where I propose that they can be associated with low and falling tones. The purpose of this subsection is to compare this account with the previous analysis of Munro and Lopez (1999), who propose a larger inventory of vowel patterns with breathy voice in Quiaviní Zapotec. These vowel patterns are included within the following table.

Table 62. Munro and Lopez (1999) patterns for what I analyzed here as breathy vowels.[87]

	High	Low	Falling	Rising
Breathy	X	*ah* *ahah*	*a'ah*+C [88] *a'ahah*	X

[87] As mentioned before, in the Munro and Lopez (1999) orthography *a* = modal vowel, *ah* = breathy, *à* = creaky vowel and *a'* = checked vowel.

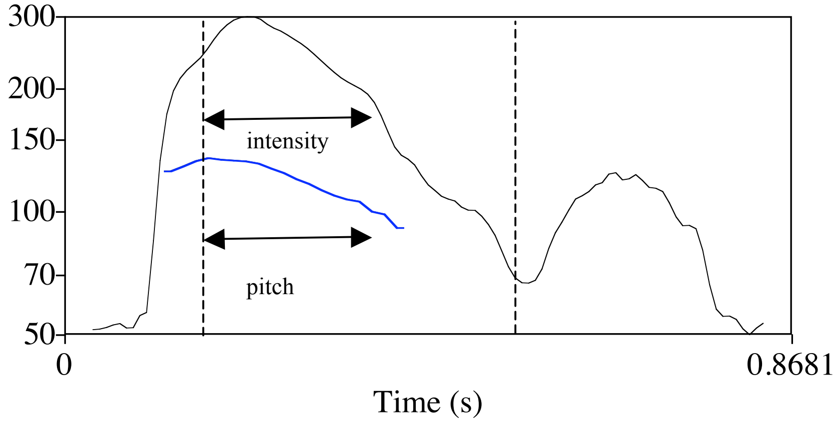
[88] Consider this kind of variation in a dictionary entry, with possible different vowel patterns within this cell (breathy-F): *wbwi'ihzh, wbi'ihzh, wwi'ihihzh, wbwihzh* 'sun'.

aa'ah+C

The Munro and Lopez (1999) vowel patterns *ah* and *ahah* are both included within the category breathy-L in my account, and both analyses agree in describing these pattern as having low tone. These durational differences certainly exist between short and long breathy vowels. Regardless of what is the best orthographic representation, the difference is predictable by coda type (short *ah* before fortis consonant, and long *ahah* before lenis consonant), and not phonologically contrastive.

Similar durational differences seem to be encoded with the vowel patterns *a'ah*+C, *a'ahah* and *aa'ah*+C, for which Munro & Lopez (1999) report falling tone, as presented here. In addition, we have the presence of checked vowels (*a'*), and my indication of coda consonant (+C). The latter indication refers to the fact that my reanalysis of words with the patterns *a'ah* and *aa'ah* is split between those with coda consonants, classified here as breathy vowels with falling tone, and those in open syllable, classified as interrupted vowels (§6.7).

In my analysis, lexical items with the patterns *a'ah* and *aa'ah* with coda (breathy-F) indicated no laryngealization. Certainly, there is always a modal beginning where the falling tone is manifested, but the falling tone passes from modal into breathy, as shown above with Figures 38 and 39. To further illustrate this, Figure 40 shows only the pitch contour (Hz) and amplitude envelope (dB) of the example in Figure 39, / na̤ʒj / ˥˩ 'wet'. We observe that neither pitch nor intensity is interrupted during the vowel duration (demarcated by the dashed lines), as expected with a checked vowel (compared with the vowel pattern *a'ah* in open syllable in section §6.5 below). Instead, these acoustic correlates show a quick rising and slow falling pitch contour, passing from modal voice to breathy. As mentioned above, this phonation type sequence, rather than being phonologically specified, results from the phonetic manifestation of breathy-F items. Since breathy voice is unable to express high frequency pitch, the necessary high pitch at the beginning of a falling tone is implemented via modal voice, and then the second portion of the vowel expresses breathiness. The inclusion of a checked vowel for these patterns in Munro and Lopez (1999) could have been an orthographic convention to indicate the described tone contour.



[n â a̤ː ʃ]

Figure 40. Pitch and intensity contours of / na̤ʒj / ˥˩ ‘wet’ by male speaker TiuL

Other vowel patterns in Munro and Lopez (1999) with breathy voice include *aha’, àah, ahaha*, presumably breathy-L, and *a’aah, a’aha, aahah, iiah, aah, aaha’*, presumably breathy-F. However, these vowel patterns were not considered in Munro, Lillehaugen and Lopez (2008); so the authors themselves simplified the original account of Munro and Lopez (1999).

6.3.5 Interim summary: Breathy vowels

Breathy voice is cross-linguistically associated with lowered tone in languages with this voice quality (Hombert et al., 1979). As shown above, this is also the case in Quiaviní Zapotec, where breathy vowels are restricted to low and falling tones, as shown in Table 63. This distribution is discussed and accounted for formally in Chapter 7.

Table 63. Tone and phonation: modal and breathy vowels

	High	Low	Falling	Rising
Modal	√	√	√	√
Breathy	X	√	√	X

Breathy voice is found in different Otomanguean languages, but this contrast is not as widespread as laryngealized voice. A possible analysis would be to consider breathiness as an enhancement of low and falling tones (along the lines of *Enhancement Theory*, e.g. Stevens and Keyser 1989) in that breathiness has developed historically as a mechanism for more easily controlling low tone (by itself, or after a high tone, so pitch falls). However, for the current synchronic state of Quiaviní Zapotec, it seems unlikely that this is the source of breathy voice in the language, because low and falling tones are also used contrastively with modal voice, as illustrated above with several minimal pairs (modal-H, L and F vs. breathy-L and F).

6.4 Creaky vowels

6.4.1 Introduction

Creaky voice, also called laryngealized voice or vocal fry,[89] is produced with the vocal folds vibrating anteriorly, but with the arytenoid cartilages pressed together; this induces a considerably lower rate of airflow than in modal voice (see e.g. Laver, 1980; Ladefoged, 1971; Gordon & Ladefoged, 2001).

In Quiaviní Zapotec creaky vowels may be associated with both high and low level tones, as well as the falling contour tone. This is shown in the following table and illustrated with examples (15-17).

Table 64. Creaky vowels and tone interaction

	High	Low	Falling	Rising
Creaky	√	√	√	X

[89] The term *laryngealized* voice is used here as a cover term to refer to both creaky and interrupted vowels.

(15) Creaky H
/ bḛlˑ / ˥ → [bḛ́lː][90] '(woman's) sister' (*bèe'll*)

(16) Creaky L
/ bḛlˑ/ ˩ → [bèḛlː] 'snake' (*bèèe'll*)

(17) Creaky F
/ bḛl / ˥˩ → [bêḛ̂ːl] 'meat' (*beèe'l*)

The purpose of this section is to describe in detail the phonetic and phonological properties of creaky vowels, providing a full account of the expression of creaky voice in Quiaviní Zapotec. The Munro and Lopez (1999) analysis (whose orthography is included in parentheses within the above examples) is presented below in §6.6.5.

6.4.2 Creaky-H

The first cases I analyze are creaky vowels with high tone. This interaction is uncommon, as creaky voice is cross-linguistically associated with lowering of the fundamental frequency. As we will see below, the actual realization of creaky vowels with high tone is a weak laryngealization, in the form of tense (stiff) voice, which is presented in Ladefoged and Maddieson (1996, p. 48) as an intermediate step between modal and creaky voice, where the vocal folds vibrate more stiffly and with a slightly lower rate of airflow than in modal voice.[91] Tense voice, in contrast to prototypical creaky voice, is compatible with the manipulation of pitch.

As discussed extensively in Chapters 2 and 3, fortis coda consonants are preceded by short vowels, and lenis consonants by long vowels. Both types of syllables are found with creaky vowels as well.

[90] As illustrated here, creaky-H vowels are produced with tense voice, [e̬] (symbol from Ladefoged and Maddieson, 1996, p. 100).
[91] This voice is not to be confused with harsh voice, sometimes also called "pressed" voice, which is produced with a different mechanism, with the upper larynx becoming highly constricted with the ventricular folds (see Edmonson and Esling 2006 for more details).

(18) Creaky-H examples: fortis coda consonant

a. / bḛlˑ / ˥ → [be̬lː] ‘(woman’s) sister’
b. / ɾɡḭlˑj/ ˥ → [ɾɡil̬ːj] ‘looks for’
c. / zḭlˑj/ ˥ → [zi̬lːj] ‘a lot of’

(19) Creaky-H examples: lenis coda consonant

a. / bḛl / ˥ → [bé͡é̬ːl̬] ‘naked’
b. / ɾɡḭbj / ˥ → [ɾɡí͡í̬ːɸʲ] ‘washes’

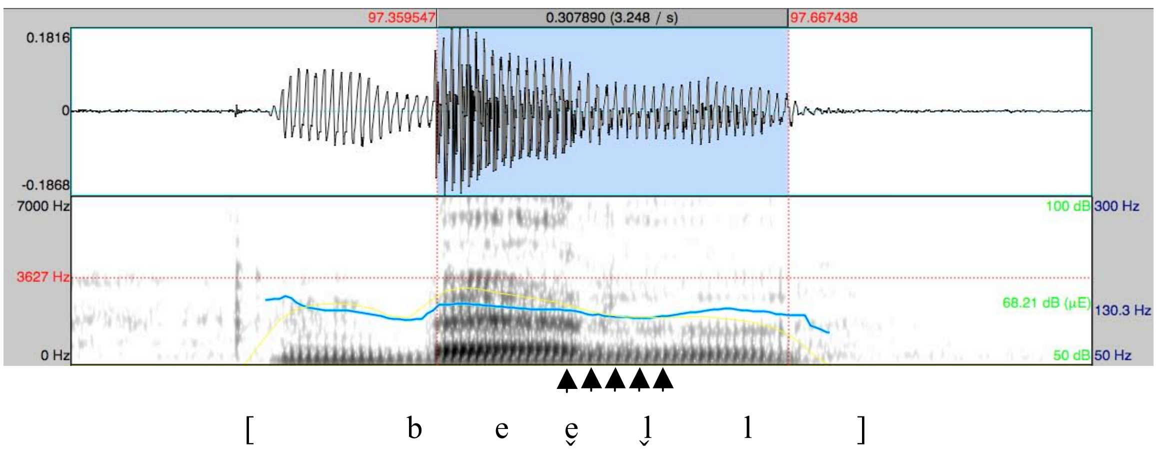


Figure 41. VCfortis example: Waveform and spectrogram of / bḛlˑ / ˥ ‘(woman’s) sister’, by male speaker TiuL (arrows indicate the tense voice portion).

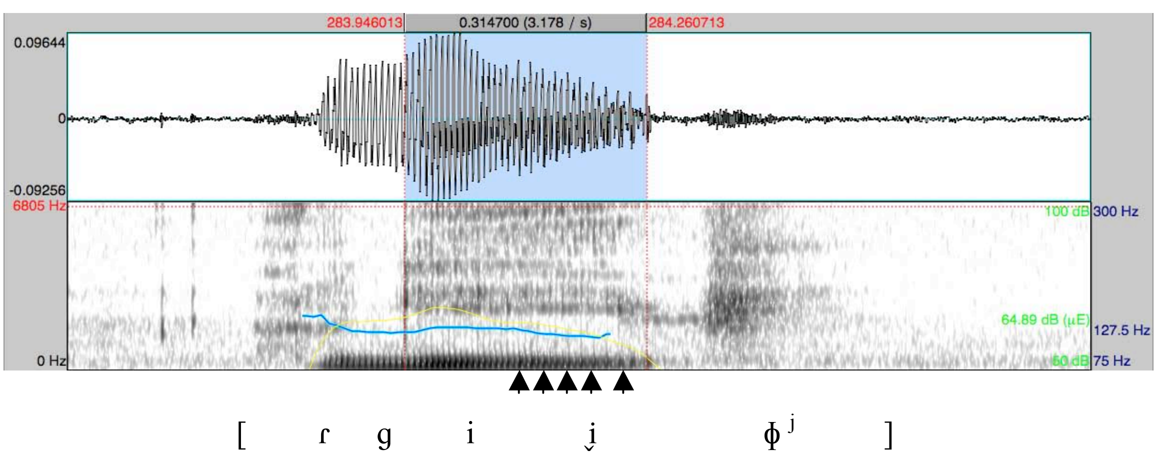


Figure 42. VClenis example: Waveform and spectrogram of / ɾɡḭbj / ˥ ‘washes’, by male speaker TiuL (arrows indicate the tense voice portion).

In terms of phonation, we observe in Figures 41 and 42 that the first part (or beginning) of the vowel is modal, whereas the second portion of it shows tense voice, mainly characterized here by the lower amplitude envelope.[92] In the case of / bḛlˑ / ˥ '(woman's) sister', the stiff or tense voice is observed at the end of the vowel and beginning of the fortis liquid. In addition, /ɾgḭbj/ ˥ 'washes' (Figure 42) shows aperiodicity of the signal (i.e. some creakiness) at the end of the vowel.

Due to the possible co-articulation of tense voice and high tone, there might be instances without modal voice in the realization of short vowels. The degree of laryngealized voice varies by speaker.

With respect to tone, we observe a relatively flat pitch all the way through the vowel (and the fortis /lˑ/ in Figure 41), in both the modal and tense portions. It never drops so much that it can no longer be tracked automatically by pitch extraction, which commonly happens with true creaky vowels that have low and falling tones (see below).

6.4.3 Creaky-L

As mentioned above, creaky voice is commonly associated with lowering of the fundamental frequency; thus, we would expect to find creaky-L items in Quiaviní Zapotec. Consider the following examples.

(20) Creaky-L examples: fortis coda consonant

a) / bḛlˑ/ ˩ → [bè͡ḛl̰ː] 'snake'
b) / bḛkw /˩ → [bḛ̀ˀkːʷ] 'dog'

(21) Creaky-L examples: lenis coda consonant or open syllable

a) / ɾgḭlj/ ˩ → [ɾgì͡ḭːlʲ] 'waters'
b) / sḭlj / ˩ → [sì͡ḭːlʲ] 'breakfast'

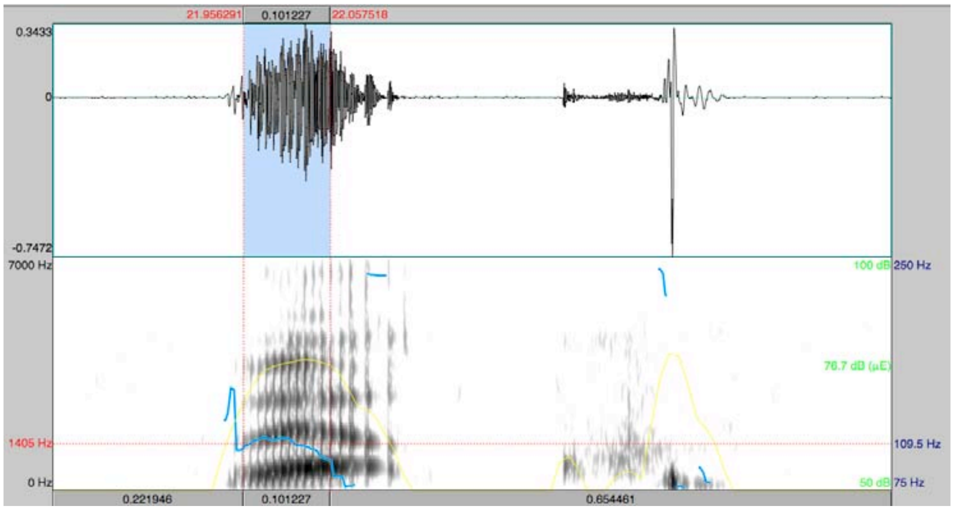
[92] As noticed in Chapter 4, this striking change in the amplitude envelope is not observed in modal vowels with low, rising or falling tones, previously analyzed as items with weak laryngealization (Munro & Lopez, 1999).

c) / ɾgḭdj / ˩ → [ɾgì͡ḭ̀ːdʲ] ‘sticks on’

d) / bdo̰ / ˩ → [bdò͡ò̰ː̰] ‘baby’

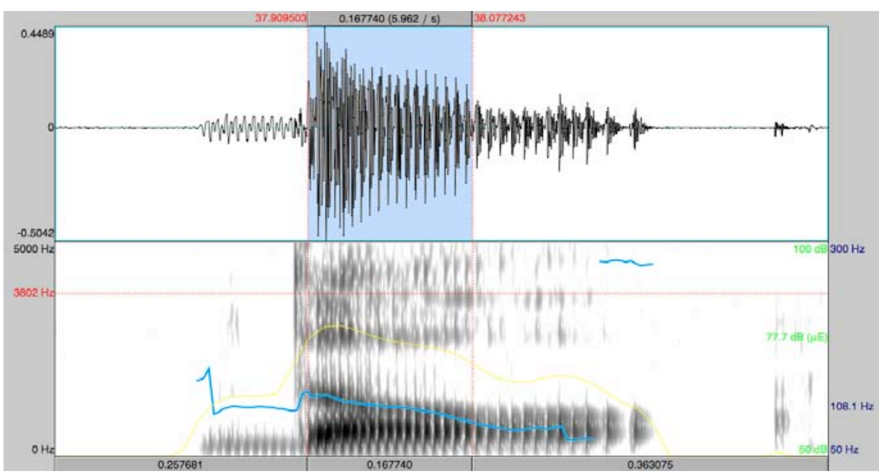
e) / ɾka̰z / ˩ → [ɾkà͡à̰ːz] ‘wants’

d) / jdo̰ / ˩ → [jdò͡ò̰ː] ‘church’



[b è ḛ ˀk w̥]

Figure 43. Waveform and spectrogram of / bḛkw / ˩ ‘dog’, by male speaker TiuL (Munro et al., 2008, sound file L3-3C).



[b d ò ò̰ o̰ ʔ]

Figure 44. Waveform and spectrogram of / bdo̰ / ˩ ‘baby’, by male speaker TiuL (Munro et al., 2008, sound file L3-3C).

Figures 43 and 44 exemplify the fact that Creaky-L items normally start with modal phonation, to continue into a creaky voice portion. Due to the degree of variation, it is possible to find some tokens with short vowels with creaky voice only; since creaky voice inherently has low pitch, tone and non-modal voice may phonetically co-occur for these items.

A crucial point here in determining the tone of these items is that pitch values during the first portion of the vowel are similar to modal-L values. Concomitantly, the amplitude envelope goes along with pitch: it is sustained (higher) during the less laryngealized vowel portion, and then it drops as the vowels show more laryngeal constriction.

Figure 43 illustrates a rhyme formed by a short vowel with fortis coda consonant. The highlighted part corresponds to the less laryngealized portion of the vowel (close to modal). The pitch averages 110 Hz (range 100-114 Hz). Although the pitch is not quite flat, the numbers are in the range of modal-L tokens of this speaker (whose pitch also tends to drop towards the end).

Figure 44 illustrates a long vowel in an open syllable. The mean pitch of the first portion (highlighted) is 107 Hz (range 115-98 Hz). Phonetically, these long vowel tokens may seem to have falling pitch. However, two points suggest that these tokens are creaky-L. First, creaky-F items normally have a phonetic rise in pitch at the beginning of the vowel, but no rise is found in creaky-L items. Second, and more important, the values of the first portion of creaky-L items are lower that those found in the first portion of creaky-F vowels, and within the modal-L range.

6.4.4 Creaky-F

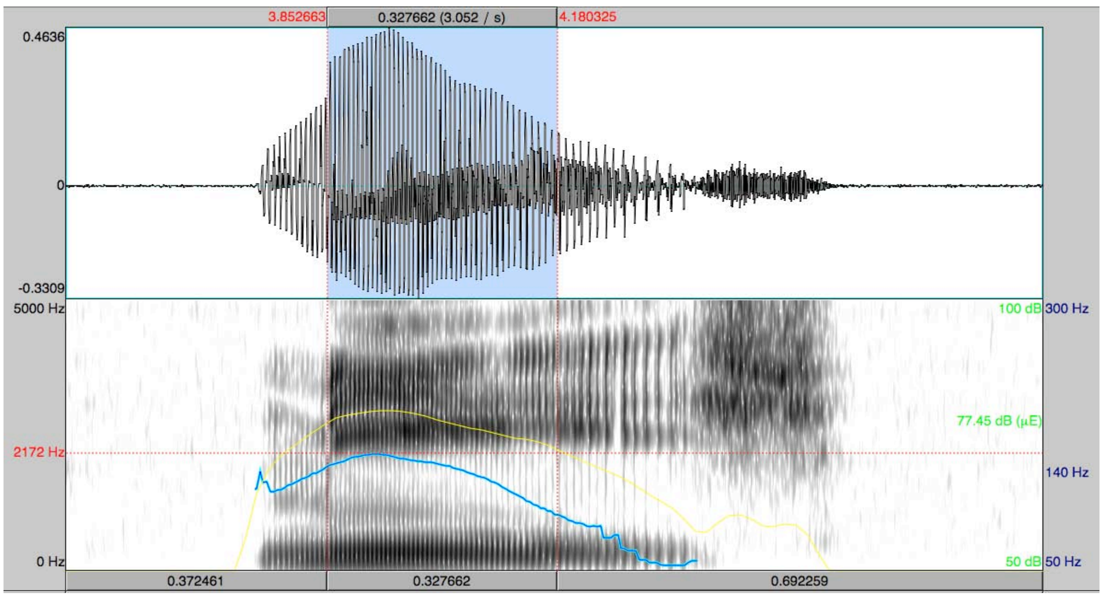
Creaky vowels also occur with falling tone, as illustrated below.

(22) Creaky-F examples: fortis coda consonant

a) / n-ga̰ts / ˥˩ → [ŋgá͡à̰tsː] ‘yellow’
b) / n-gasja̰ts / ˥˩ → [ŋgasjá͡à̰tsː] ‘really black’

(23) Creaky-F examples: lenis coda consonant or open syllable

a) / mḭʒ / ˥˩ → [mí͡ḭ̀ːʒ] ‘Mixe’
b) / ja̰ / ˥˩ → [já͡à̰ː] ‘up’
c) / nda̰ / ˥˩ → [ndá͡à̰ː] ‘hot’
d) / ʒ ḭʒ / ˥˩ → [ʒí͡ḭ̀ːʒ] ‘pineapple’
e) / beṵ / ˥˩ → [béṵ̀] ‘coyote’



[m íː ḭ̀ ʒ]

Figure 45. Waveform and spectrogram of / mḭʒ / ˥˩ ‘Mixe’, by male speaker TiuL (Munro et al., 2008, sound file L3-3D).

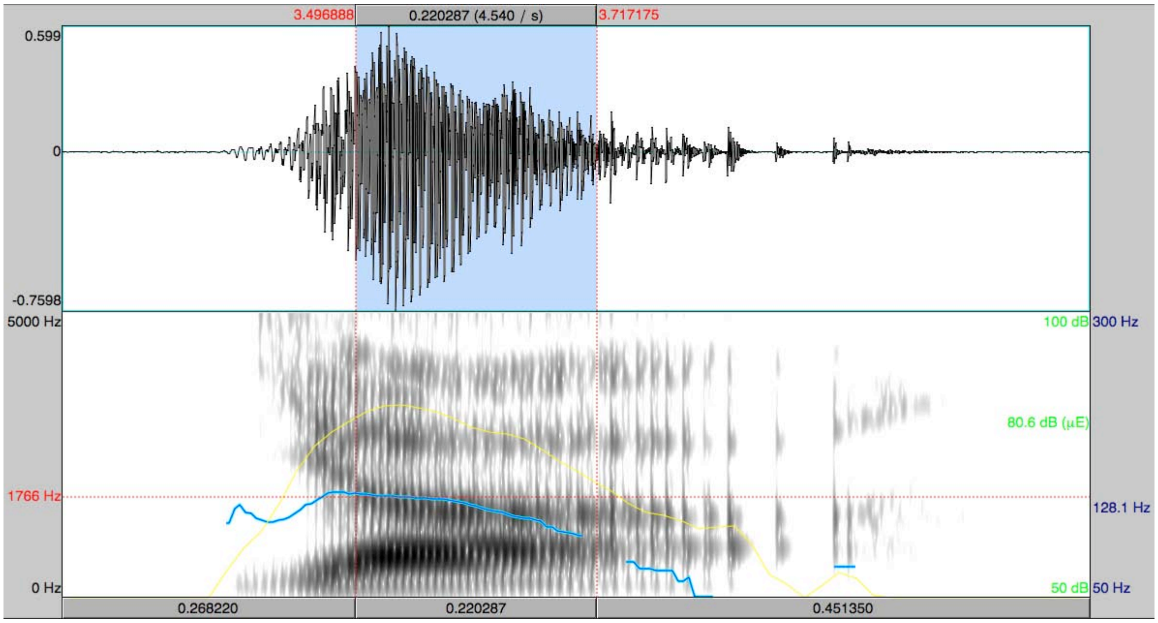


Figure 46. Waveform and spectrogram of / ja̰ / ˥˩ 'up', by male speaker TiuL (Munro et al., 2008, sound file L3-3D).[93]

In terms of phonation, the first part of the vowel in creaky-F tokens is always modal, whereas the second (or last) part is creaky. Both Figures 45 and 46 clearly illustrate this voice sequence.

With respect to tone, often there is a small rise at the beginning of the vowel, so that the pitch might be sufficiently high to attain a significant falling contour.[94] This initial rise is clear at the beginning of the vowel in Figure 45, which reaches a maximum pitch of 157 Hz (even higher than the high tone pitch average of this speaker). The pitch falls to 101 Hz during the modal portion, continuing to fall even lower during the final creaky vowel portion.

These high pitch values at the beginning are similar to those found in modal-H values and this is the crucial difference to distinguish creaky vowels with falling tone versus low tone. Let us consider in parallel an example of each.

---

[93] Minimum pitch: 105 Hz; Maximum pitch: 142 Hz.

[94] In Figures 44, we also observe a small rise at the beginning the creaky-L vowel (/ bdo̰ / ˩ 'baby'), but this seems to be related with the voicing of the consonant (Hombert et al., 1979). In contrast, the rise is clearer with /m/ in Figure 45 for / mḭʒ / ˥˩ 'Mixe', and cross-linguistically nasals don't lower F0.

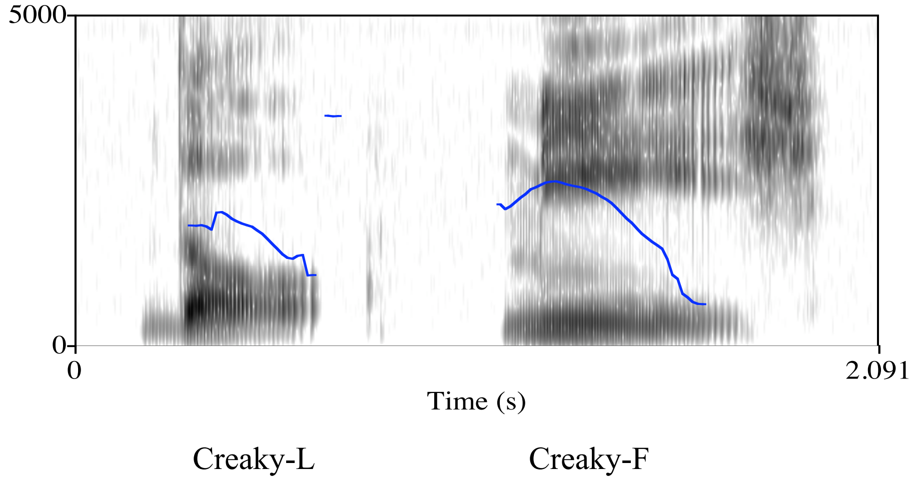


Figure 47. Spectrograms and pitch of / bdo̰ / ˩ ‘baby’ and / mḭʒ / ˥˩ ‘Mixe’, by male speaker TiuL.

There are important differences between creaky-L and creaky-F items, illustrated by Figure 47. For the former items there is never a clear pitch rise at the beginning, pitch is relatively flat during the less laryngealized portion, where I claim the phonological tone is expressed; then the pitch drops as the vowel gets creakier, to the point that it becomes difficult (or impossible) to track. On the other hand, creaky-F tokens normally show a rise at the beginning of the vowel and always have higher pitch values during the first modal vowel portion, showing a different pitch contour than that of creaky-L tokens.

Strictly speaking both types of creaky vowels phonetically have a falling pitch (creaky-F shows a high-falling contour, whereas creaky-L a low-falling one); however, in the case of creaky-L tokens most of the fall occurs during the laryngealized portion, where the phonological tone is no longer expressed. In contrast, the examples of creaky-F tokens show that the fall is noticeable during the modal portion.

Perceptually, this seems like a case where the listener may be abstracting away from effects that are predictable, as in the case of abstracting away from the effects of co-articulation. Perceivers know that creaky voice causes pitch lowering, so the lowering due strictly to such phonation does not cause the tone to be perceived as falling.

The phonetic pitch fall characteristic of creaky vowels with low tone has also been described for other languages. According to Picanço (2005), Mundurukú (a Tupí language spoken in the Amazonian basin of Brazil) has both contrastive tones and phonation types: modal voice allows high vs. low tone, whereas creaky vowels only allow low tone. Comparing modal vs. creaky vowels with low tone, the latter is characterized by "lowered fundamental frequency, glottal pulses with longer duration, and variation between adjacent glottal pulses"; on top of that, pitch may lower as the vowel gets creakier, in other words, "Creaky voice is […] manifested as a gradual fall in pitch." (Picanço, 2005, p. 38).

6.4.5 Munro and Lopez (1999): Creaky vowels

The previous sections show my analysis of creaky vowels in Quiaviní Zapotec, where I propose that these vowels can be associated with high, low and falling tone. The previous account of Munro and Lopez (1999) proposes only falling tone for different vowel patterns with creaky vowels, included in Table 65. In this section, I compare the two analyses, followed, in the next section, by an acoustic analysis that quantitatively establishes the phonetic characteristics of creaky vowels in Quiaviní Zapotec.

Table 65. Munro and Lopez (1999) patterns for what are analyzed here as creaky vowels.[95]

	High	Low	Falling	Rising
Creaky	*àa'* (some)[96]	*àà'*	*a'àa'* *aàa'*	X

In all these vowel patterns there is a creaky vowel followed by a checked one at the end (*àa'*). If my understanding of the Munro and Lopez (1999) orthography is correct,

[95] Other vowel patterns with creaky vowels described in Munro and Lopez (1999) include *àa'a*+C, *ààa'ah* and *aàa'ah*. The dictionary entries with the pattern *àa'a*+C that have a coda consonant other than /n/ (e.g. *rtàa'az* 'beats up' or a variation of *bèe'cw* / *bèe'ecw* 'dog', are reclassified here as creaky-L tokens; whereas the laryngealization of examples with /n/ in coda, as *gùu'an* 'bull' and *zhìi'iny* child', are considered here interrupted vowels (§6.5). The vowel patterns *ààa'ah* and *aàa'ah* are found in only a few lexical items, reanalyzed here as creaky-L and creaky-F, respectively. These vowel patterns were not included in the simplified analysis of Munro et al (2008).
[96] The pitch analysis of lexical items with the vowel pattern *àa'* suggests a split between tokens with high and low tone.

it corresponds phonologically to / a̰aˀ /, but probably corresponds phonetically to [a̰ˀ], as there is never modal voice between the creakiness and a glottal stop (when one is clearly present). I argue here that the presence of the glottal stop is phonetically predictable and thus not part of the underlying phonological representation.

The realization of creaky vowels is directly related to the segment that follows the vowel. If followed by fortis stops ([-continuant, -sonorant, +fortis]) or pause, creaky vowels normally end in a glottal closure (see examples in (25) and Figure 48); whereas if the following segment is a fricative, liquid, glide or a vowel (i.e. [+continuant] segments[97]) a glottal stop does not occur (examples in (26) and Figures 49 & 50). This may be represented with the (not absolute) phonetic rules in (24).

(24) a. creaky vowel → a̰ˀ / _ [-continuant, -sonorant, +fortis] or # [98]

b. creaky vowel → a̰ / (elsewhere)

(25) Creaky vowels followed by fortis oral stop or utterance-final

a. / la̰ts /	˩ → [là͡a̰ˀts]	(*làa'ts*)	‘flat area’
b. / baɾga̰ /	˩ → [baɾ.ˈgà͡a̰ːˀ]	(*bargàa’*)	‘grasshopper’
c. / bdo̰ /	˩ → [bdò͡o̰ːˀ]	(*bdòo’*)	‘baby’
d. / mna̰ /	˩ → [mnà͡a̰ːˀ][99]	(*mnnààa’*)	‘woman’

(26) Creaky vowels followed by [+continuant] segment

a. / dḭʒ /	˩ → [dì͡ḭːʒ̊]	(*dìi'zh*)	‘language’
b. / ɾka̰z /	˩ → [ɾkà͡a̰ːz]	(*r-càa'z*)	‘wants’
c. / gḛlˑ /	˩ → [gè͡ḛlː]	(*guèe'll*)	‘midnight’

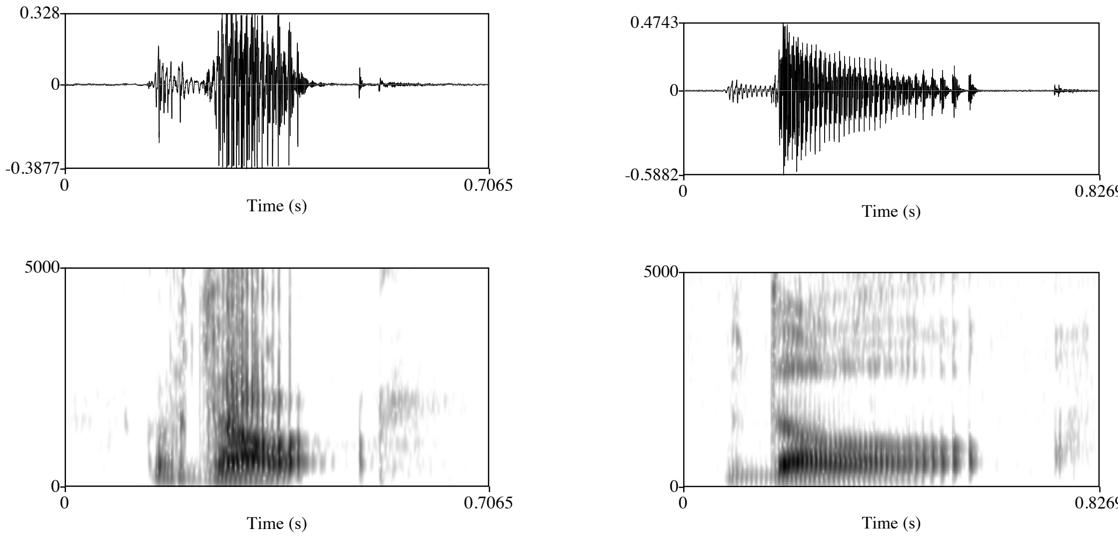
[97] Although nasals are orally [-continuant] sonorants, they seem to pattern with the rest of [+cont] segments with respect to the presence or absence of a glottal stop (see Bernhardt & Stemberger, 1998, for a discussion of the feature [continuant] for nasals). So far, in tokens of creaky vowels followed by nasal consonants, no glottal has been detected (the featural implications of this pattern are beyond the scope of this dissertation, but see Mielke (2008 [2004]) on the ambivalence of nasals with respect to [continuant] specification). Lenis stops are normally fricated in coda position, and thus no glottal stop is present in the vowel.

[98] The symbol # indicates a pause or end of utterance.

[99] Gordon and Ladefoged (2003, p. 9) illustrates the same issue of creaky vowels ending with a glottal stop at the end of utterance, their transcription of *mnnààa'* ‘woman’ is also [mna̰ʔ].

d. / bḛlˑ /   ˩ → [bḛ͡ḛlː]   (*bèèe'll*)   'snake'

The above patterns are illustrated in Figure 48, with some acoustic examples.



[β d ò̰ˑ   ʔ   ]   [b d ò   o̰ː   ʔ]

Figure 48. Waveform and spectrogram of / bdo̰ / ˩ by male speaker TiuT (from personal fieldwork) and by TiuL (Munro et al., 2008, Unida 1; sound file L3-3C)

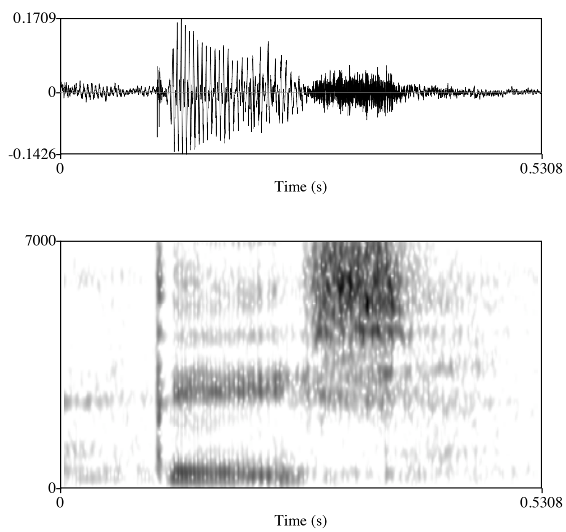
The possible (expected) ending of creaky voice into a glottal stop may be explained physiologically. A creaky vowel usually starts with modal phonation (although sometimes the vowel is creaky right from the beginning), then, the vibration occurs only anteriorily with the arytenoid cartilages pressed together. As creakiness continues, the glottal pulses become more and more sporadic (this period of creakiness can be considered successive glottal closures). If an oral stop or a pause follows one creaky vowel the natural way to finish the vowel is to simply cease the vibration, i.e. maintain a glottal closure. In addition, the presence of the glottal stop may enhance the glottalization of the vowel and the oral stop closure. I consider this optional (potential) final closure to be phonetic variation rather than phonemic contrast in Quiaviní Zapotec,[100] and possibly

[100] Morphologically, the presence of the glottal stop in creaky vowels is also predictable in Quiaviní Zapotec. When a vowel-initial clitic/suffix follows a stop final root with creaky vowel, there is no glottal closure, as the stop resyllabifies with the clitic/suffix: / la̰ts / ˩ → [la̰͡a̰ˀts] 'flat area', but / la̰ts + eˀ/ ˩ → [la̰͡a̰.tseˀ] 'small flat area'.

cross-linguistically (see also Picanço, 2005; and Jiang-King, 1999, for similar characteristics in the description of creaky vowels in Munduruku and Chinese, respectively).

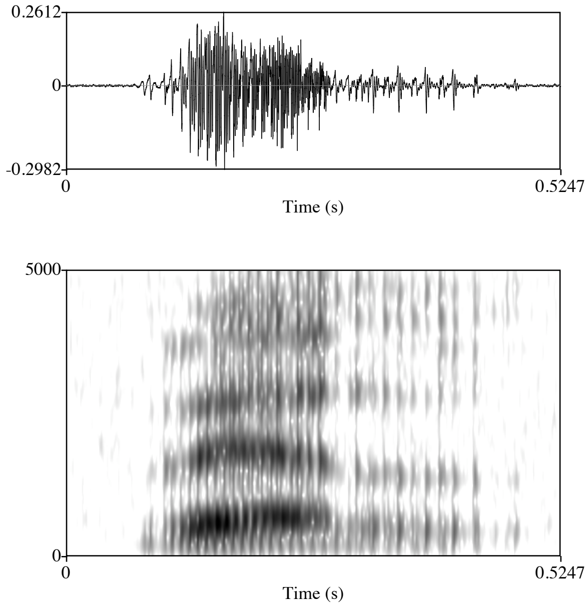
Other phonetic analyses of creaky vowels in different Zapotec languages have also shown the possibility of creaky vowels ending in a glottal stop (including Jones and Knudson, 1977; Antonio Ramos, 2007; and Arellanes, 2009, among others). According to Jones and Knudson (1977), in San Juan Guelavía Zapotec creaky vowels “are checked before pause” (p. 17); crucially, what they mean by checked here is a creaky vowel that ends with a glottal stop before pause, as an allophonic variant of a creaky vowel, just as presented for Quiaviní Zapotec here.

In comparison, creaky vowels followed by continuant segments do not end with a full glottal closure. Consider the following figures.



[d̥ ʰ ì ḭ ʒ̊]

Figure 49. Waveform and spectrogram of / dḭʒ / ˩ ‘word’ by female speaker LiaCh.



[b é̬ ḛ̀ l̰ː]

Figure 50. Waveform and spectrogram of / ḛl / ˥˩ (*bèèe'll*) ‘snake’ by male speaker TiuL (Munro et al., 2008, sound file L3-3C)

The important fact about the figures above is that there is no glottal stop at the end of the vowel, there is just the transition from the creaky vowel into the coda consonant, which in the case of fortis /l/ shows appreciable creakiness.

In addition to the issue of the final checked vowel in these vowel patterns, differences between the vowel patterns *àa'* and *ààa'* imply a duration difference, with the latter being longer. Another inherent difference seems to be the presence of a modal beginning for the vowel patterns *a'àa'* and *aàa'*, which I recategorize as creaky vowels with falling tone. The orthographic convention to represent modal voice may suggest a correlation between the above phonetic description, where I show that creaky vowels with falling tone always start with modal phonation, displaying the phonological tone in this portion of the vowel.

In order to properly compare the analysis presented in the previous sections and that of Munro and Lopez (1999), I conducted an acoustic analysis to clarify the phonetic and phonological properties of these vowels.

6.4.6 Acoustic experiment: Creaky vowels

6.4.6.1 Introduction

The hypothesis of this experiment is that creaky vowels in Quiaviní Zapotec bear contrastive tone. In particular, pitch and voice quality are properties distinguishing creaky vowels; duration may also be a distinguishing parameter. The phonetic parameters considered in this experiment then are **pitch**, **jitter** (see Chapter 4), and **duration**, as acoustic correlates of tone, phonation type, and length, respectively. For creaky vowels with high tone, I predict high pitch values and (since they are normally realized with tense voice) low jitter percentages (as a reflection of a less constricted voice); creaky vowels with low tone should show low pitch values and high jitter values (strong laryngealization); finally, creaky vowels with falling tone would show a falling contour and intermediate-to-strong jitter values. As the Munro and Lopez (1999) vowel patterns predict, creaky-H tokens may be shorter compared to creaky-L and creaky-F ones.

(27) Predictions: Creaky vowels

i) Creaky-H: high pitch and low jitter %

ii) Creaky-L: low pitch and high jitter %; vowels are longer than creaky-H ones

iii) Creaky-F: falling pitch and intermediate-to-low jitter %

6.4.6.2 Methods

Stimuli: The stimuli consisted of five words for each creaky vowel/tone pair. Most of these words are (near) minimal pairs. Items with modal vowels with high, low and falling tones (Table 67) were included among the stimuli in order to have a basis for comparison for pitch.

Table 66. Stimuli: creaky vowels

		Reanalysis	*dictionary*	gloss
Creaky-H (*àa'*)	1	/ ɾgḭbj / ˥	*rguìi'by*	'washes'
	2	/ zḭlˑj/ ˥	*zìi'lly*	'a lot of'
	3	/ bḛlˑ / ˥	*bèe'll*	'sister'
	4	/ ɾga̰n / ˥	*rgàa'n*	'pets'
	5	/ ʐ a̰ /˥	*zh:àa'*	'bottom'
Creaky-L (*àa'*)	6	/ ɾgḭdj / ˩	*rguìi'dy*	'sticks on'
	7	/ sḭlʲ / ˩	*sìi'lly* (lenis C?)	'breakfast'
	8	/ bḛlˑ/ ˩	*bèe'll*	'snake'
	9	/ ga̰ / ˩	*gàa'*	'nueve'
	10	/ jʒa̰ / ˩	*yzhàa'*	'animal'
Creaky-F (*a'àa'* & *aàa'*)	11	/ ɾdḭbj / ˥˩	*rdi'ìi'by*	'ties to'
	12	/ ʒ ḭlˑj / ˥˩	*zhiìi'lly*	'wool'
	13	/ ʒ ḭʒ / ˥˩	*zhi'ìi'zh*	'pineapple'
	14	/ ɾḛz / ˥˩	*re'èe'z*	'stripes'
	15	/ ʒ ḭnj ga̰n /˥˩	*(zhìi'iny) gaàa'n*	'son'

Table 67. Control stimuli: modal vowels

		Reanalysis	*dictionary*	gloss
Modal-H	1	/ ʒi / ˥	*zhii*	'tomorrow'
	2	/ nda / ˥	*ndaa*	'bitter'
	3	/ belˑ / ˥	*Be'll*	'Abel/Avelina'
	4	/ dṵ gilˑj / ˥	*(dùu') guiilly*	'thread'
	5	/ ɾga / ˥	*rgaa*	'feels pity'
Modal-L	6	/ ʒi / ˩	*zhìi*	'quite'
	7	/ nda / ˩	*ndàa*	'sensitive'
	8	/ galˑj / ˩	*gàally*	'twenty'
	9	/ ɾginj / ˩	*rguìiny*	'beats'
	10	/ be / ˩	*bèe*	'mesquite bean'
Modal-F	11	/ ʒilˑj / ˥˩	*zhi'ìilly*	'sheep'
	12	/ bibj / ˥˩	*bi'ii'by*	'pipal (plant)'
	13	/ dai / ˥˩	*da'ài*	'piece of (half)'
	14	/ aʐ / ˥˩	*a'àazh:*	's/he'
	15	/ gelˑ / ˥˩	*gue'èell*	'by chance'

All these words were recorded in the following carrier phrase:

(28) Carrier phrase
[mnḭː ______ nado̰ta]   'Say _____ first'
(orthography: *Mnììi'*______ *nadòo'ta*)

The stimuli were recorded by two native speakers of Quiaviní Zapotec: female speaker LiaL (35 years old) and male speaker TiuC (40). Three repetitions of each phrase with creaky vowels were collected based on a randomized list, for a total of 90 tokens (5 creaky-H + 5 creaky-L + 5 creaky-L = 15 x 3 repetitions x 2 speakers = 90 tokens). In addition, for the pitch comparison, two repetitions of each phrase with modal vowels were also recorded for a total of 60 tokens (5 modal-H + 5 modal-L + 5 modal-L = 15 x 2 repetitions x 2 speakers = 60 tokens). The stimuli were recorded using a Marantz 660 solid-state recorder and a Countryman lapel microphone (phantom power). Measurements were done in Praat for Mac (version 5.1.07; Boersma and Weenink, 2009); results were compiled and statistics run (two tailed unequal variance t-tests) in Excel 2004 for Mac.

Measurements of pitch include three particular points: Initial (I), Middle (M) and Final (F); Initial and Final measurements were taken 20 ms after the onset of the vowel and 20 ms before its offset, respectively, to avoid tone-perturbation from neighboring segments. These measurements were taken within the segmental tone-bearing unit, that is the whole vowel for items with lenis coda consonants and the whole rhyme for vowels followed by fortis sonorant consonants.[101]

With respect to the phonetic degree of laryngealization, in Chapter 4 (tone experiments), periodicity was successfully calculated by jitter (ppq5), which measures the variation in duration of glottal cycles. Following the same procedure as in Chapter 4, jitter values were obtained during the six glottal pulses at the center of the vowel (the minimum required for jitter (ppq5) is 5 pulses). Finally, I measured the duration of all vowels and all coda consonants.

[101] In Chapter 5, it was demonstrated that fortis sonorants in coda position are tone-bearing units in Quiaviní Zapotec; consequently, they are taken into account in this acoustic comparison, for pitch and intensity measurements.

6.4.6.3 Results

Figure 51 illustrates the average pitch contours of creaky vowels for the female speaker, LiaL. Tables following each figure present the average numbers and their standard deviation, as well as their statistical analysis. Creaky-H tokens have higher pitch values compared to creaky-L ones, and their differences are significant. Creaky-F tokens show a clear falling contour pitch; during the initial and middle intervals, their pitch values are higher and statistically different compared to creaky-L tokens, but not compared to creaky-H ones. At the final interval creaky-F and creaky-L tokens are not significantly different.

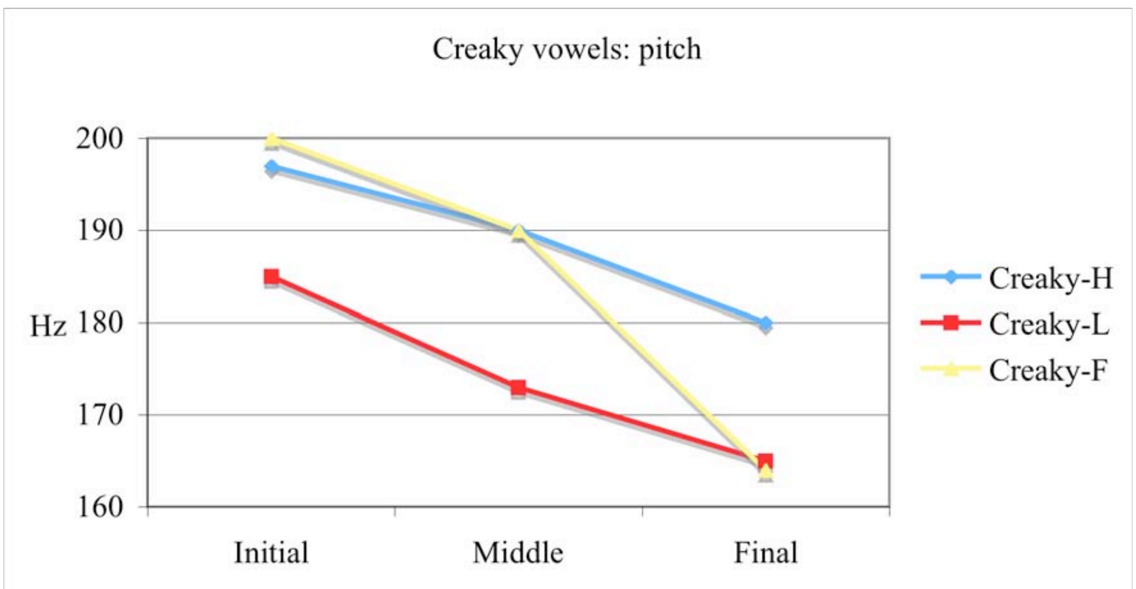


Figure 51. Pitch average contours for creaky vowels (LiaL).

Table 68. Creaky vowels: pitch (LiaL)

Pitch		Initial	Middle	Final
Creaky-H	Mean	**197**	**190**	**179**
	SD	8.1	4.9	6.9
Creaky-L	Mean	**187**	**173**	**162**
	SD	5.2	7.3	7.2
Creaky-F	Mean	**200**	**190**	**164**
	SD	9.4	15.4	7.3

Table 69. Probability values from t-test for creaky vowels: pitch (LiaL)

T-TEST	Initial	Middle	Final
Creaky -H vs. L	**0.007**	**0.001**	**0.002**
Creaky -H vs. F	0.104	0.679	**0.012**
Creaky -L vs. F	**0.003**	**0.045**	0.507

In comparison with creaky vowels, the following figure and table show the average pitch contours of modal vowels for LiaL. Although with higher overall values, similar patterns to those of creaky vowels are observed in modal vowels.

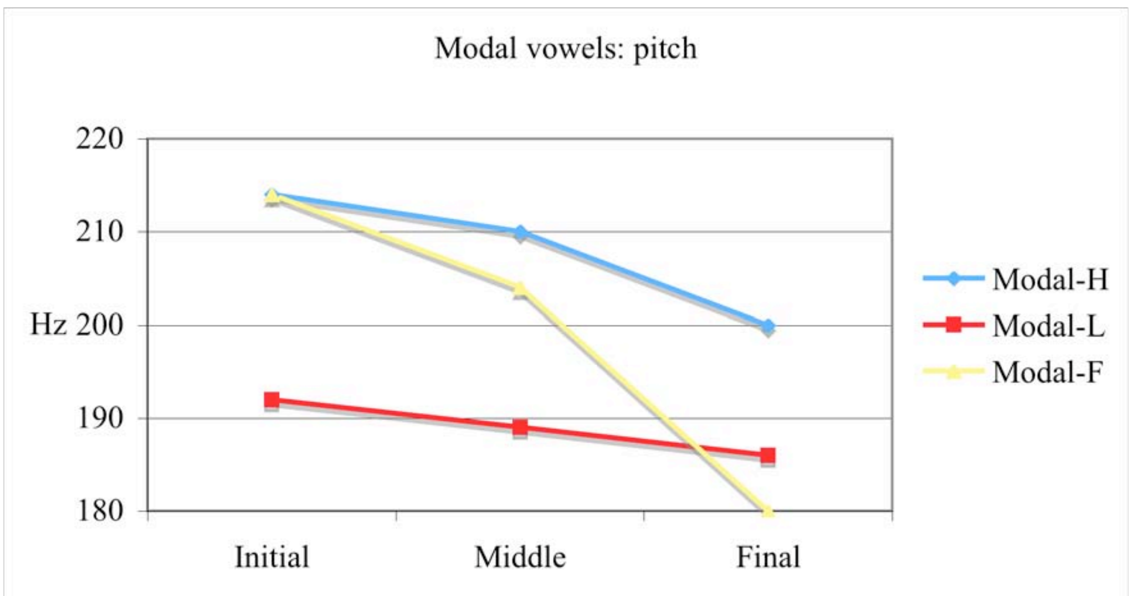


Figure 52. Pitch average contours for modal vowels (LiaL).

Table 70. Modal vowels: pitch (LiaL)

Pitch		Initial	Middle	Final
Modal-H	Mean	**214**	**210**	**200**
	SD	11.3	13.8	22.4
Modal-L	Mean	**192**	**189**	**186**
	SD	3.1	8.1	8.7
Modal-F	Mean	**214**	**204**	**180**
	SD	23.1	21.4	14.6

Similar results were obtained for the male speaker, TiuC. Average pitch contours of creaky vowels appear in Figure 53, followed by Tables 71 and 72, which present the mean and standard deviation, as well as their statistical analysis.

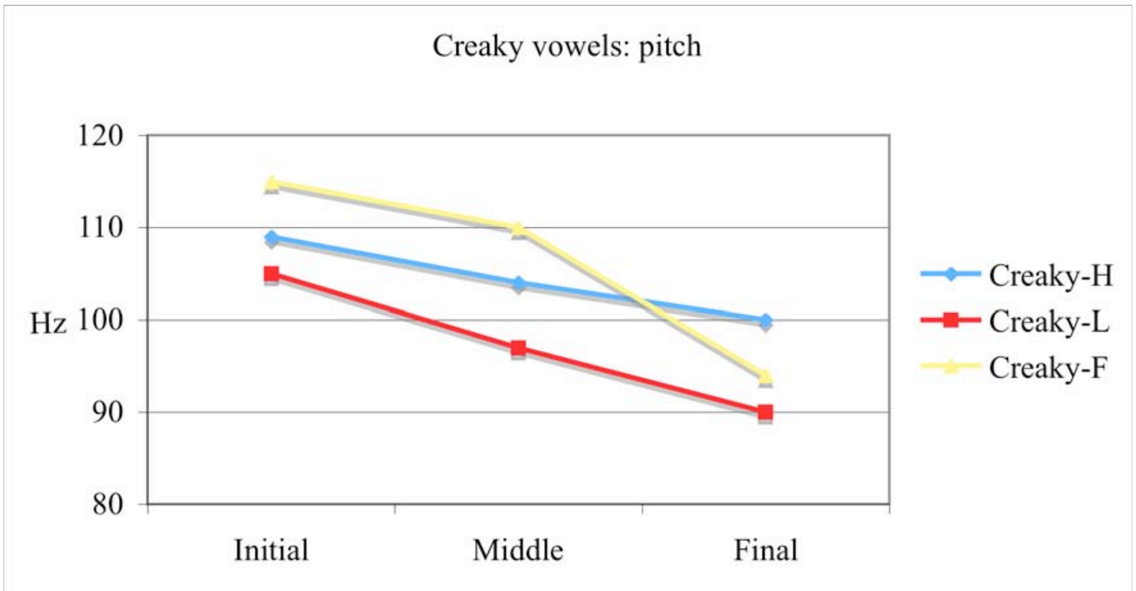


Figure 53. Pitch average contours for creaky vowels (TiuC).

Table 71. Creaky vowels: pitch (TiuC)

Pitch		Initial	Middle	Final
Creaky-H	Mean	**109**	**104**	**100**
	SD	4.1	4.2	3.5
Creaky-L	Mean	**105**	**97**	**90**
	SD	3.2	6.6	7.3
Creaky-F	Mean	**115**	**110**	**94**
	SD	8.4	7.7	7.3

Table 72. Probability values from t-test for creaky vowels: pitch (TiuC)

T-TEST	Initial	Middle	Final
Creaky -H vs. L	**0.016**	**0.033**	**0.005**
Creaky -H vs. F	0.123	0.060	0.066
Creaky -L vs. F	**0.012**	**0.003**	0.278

The following figure and table show the average pitch contours of modal vowels for TiuC.

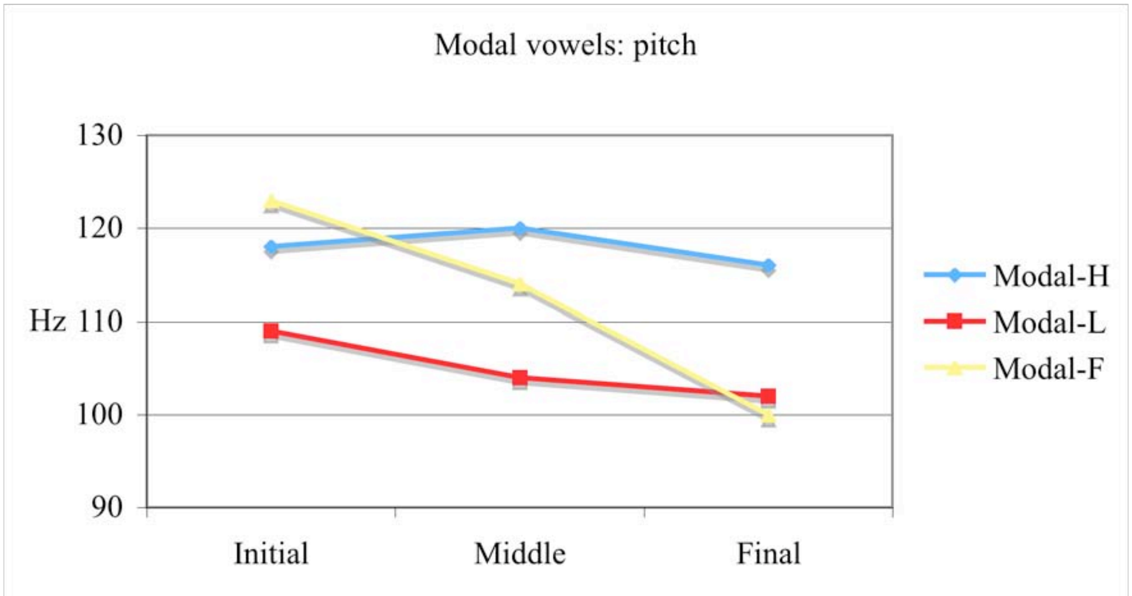


Figure 54. Pitch average contours for modal vowels (TiuC).

Table 73. Modal vowels: pitch (TiuC)

Pitch		Initial	Middle	Final
Modal-H	Mean	**118**	**120**	**116**
	SD	4.8	6.3	7.3
Modal-L	Mean	**108**	**103**	**101**
	SD	7	4.9	4
Modal-F	Mean	**123**	**114**	**100**
	SD	10.3	11.3	5.2

Jitter was used as the acoustic parameter to differentiate the amount of laryngealization among creaky vowels. The creakier the voice quality, the more aperiodic is the signal and the higher the amount of jitter. Accordingly, creaky-H tokens showed the weakest laryngealization for both subjects, with the male speaker showing higher levels of jitter.

Table 74. Creaky-H versus creaky-F: Jitter ppq5 (voice quality)[102]

Jitter (ppq5)		TiuC	LiaL
Creaky-H	Mean	0.398%	0.213%
	SD	0.20	0.09
Creaky-L	Mean	1.259%	0.541%
	SD	1.28	0.46
Creaky-F	Mean	0.467%	0.444%
	SD	0.37	0.17

Table 75. Probability values from t-test for creaky vowels: jitter (TiuC)

T-TEST: jitter(ppq5)	TiuC	LiaL
Creaky -H vs. L	0.099	0.110
Creaky -H vs. F	0.641	**0.020**
Creaky -L vs. F	0.129	0.619

The difference between creaky-H vs. creaky-L tokens is marginally significant. Creaky-H vs. creaky-F tokens were not significantly different for TiuC, but significant for LiaL. No statistical difference was found between creaky-L vs. creaky-F tokens.

With respect to duration, the Munro and Lopez dictionary (1999) indicates duration in the orthography, *àa'* (creaky-H here) versus *ààa'* (creaky-L here). Duration measurements were obtained differently from the previous phonetic parameters. Vowels and coda consonants were measured individually, so we can clearly compare VC_{fortis} and VC_{lenis} rhymes; results are given by items, plus total means.

Table 76. Creaky-H vs. L durational patterns (VCfortis)

Creaky-H (àa')	gloss	V	Cfortis	Creaky-L (ààa')	gloss	V	Cfortis
/ bḛlˑ / (*bèe'll*)	'sister(w)'	124	193	/ bḛlˑ/ (*bèèe'll*)	'snake'	109	131
/ zḭlˑj / (*zìilly*)	'a lot of'	130	189				
	Mean	**127**	191		Mean	**109**	131

[102] In a pilot study of the creaky vowels, jitter results from TiuL —one of the authors of the Quiaviní Zapotec dictionary, Munro and Lopez (1999)— were higher as a result of, I would say, the lower pitch range of this consultant. Creaky-H tokens average 0.697% versus 1.488% for creaky-L ones. In relation to some vowel patterns discussed in Chapter 4, this lower pitch range of TiuL could have also influenced the classification of modal phonation of some lexical items as weak laryngealization.

Table 77. Creaky-H vs. L durational patterns (VClenis)

Creaky-H (àa’)	gloss	Vː	Clenis	Creaky-L (ààa’)	gloss	Vː	Clenis
/ ɾgḭbj / (*rguìi’by*)	‘washes’	315	95	/ ɾgḭdj / (*rguììi’dy*)	‘sticks on’	255	80
/ ɾga̰n / (*rgàa’n*)	‘pets’	182	78	/ ga̰ / (*gààa’*)	‘nueve’	270	
/ z̨ a̰ / (*zh:àa’*)	‘bottom’	191	77	/ jʒa̰ / (*yzhààa’*)	‘animal’	229	
				/ sḭlʲ / (*sììi’lly*) [103]	‘breakfast’	318	68
	Mean	**229**	83		Mean	**268**	74

Resembling the findings for modal vowels in Chapter 3, results clearly show that creaky short vowels appear before fortis consonants, and creaky long vowels before lenis consonants. Within each of these rhyme types, there is a small difference in the predicted direction (creaky-L tokens are slightly longer that creaky-H ones).

6.4.6.4 Discussion

Results for pitch are according to the predictions and the pitch contours described in the previous sections: creaky-H tokens had significantly higher pitch values at all points compared to creaky-L ones. Creaky-F tokens show a clear falling contour pitch, with similar values to creaky-H tokens during the first two intervals, but similar results with creaky-L at the end. As described above, the final portion of both creaky-L and creaky-F vowels shows prototypical creaky voice, thus, the similarity is expected. In comparison with modal voice, creaky pitch values are lower, but still within the range of pitch for modal vowels. In other words, the laryngeal constriction shifts the tonal patterns downwards in creaky voice.

With respect to jitter, as creaky vowels with high tone are normally realized with weak laryngealization, i.e. tense (or stiff) voice, we expected them to show less jitter than creaky-F and, especially, than creaky-L. This was in fact reflected in the study, but only marginally. This marginal significance suggests that, although these vowels belong to the

[103] The coda sonorant of the item / sḭlʲ / (*sììi’lly*) ˩ ‘breakfast’ was previously described (Munro and Lopez 1999) with fortis /l/ in coda; however, here it is reclassified as lenis /l/ because of their consistent short duration. The duration of sonorant consonants in codas, particularly /l/, is more difficult to determine than the duration of obstruents (Pam Munro, personal communication, May 2009). This makes the classification of such consonants as fortis or lenis more difficult.

phonemic category of creaky vowels, speakers consistently use different levels of laryngealized voice to cue tone. Creaky-F tokens show intermediate jitter. More precise jitter results, especially to differentiate creaky-F from the other creaky vowels, might be obtained by measuring jitter at additional points during the vowel. The topic requires further research.

Results corroborate the hypothesis that pitch and jitter (tone and voice quality) are important acoustic properties for differentiating creaky vowels with high versus low tone, and suggest that speakers use them as primary cues. Duration might be a secondary characteristic.

6.4.7 Interim summary: Creaky vowels

The sections above have presented a new classification of creaky vowels in Quiavini Zapotec. As illustrated in the table below, I consider tone as phonologically relevant. I argue that creaky vowels with high tone are realized as having tense voice, whereas vowels with low and falling tones show prototypical creaky voice. In all these cases, the first portion of the vowel is modal phonetically, allowing the perceptible realization of those tones that are phonologically present. These characteristics were quantitatively confirmed by the acoustic experiment above.

Table 78. Laryngeal constriction variation

	High	Low	Falling
Creaky / ḛ /	[é͡é̬] (tense)	[è͡ḛ] (creaky)	[ê͡ḛ] (creaky)

6.5 Interrupted vowels

6.5.1 Introduction

In terms of the aperture between the arytenoid cartilages, the two extreme glottal states are a voiceless sound, with the arytenoids furthest apart, and a glottal closure, with the arytenoids closest together. This glottal closure is part of the fourth phonation type found in Quiaviní Zapotec, that is *interrupted vowels* (or glottalized voice); the goal of this section is to present the phonetic and phonological characteristics of these vowels and the tones they may be associated with.

In Quiaviní Zapotec, the term *interrupted vowels* refers to the strongest degree of laryngeal constriction in vowels in this language, phonologically transcribed as /aˀ/. The superscript glottal stop indicates that the glottal closure is part of the vowel, i.e. it is a vocalic feature and not an independent segment (see more below).

Interrupted vowels are phonetically pronounced either as checked [aʔ] (a modal vowel followed by a glottal closure) or as rearticulated [aˀa] (a sequence of modal vowel-glottal stop-modal vowel). Both realizations have a similar overall duration, but the glottal closure in the former is normally longer, and thus, it is not transcribed with a superscript. The glottal stop in interrupted vowels (either as checked or rearticulated) can range from a full closure to extremely low amplitude glottalized vowel. Which output is produced depends on the tone the vowels occur with. High-tone items are manifested with checked vowels, whereas low and falling tones are produced with rearticulated vowels. These different productions (checked vs. rearticulated) are grouped together because they use the same laryngeal mechanism: extreme glottalization (either glottal closure or very pronounced creakiness). This phonation is not found with a rising tone (Table 79).

Table 79. Interrupted (Checked/rearticulated) vowels and tone interaction

	High	Low	Falling	Rising
Interrupted	√	√	√	X

(29) Interrupted-H (checked)
/ ɾgaˀ / ˥ → [ɾgáʔᵃ̥] [104] ‘gets green again’

(30) Interrupted-L (rearticulated)
/ ɾgaˀ / ˩ → [ɾgàˀà] ‘gets caught’

(31) Interrupted-F (rearticulated)
/ ɾgaˀ / ˥˩ → [ɾgáˀà] ‘pours’

Before analyzing each of these vowels in more detail, an important issue is the phonological status of the glottal closure in Quiaviní Zapotec. This is a controversial topic in Zapotec and Otomanguean languages in general. The majority of analyses consider it a vocalic feature of interrupted vowels (e.g. Suárez, 1973; Jones & Knudson, 1977; Lyman & Lyman, 1977; Pickett, Black & Marcial, 2001; Smith-Stark, 2003; Beam de Azcona, 2004; Antonio Ramos, 2007; Merrill, 2008; Arellanes, 2009), including the analysis of Munro and Lopez (1999) for Quiaviní Zapotec. A minority of analyses, nonetheless, have argued for the glottal stop as an independent phoneme (e.g. Avelino, 2004). In Quiaviní Zapotec, there are phonemic, morphological and distributional arguments in favour of the analysis of the glottal stop as part of the vowel. In what follows, I present six reasons to interpret an interrupted vowel as a single vowel interrupted by a laryngeal gesture, rather than as a disyllabic sequence involving two distinct tokens of the same vowel, separated by a glottal stop.

First, all consonants in Quiaviní Zapotec appear in onset position and in consonant clusters (see phonotactics section in Chapter 1). The glottal stop does not occur prevocalically, i.e. the glottal stop is banned from appearing in a syllable onset. If it is a segment, it is the only segment in Quiaviní Zapotec with this kind of defective distribution.[105] (Nonetheless, this in itself is not a sufficient argument to reject the glottal closure as an independent segment.)

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[104] Interrupted vowels with high tone normally have an echo vowel after the glottal stop. This is discussed in detail in subsequent sections.
[105] An additional distributional fact in Juchitán Zapotec (Isthmus; Pickett, Black & Marcial, 2001) and Chichicapan Zapotec (Valley; Smith-Stark, 2003) is that there are no codas in these languages (except for /n/ in Chichicapan).

Second, interrupted vowels have the same tonal sequences as single vowels (except for the absence of rising tone). If they were disyllabic sequences, we might expect roots with an interrupted vowel to exhibit a richer inventory of tonal melodies.

Third, morphologically native roots are monosyllables,[106] thus, it is logical to group roots with rearticulated vowels with the rest of the roots. It would be odd to have a single type of disyllabic root, all of which “coincidentally” have a /ʔ/ as their medial consonant.

Fourth, regardless of tone, interrupted vowels (both checked and rearticulated) occur either in open syllables (mostly) or followed by lenis sonorants; fortis consonants are banned in coda position with interrupted vowel nuclei.[107] (The same phonotactic characteristics have been described for interrupted vowels in Cajonos Zapotec (Nellis & Hollenbach, 1980, pp. 97-98) and San Pablo Güilá Zapotec (Arellanes, 2009)). Interrupted vowels are analyzed here as bimoraic (see below, and Chapter 7); hence since fortis consonants are moraic in coda (Chapter 3), this is incompatible with a vowel that is necessarily bimoraic.[108] This type of phonotactic distribution is common in languages with bimoraic vowels and moraic codas, but the motivation for the restriction is not obvious if the rearticulated vowel is split across two syllables, and the second syllable has a monomoraic vowel followed by a moraic coda.

Fifth, interrupted vowels normally possess a single vowel quality; only a small minority are diphthongs. If they were disyllabic sequences this would be a surprising coincidence (cf. Stemberger, 1993).

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[106] Apart from loanwords, only a few roots seem to be disyllabic, but all of them are wS. Rearticulated vowels would be the only Sw roots (given that the 1st part of the vowel tends to be longer & louder than the 2nd).

[107] In the Quiaviní Zapotec dictionary (Munro & Lopez, 1999), the vowel patterns that I analyze as checked and rearticulated vowels are in fact not followed by fortis obstruents. There are only a few cases in which fortis sonorants follow these vowel patterns in the dictionary (e.g. *gùu'ann* ‘bull’, analyzed here as / ɡuʔan / ˥˩). Acoustic analysis of these sonorant consonants has shown that their duration is similar to lenis consonants, so I reanalyze them as lenis.

[108] The duration of interrupted vowels (see the acoustic comparison below) corresponds to that of long modal vowels, analyzed in Chapter 3 as bimoraic. This analysis is sound, in that interrupted vowels may stand alone as prosodic words or in prominent positions within phrasal contexts. This characteristic implies that they satisfy the minimal requirement of prosodic words to form a bimoraic foot (Chapter 3). The moraicity of these vowels will be discussed in the following chapter.

Sixth, the glottal stop does not serve as a sufficient consonantal barrier between vowels. When speakers are asked to separate words into syllables, rearticulated vowels are treated as one syllable.[109]

For all these reasons, summarized in (32), I concur with Munro and Lopez (1999) and combine the laryngeal components with vowels to create a distinct series of interrupted vowels, in addition to modal, breathy and creaky vowels in Quiaviní Zapotec (the phonological specification of all these vowels is presented in the next chapter).

(32) Summary: glottal stop as a vocalic feature in interrupted vowels (/aˀ/)

1. /ʔ/ defective distribution (not in onset, not in clusters)
2. Interrupted vowels have the same tonal sequences as single vowels
3. Monosyllabic tendency of the language (roots = 1σ)
4. *VʔC$_{\text{fortis}}$, predicted by bimoraicity of interrupted vowels
5. Same vowel quality, i.e. one vowel gesture (diphthongs a minority)
6. Perceived as single syllables by native speakers
   (ʔ ≠ sufficient consonantal barrier, i.e. syllable boundary)

I now turn to the description of each of the tonal types of interrupted vowels. The acoustic examples used for the following sections correspond to the productions of one male speaker, TiuC (42 years old).

6.5.2 Interrupted-H

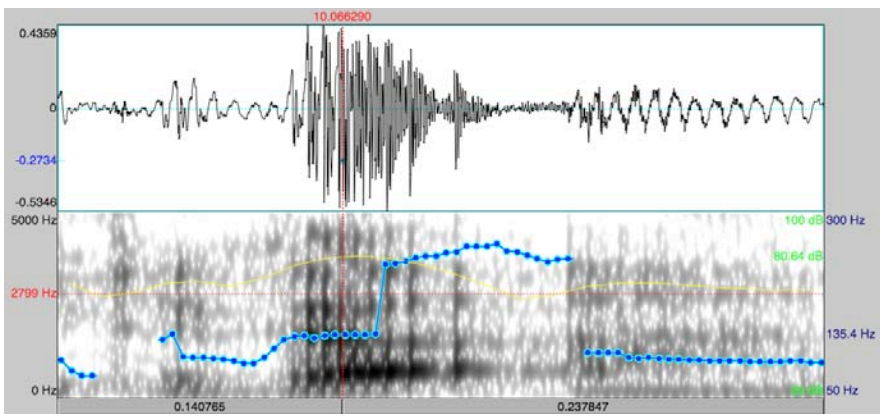
The first type of interrupted vowel I will describe is interrupted-H, which is realized as checked. Additional examples are provided in (33).

(33) Interrupted-H examples
 a. / ɾgaˀ / ˥ → [ɾgáʔᵃ] ‘gets green again’
 c. / baˀ / ˥ → [báʔᵃ] ‘earlier today’

[109] With respect to how speaker judgments were elicited, first, they were asked to divide the words into syllables (e.g. giving a Spanish example); second, consultants were asked to clap once per syllable as they pronounced the words; and third, sometimes I also asked the speakers to whistle the words. Munro and Lopez (1999) also mention that the vowel patterns corresponding to interrupted vowels (see §5.5.5) are reported as single syllables by native speakers.

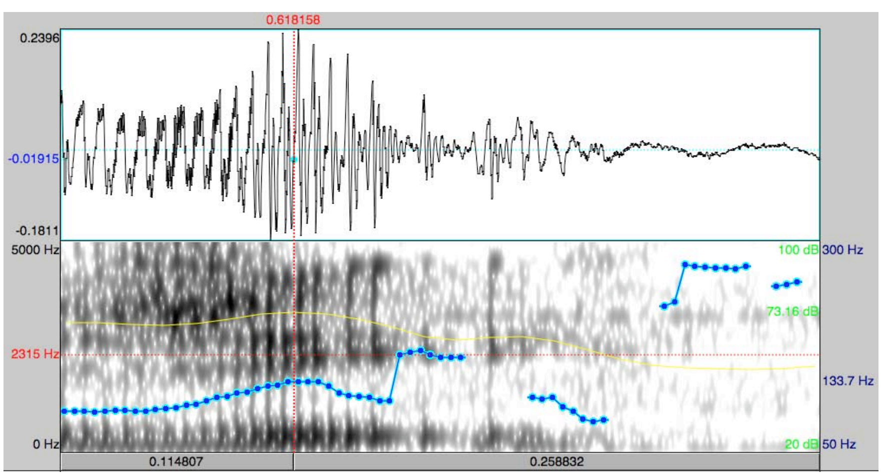
b. / ʒiˀ /   ˥ → [ʒíʔⁱ̥]   ‘cold’
d. / ɾʒiˀ /   ˥ → [ɾʒíʔⁱ̥]   ‘spills’
e. / = aˀ /   ˥ → [aʔ]   ‘1s clitic’

Interrupted vowels with high tone are produced as checked vowels: a modal vowel portion followed by a glottal closure. This interrupted portion is commonly released into a voiceless short vowel that resembles what has been analyzed in other languages as an echo vowel (e.g. Hindi, Chumash (Cram, Linn & Nowak, 1996)), which will be discussed in more detail below. Consider the waveform and spectrogram of following acoustic examples of interrupted vowels with high tone.



[ɾ g a a̰ ʔ ḁ]

Figure 55. Waveform and spectrogram of / ɾgaˀ / ˥ → [ɾgáʔᵃ̥] ‘gets green again’ by male speaker TiuC.



[ʒ i ḭ ʔ ⁱ̥]

Figure 56. Waveform and spectrogram of / ʒiˀ / ˥ → [ʒíʔⁱ̥] ‘cold’ by male speaker TiuC.

Both examples show high pitch values for the first vowel portion, averaging 131 Hz for the first example and 129 Hz for the second. Modal-H tokens for this speaker are normally produced above 120 Hz; hence, these tokens are well within the range of high tone pitch values. The duration of the portion with modal voicing (first portion) may be difficult to measure as the interrupted boundary is not always clear. For the first example, [ɾgáʔᵃ] 'gets green again', the first 70 ms can certainly count as the first vowel portion. The next 15 ms show clear glottalization before the actual glottal closure. By the same token, it is difficult to determine the exact duration of the laryngealized portion of the vowel. Is it exclusively the glottal stop? Shall we include the previous glottalization in the vowel? This is a difference of 16 ms (50 vs. 66 ms) for the same item. Because the period in question is basically a transitional one, I will consider anticipatory creaky voice as part of the interrupted portion of the interrupted vowel for two reasons: 1) it no longer conveys to the tonal information of the vowel, that is, the pitch is normally not recoverable; and (2) for some tokens —particularly in interrupted-L and F— there may be no actual glottal stop, but a short very-low-amplitude period of strong glottalization (i.e. creaky voice). I analyze the first example as an initial modal vowel portion of 70 ms followed by 66 ms of glottalization, and the second example as an initial vowel portion of 68 ms plus 70 ms of glottalization.

With respect to the release of the glottal closure, the term "echo vowel" has been applied for a vowel-glottal stop sequence at the end of the phrase; the echo vowel is the same as the vowel before the glottal stop, but it is whispered and faint (e.g. [aʔḁ] for /aʔ/ 'arrow' in Chumash (Cram, Linn and Nowak 1999)). I adopt this term for the glottal release in the case of interrupted vowels with high tone. This echo vowel does not seem to be relevant to tone, as its pitch is inconsistent (commonly voiceless) and the formants are very weak. Nonetheless, interrupted vowels in roots (prominent positions) are claimed to be bimoraic (Chapter 2), thus, the release of the glottal portion is necessary to identify the long duration of the whole vowel.

Considering all interrupted vowels, the acoustic analysis of interrupted-H tokens shows that the release of the glottal closure is weaker compared to the second vowel portion (after the glottalization) of rearticulated vowels with low and falling tone. The latter has more regular pulses and modal-like voice quality, higher intensity values, and clearer formants than those of interrupted-H items (see next sections).

Diphthongs may be used as another piece of evidence determining the phonological status of the echo vowel. In Quiaviní Zapotec, glottalization appears in between the two vowel qualities for diphthongs in interrupted vowels. Another possibility would be to have both vowel qualities before the glottal closure; however, I have not identified this type of case within interrupted vowels. Accordingly, if interrupted-H items are realized as checked vowels, we do not expect to find diphthongs. This prediction is correct: for interrupted vowels with high tone, we find only homorganic examples (same vowel quality).[110] On the other hand, both interrupted vowels with low and falling tones have lexical items with diphthongs.

Finally, clitics are another piece of evidence for analyzing interrupted vowels with high tone as checked vowels. Following Munro and Lopez (1999), 1s and 2s correspond to checked vowels with high tone, as Table 80 shows.[111]

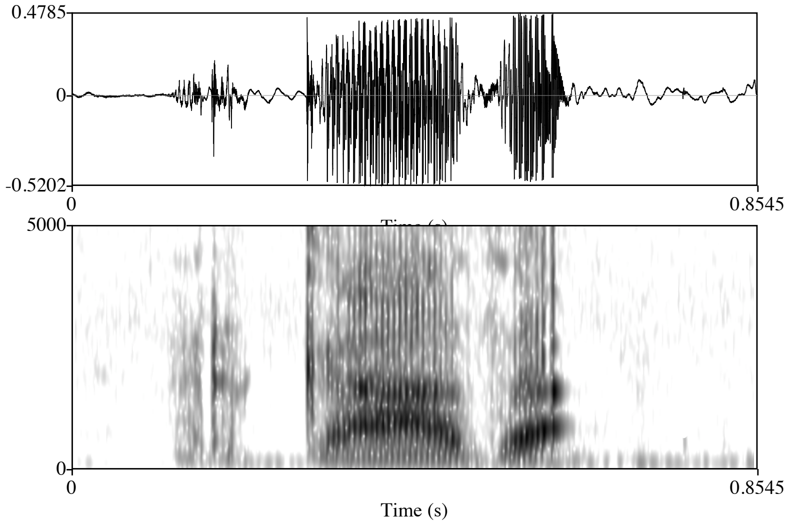
Table 80. Quiaviní Zapotec Pronouns and clitics: interrupted (checked)-H (adapted from Lee, 2006; Munro & Lopez, 1999)

		dic. pronoun	dic. clitic	gloss
1s	/ aˀ /	*nàa'*	*-a'*	'I'
2s informal	/ uˀ /	*liu'*	*-u'*	'you (informal)'
2s formal	/ juˀ /	*làa'yuu'*	*-yuu'*	'you (formal)'

For illustration, consider example (34) and Figure 57 from male speaker TiuT (76 years old) and examples (35-36) and Figures 58-59 from female speaker LiaB (19 years old).

(34) *r-càa'z=a'* / ɾka̰zaˀ / ˩˥ 'I want…'
HAB-wants-1s

[110] Interrupted vowels with high tone correspond to the dictionary pattern *aa'ah*. Within this pattern there is only one example of a diphthong *gii'ah* 'will drink'. The pitch pattern of this item, nonetheless, corresponds to that of interrupted vowels with falling tone; thus, we may reclassify the item.
[111] There are no other person clitics with interrupted vowels.

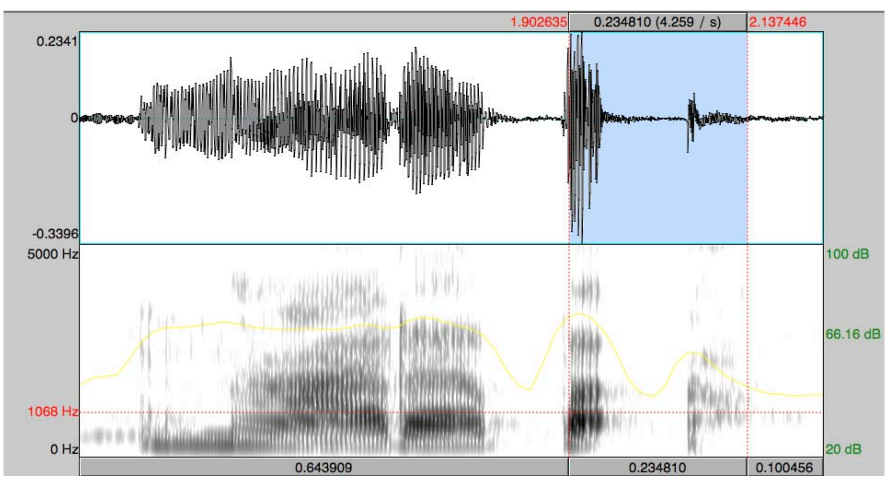


[r kʰ a̰ z a a̰ ʔ]

Figure 57. Waveform and spectrogram of *r-càa'z=a'* / ɾka̰zaˀ / ˩ ˥ 'I want…' by male speaker TiuT.

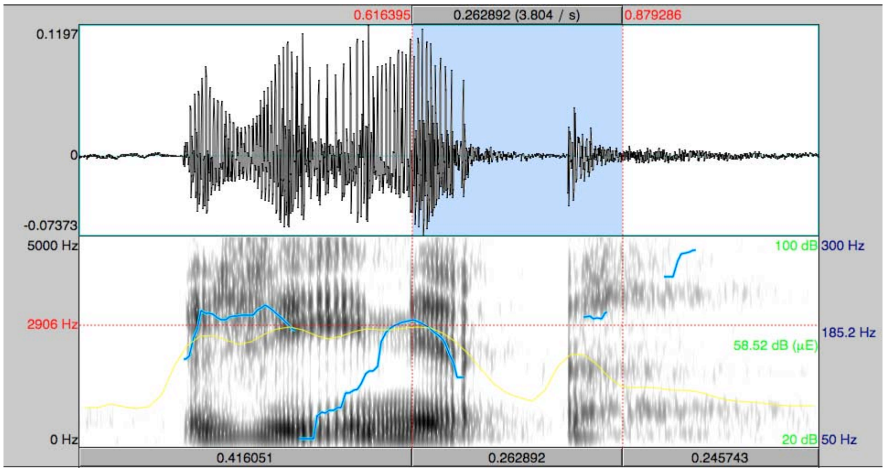
(35) *nàa r-àa'p=a'* / na̰ ɾa̰paˀ / ˩ ˥ 'I have…'
I HAB-have=1s

(36) *zhìi'iny=a'* / ʒiˀnjaˀ / ˥˩ ˥ 'my son'
son=1s



[n à̰ ɾ à̰ p áᵃ ʔ]

Figure 58. Waveform and spectrogram of *nàa' r-àa'p=a'* / na̰ ɾa̰paˀ / ˩ ˩ ˥ 'I have…' by female speaker LiaB.



[ʒ í ḭ ì n já a̰ ʔ ᵃ̥]

Figure 59. Waveform and spectrogram of *zhìi'iny=a'* / ʒiˀnjaˀ / ˥˩ ˥ 'my son' by female speaker LiaB.

These three clitic-vowel examples clearly illustrate the realization of interrupted-H vowels as checked ones, as very commonly there is no echo vowel. In the three cases, the clitic vowel starts with a modal voice period (with high pitch values for both speakers), followed by a short period of glottalization, and a full and clear glottal stop. In the case of the male speaker, there is no apparent release of the glottal, whereas the female speaker has clear releases for both glottal closures; the first is simply a glottal stop release and the second contains a short echo vowel. Based on these examples, (37) summarizes some possible realizations of / =aˀ / ˥ '1s clitic'.

(37) / =aˀ / ˥ '1s clitic' → [áʔ] ~ [áᵃʔ] ~ [áʔᵃ̥] ~ [áˀ]

In order to confirm the realization of interrupted-H vowels as indicated, I conducted an informal perceptual (field) test with three different speakers to determine the relevance of the second vowel portion for interrupted-H items. Based on the acoustic tools of *Praat* (version 5.1.07; Boersma & Weenink, 2009), I manipulated different acoustic cues of interrupted vowels and asked the speakers what word they heard. For this test, I considered minimal pairs between interrupted vowels with high tone versus those with low and falling tones, like those in (38) and (39).

(38) / baˀ / ˥ → [báʔᵃ̥] ‘earlier today’ vs. / baˀ / ˩ → [bàˀà] ‘eyeball’

(39) / ʒiˀ / ˥ → [ʒíʔⁱ̥] ‘cold’ vs. / ʒiˀ / ˥˩ → [ʒíˀì] ‘nose’

The most important manipulation consisted of cutting the second vowel portion of rearticulated vowels like [bàˀà] ‘eyeball’ and [ʒíˀì] ‘nose’, reducing them only to a glottal release. When speakers heard these manipulated recordings they identified them as [báʔᵃ̥] ‘earlier today’ and [ʒíʔⁱ̥] ‘cold’, respectively. In other words, when these minimal pairs were perceived as checked vowels, they were identified with interrupted-H items.[112] With respect to tone, the fact that interrupted-F items are being reinterpreted as interrupted-H makes perfect sense. The initial portions of the former have high tone, thus they are equivalent to interrupted (checked)-H. With respect to interrupted-L vowels interpreted as interrupted (checked)-H, we must recall the relative characteristic of tone. Although the original recording corresponds to low tone values, the subject is hearing the word out of context, thus, s/he compensates for the pitch values and the main cue to identify the token is the checked production of it.[113] These results suggest that the analysis of interrupted-H vowels as checked is correct. (This issue will be reconsidered in the acoustic experiment in §6.7.5, where results show that pitch differences were also significant.) Nevertheless, these perceptual tests should be considered as an informal observation. It is desirable for future research to conduct a complete perceptual experiment in this regard. I now turn to the description and analysis of interrupted vowels with low tone.

6.5.3 Interrupted-L

In this section I address the manifestation of low tone with interrupted vowels. Consider the examples in (40) and the acoustic figures that follow.

[112] When these words were not shortened, the words were correctly perceived as the rearticulated vowels [bàˀà] ‘eyeball’ and [ʒíˀì] ‘nose’.

[113] Additional cues to identify tone abound in the literature. For instance, in a perceptual study of Yoruba, Hombert (1976) found that presence/absence of contour was more important than absolute pitch level in identifying particular tones in Yoruba.

(40) Interrupted-L examples

a. / ɾgaˀ /   ˩ → [ɾgàˀà]   ‘gets caught’

b. / ɾgjaˀ / ˩ → [ɾgjàˀà]   ‘dances’

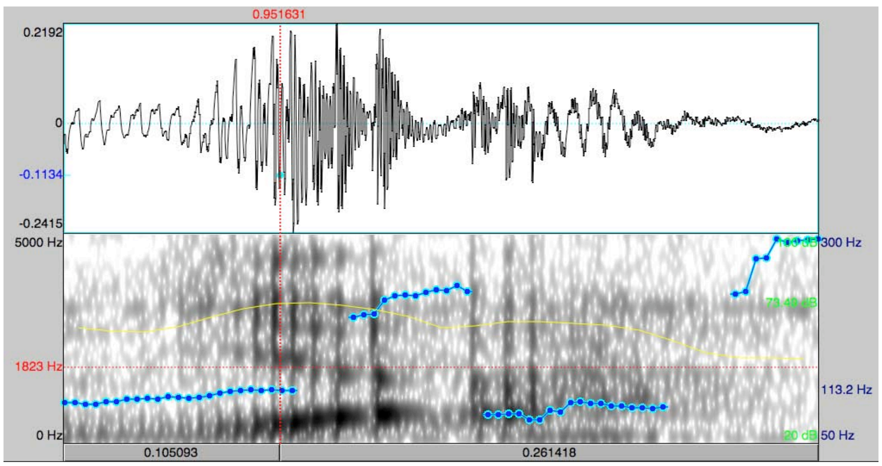
c. / btjaˀ /   ˩ → [btjàˀà]   ‘epazote’

d. / ndaˀ /   ˩ → [ndàˀà]   ‘had broken’

e. / ɾbeˀ /   ˩ → [ɾbèˀè]   ‘takes out’

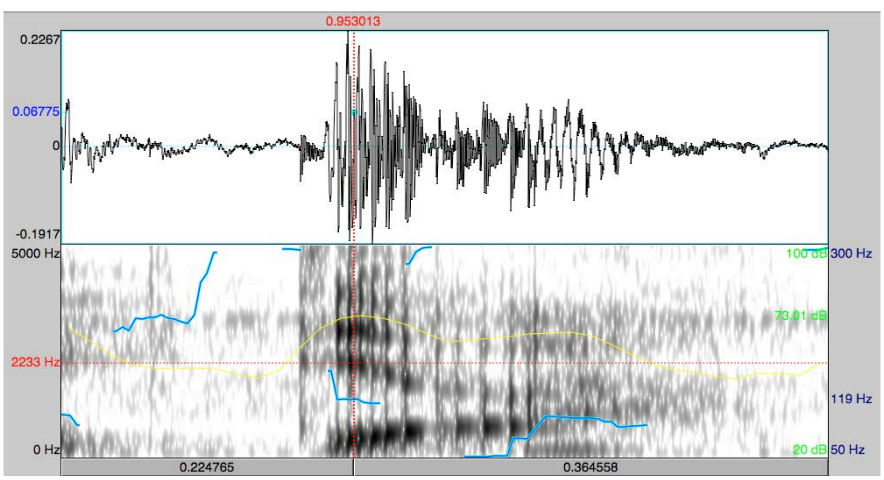
f. / giˀa /   ˩ → [gìˀà]   'market’

g. / tseˀiɲ / ˩ → [tsèˀìɲ]   ‘thirteen’



[ɾ   ɣ   j   à   a̱   ʔ   à   ]

Figure 60. Waveform and spectrogram of / ɾgjaˀ / ˩ → [ɾgjàˀà] ‘dances’ by male speaker TiuC.



[β   t   ʰ j à   a̱   à   ]

Figure 61. Waveform and spectrogram of / btjaˀ / ˩ → [btjàˀà] ‘epazote’ by male speaker TiuC.

The pitch of the first portion of the vowel in the examples above is 103 Hz for [ɾgjàˀà] 'dances' and 98 Hz for [btjàˀà] 'epazote', clearly different from the interrupted-H items (above 125 Hz), and in the range of modal-L values (~100 Hz for TiuC). The second portions of the vowels show 90 Hz for the first example and 97 Hz for the second; again, low pitch values. As with interrupted high-tone vowels, it is difficult to define the interrupted period of interrupted-L vowels because the boundaries are not always clear. Both examples have an initial modal vowel portion of approximately 50 ms. The first example then has a short period of creakiness followed by a short glottal stop, of another 50 ms; the second example does not show a proper sustained glottal closure at any point, but continuous strong creaky voice with a pronounced drop in the amplitude envelope, lasting 70 ms. Finally, we have between 60 to 70 ms for the second vowel portion. Total duration of these vowels is 180 ms and 222 ms, respectively. These numbers correspond to the duration of long vowels and, therefore, justify an analysis as bimoraic vowels.

Based on the analysis of several examples, (41) illustrates some of the phonetic variation of interrupted vowels with low tones.[114]

(41) / aˀ / ˩ → [àʔà] ~ [àˀà] ~ [àa̰à]

The glottal closure of the interrupted vowel with low tone (as well as with falling tone as we will see below) has some variation in its phonetic realization as it may be pronounced as a full glottal stop, as a short one, or as a period of strong glottalization. An obligatory modal vowel portion follows all these variants. One question about the analysis of interrupted-L vowels is the phonetic and phonological role of the second vowel portion, which, in contrast with interrupted-H vowels, does not seem to be an echo vowel (which is very short, and voiceless or breathy), but a fully voiced portion relevant for the phonological identification of interrupted (rearticulated)-L vowels.

The first argument for such consideration is the acoustic characteristics of the second vowel portion in interrupted-L vowels. Although it is never as consistent as the first portion, we normally find modal voice or modal-like voice; consequently, we find

[114] The main difference between the realizations of full glottal stop versus a short one is not only duration, but also a more noticeable drop in the amplitude envelope for the former.

meaningful measures of pitch and intensity values. These pitch values are normally similar for the first and second vowel portions, giving the impression of a single vowel gesture interrupted in the middle by a laryngeal gesture.

Another important argument for the rearticulated realization of interrupted vowels with low tone is the existence of diphthongs with this vowel pattern (see the plausible diphthongs in Quiaviní Zapotec in the phonotactics section in Chapter 1). For interrupted vowels, the realization of diphthongs is a rearticulated vowel, having one vowel quality before and the other after the glottalization.[115] Consider the examples in (42).[116]

(42) Interrupted-L (diphthongs)

a. / giˀa /	˩ → [gìˀà]	‘market’
b. / gagjeˀi /	˩ → [gagjèˀì]	‘around’
c. / ɾtiˀa /	˩ → [ɾtìˀà]	‘drinks’
d. / ʐgiˀa /	˩ → [ʐgìˀà]	‘Teotitlán del Valle’
e. /baɾ kigiˀa/	˥˩ → [báɾ kigìˀà]	‘first barrio’
f. / nduˀa /	˩ → [ndùˀà]	‘Oaxaca’

Possibly, another reason for these vowels to be pronounced as rearticulated vowels is to simply cue the speakers to a different tone. Realizing both interrupted H and L as checked vowels could obscure the contrast, whereas having an additional timing cue might facilitate such discrimination.

6.5.4 *Interrupted-F*

Finally, I conclude with the description of interrupted vowels with falling tone. Below, I list some examples of this type of vowel and describe the acoustic properties of some representative examples.

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[115] As mentioned in the previous section, the two possibilities for a diphthong to be realized as an interrupted vowel with high tone are: (i) as a checked vowel where both vowel qualities are produced before the glottalization; or ii) as a rearticulated vowel (with one vowel quality before and the other after the glottalization). In both cases pitch should be high to be classified as interrupted-H tokens. However, all checked vowels (i) are monophthongal, whereas for all rearticulated vowels (ii) the second vowel portion has low pitch.

[116] See §1.4.4 (phonotactics) in Chapter 1 for the diphthongs possible in Quiaviní Zapotec.

(43) Interrupted-F examples

a. / ɾgaˀ / ˥˩ → [ɾgáˀà] ‘pours’

b. / ɾaˀn / ˥˩ → [ɾáˀàn] ‘plows’

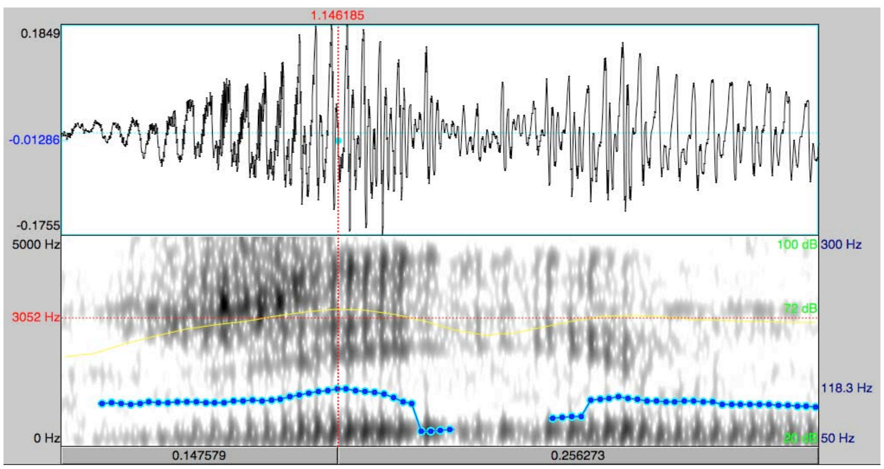
c. / ʒiˀ / ˥˩ → [ʒíˀì] ‘nose’

d. / ʒiˀnj / ˥˩ → [ʒíˀìɲ] ‘son’

e. / btjaˀ / ˥˩ → [btjáˀà] ‘scrapped’

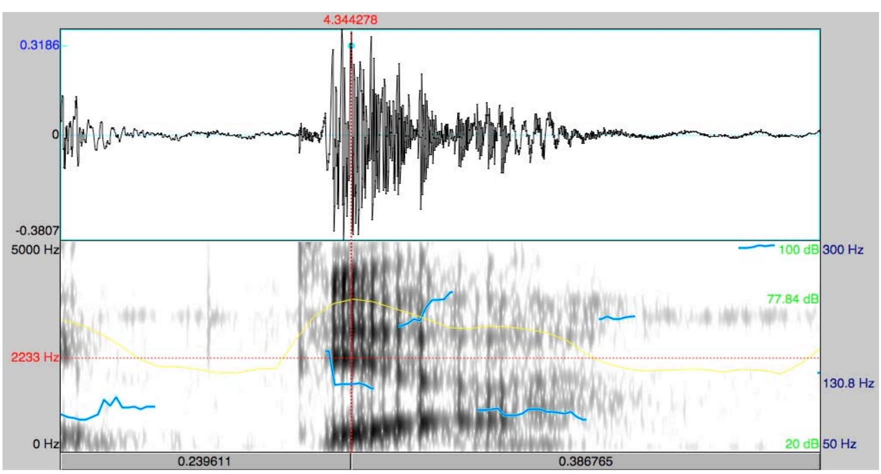
f. / ɾtiˀa / ˥˩ → [ɾtí ˀà] ‘gathers’

g. /ɾzeˀinj/ ˥˩ → [ɾzéˀìɲ] ‘get capricious’



[ʒ í ʔ ì]

Figure 62. Waveform and spectrogram of / ʒiˀ / ˥˩ → [ʒí ˀì] ‘nose’ by male speaker TiuC.



[b t ʰ j á a̰ ˀ à ḁ]

Figure 63. Waveform and spectrogram of / btjaˀ / ˥˩ → [btjáˀà] ‘scrapped’ by male speaker TiuC.

Starting with the analysis of pitch, both vowels show falling contours for the vowel as a whole. Based on the first and second vowel portions, the word [ʒíˀì] 'nose' shows a contour of 118-104 Hz, and [btjáˀà] 'scrapped', 121-100 Hz. Both examples are comparable to modal-H beginning and modal-L end equivalences, or to modal-F contour values. As the examples illustrate, falling tone is divided into the first and second vowel portions of the rearticulated vowel, and phonetically it is realized as a relatively flat high tone, on the first vowel portion, and a relatively flat low on the second vowel portion; instead of what could have been a high-mid contour followed by mid-low contour. Similar phonetic realizations of falling tone in interrupted vowels have been found for Quiaviní Zapotec children (J. Stemberger, personal communication, February 17, 2010).

Regarding duration, the first word starts with a modal vowel portion (68 ms), followed by a short creaky vowel and a glottal closure (less than 50 ms), and then a second modal vowel period (~ 65 ms). The syllable nucleus of the second word starts with a modal vowel portion (51 ms), followed by 68 ms of glottalization (a creaky portion with a short glottal stop, or simply as a period of creakiness), and a modal vowel portion (~ 61 ms) trailing off into voicelessness. The manifestation of these vowels is similar to that of interrupted-L vowels, showing variation for the interrupted portion in the middle. All these vowels have a larger amplitude drop than with simple creaky vowels. As a final point, these vowels can also be analyzed as phonologically long, at 199 and 195 ms, respectively.

6.5.5 Munro and Lopez (1999): Interrupted vowels

Munro and Lopez (1999) developed an orthography for Quiaviní Zapotec that presupposes a different phonological analysis than the one presented in the sections above regarding interrupted vowels. The objective of this discussion is to compare the two analyses, followed by a quantitative examination of interrupted vowels in Quiaviní Zapotec.

Table 81 presents the vowel patterns in Munro and Lopez (1999) that are considered here interrupted vowels.

Table 81. Munro and Lopez (1999) patterns for what is analyzed here as interrupted vowels

	High	Low	Falling	Rising
Interrupted	*aa'ah* (no coda)	*àa'ah* (no coda)	*a'ah* (no coda)	X
	a' (clitics)		*àa'a*+n	

These vowel patterns include sequences of different phonation types,[117] which may represent orthographic conventions rather than strict phonetic or phonological representation.

Although Munro and Lopez (1999) report a surface falling tone for all the vowel patterns in Table 81 (except clitics), the orthographic differences among them pattern with more specific pitch differences. In other words, I have found a systematic distinction that has to do with pitch/tone, though the orthographic depiction of the contrast does not convey this directly.

The orthography of these vowel patterns suggests a breathy vowel at the end; in my analysis, this corresponds to the echo vowel in interrupted vowels with high tone, which I argue is not relevant for tone, and to the second vowel portion of interrupted vowels with low and falling tones. Certainly, this second vowel portion may be acoustically weak and with a period of voicelessness at the end, especially if the word is pronounced in isolation or at the end of a phrase. In other contexts, however, no breathiness or voicelessness of this second vowel portion is found. For example, the vowel pattern *àa'a* is also reanalyzed as an interrupted vowel with falling tone, and although its production as a rearticulated vowel is clear, it never shows breathiness in the second half. This is illustrated in (44); these items all have a lenis coda.

(44) Interrupted-F, *àa'a* pattern

a. / ɾaˀn / ˥˩ → [ɾáˀàn] 'plows' (*ràa'an*)
b. / ʒiˀnj / ˥˩ → [ʒíˀìɲ] 'son' (*zhìi'iny*)
c. / ɾzeˀinj / ˥˩ → [ɾzéˀìɲ] 'get capricious' (*rzèe'iny*)

117 Recall that the Munro and Lopez (1999) orthography represents the four phonation types as follows: modal vowel *a*; breathy vowel *ah*; creaky vowel *à*; checked vowel *a'*.

These interrupted vowels appear in closed syllables before sonorants, and there is no context in which the rearticulated vowel shows any voicelessness at the end. For items in open syllables, we have seen above that for interrupted-H the second vowel portion is acoustically weak and has no information regarding tone (several tokens actually lack pitch, including all clitics); whereas for interrupted L and F, it was shown that this second vowel portion bears phonological information (clearer voicing). In other words, the analysis of the second vowel portion in interrupted vowels is crucial for distinguishing between interrupted (checked)-H versus interrupted (rearticulated)-L and -F. In order to confirm this analysis and in comparison with Munro and Lopez (1999), I conducted an acoustic experiment to determine the most relevant phonetic properties of these vowels.

6.5.6 Acoustic experiment: Interrupted vowels

6.5.6.1 Introduction

The hypothesis of this study is that interrupted vowels in Quiaviní Zapotec bear contrastive tone. The tonal distinctions within this phonation type will be observable in terms of pitch and the timing realization (checked versus rearticulated). The specific predictions are listed in (45).

(45) Tone (pitch) predictions: interrupted vowels

i) Interrupted (checked)-H: high pitch values during the first vowel portion.
ii) Interrupted (rearticulated)-L: low pitch values during the first and second vowel portions
iii) Interrupted (rearticulated)-F: high pitch values during the first vowel portion and low during the second.

With respect to the phonetic realization of interrupted vowels, the difference between a checked (interrupted-H) and a rearticulated (interrupted-L/F) vowel relies on the phonetic characteristics of the second vowel portion. The predictions are as presented in (46):

(46) Second vowel portion: interrupted vowels:

In comparison with interrupted-L/F, the second vowel portion of interrupted-H tokens (echo vowel) would show:

i) lower intensity values;
ii) shorter duration; and
iii) shorter voicing (fewer pitch pulses).

6.5.6.2 Methods

Stimuli: The stimuli consisted of four items of each type of interrupted vowel (interrupted-H, interrupted-L and interrupted-F), along with modal vowels with the same tone contrast (in order to compare the tone levels). All the items considered for this study are (near) minimal pairs.[118]

[118] I thank Pam Munro for supplying me with several of these pairs.

Table 82. Stimuli interrupted vowels

			dictionary	gloss
Interrupted-H	1	/ ɾgaˀ / ˥ → [ɾgáʔᵃ̥]	*rgaa'ah*	'becomes green again'
	2	/ ʒiˀ / ˥ → [ʒíʔⁱ̥]	*zhii'ih*	'cold'
	3	/ baˀ / ˥ → [báʔᵃ̥]	*baa'ah*	'earlier today'
	4	/ ɾʒiˀ / ˥ → [ɾʒíʔⁱ̥]	*rzhii'ih*	'spills'
Interrupted-L	5	/ ɾgaˀ / ˩ → [ɾgàˀà]	*rgàa'ah*	'gets caught'
	6	/ ʃtiˀ / ˩ → [ʃtìˀì]	*xtìi'ih*	'handle'
	7	/ baˀ / ˩ → [bàˀà]	*bàa'ah*	'eyeball'
	8	/ btjaˀ / ˩ → [btjàˀà]	*btyàa'ah*	'epazote'
Interrupted-F	9	/ ɾgaˀ / ˥˩ → [ɾgáˀà]	*rga'ah*	'pours'
	10	/ ʒiˀ / ˥˩ → [ʒíˀì]	*zhi'ih*	'nose'
	11	/ btiˀ / ˥˩ → [btíˀì]	*bti'ih*	'blister'
	12	/ btjaˀ / ˥˩ → [btjáˀà]	*btya'ah*	'scrapped'

Table 83. Complementary stimuli: modal vowels

			dictionary	gloss
Modal -H	1	/ nda / ˥ → [ndáː]	*ndaa*	'bitter'
	2	/ ʒi / ˥ → [ʒíː]	*zhii*	'tomorrow'
	3	/ gjia / ˥ → [gʲííːá]	*gyiia*	'will go home'
	4	/ rga / ˥ → [rgáː]	*rgaa*	'feels pity'
Modal -L	5	/ nda / ˩ → [ndàː]	*ndàa*	'sensitive'
	6	/ ʒi / ˩ → [ʒìː]	*zhìi*	'quite'
	7	/ gia / ˩ → [gìːà]	*gyìa*	'agave root'
	8	/ be / ˩ → [bèː]	*bèe*	'mesquite bean'
Modal-F	9	/ aʐ / ˥˩ → [âːʐ]	*a'àazh:*	's/he'
	10	/ ʒilj / ˥˩ → [ʒîːlʲ]	*zhi'ìilly*	'sheep'
	11	/ gel / ˥˩ → [gêːl]	*gue'èell*	'by chance'
	12	/ beu / ˥˩ → [bêˑu]	*Be'èu*	'moon, month'

Every word was recorded three times from a randomized list by one male speaker (TiuC) and one female speaker (LiaL) using the convenient carrier phrase:

(47) [mnḭ ______ nado̰ta] ‘Say ______ first’
(*Mnìì'* ______ *nadòo’ta*)

Acoustic measurements: As mentioned above, the acoustic parameters considered in this analysis are pitch, intensity, duration and pitch pulses.[119]

As illustrated above, interrupted vowels normally consist of a modal vowel interrupted in the middle by a period of glottalization. Thus, these vowels were divided into three portions for measurement purposes.

(48) Vowel divisions

- 1st vowel portion (modal-voice-like)
- interrupted /glottalized portion (glottal closure or creakiness)
- 2nd vowel portion (modal-voice-like)

For the division criteria of interrupted vowels, I already discussed the difficulty of determining the boundary between the 1st vowel portion and the interrupted section. The main issue is the variation of this glottalized portion, which most of the time includes a transitional interval. The criterion that I follow in this study is to consider anticipatory creaky voice as part of the interrupted portion of the interrupted vowel: creakiness and full glottal closure are both acceptable phonetic realizations, and particular tokens may have one or both.

Pitch was obtained only for the modal vowel portions; it was not measured during the glottalized section of the vowel. Intensity and duration were measured for each section (as well as the whole vowel), although the significance of these parameters relies on the second vowel portion. Finally, the duration of the second vowel portions was broken down into the percentage of voicing, decided via the presence vs. absence of pitch pulses. Modal vowels were measured for average pitch in the cases of high and low tokens, and at the beginning and end of the vowel in the case of falling tone. (See §3.2 in Chapter 3 for operational definitions regarding the “beginning” and “end” of a vowel.)

119 Periodicity (jitter) and spectral tilt have been used in other sections of the dissertation to determine the voice quality of different items. For this comparison, the phonation type of interrupted vowels is not in question. All of them show strong glottalization, so these parameters were not included.

6.5.6.3 Results

The first parameter I present is pitch. Mean values and standard deviations for interrupted vowels (pitch under investigation) and modal vowels (control), for both female and male speakers, are given in Table 84 and Table 85.

Table 84. Pitch results for interrupted and modal vowels — female speaker, LiaL

Pitch (Hz)		1stV	Glot	2ndV		Total
Mean	Interrupted-H	**222**	NA	**170**	Modal-H	**206**
SD [120]		28	NA	25.9		9
Mean	Interrupted-L	**186**	NA	**181**	Modal-L	**188**
SD		9.7	NA	8.1		4
Mean	Interrupted-F	**199**	NA	**165**	Modal-F	**201-171**
SD		11	NA	23.3		10

Table 85. Pitch results for interrupted vowels — male speaker, TiuC

Pitch (Hz)		1stV	Glot	2ndV		Total
Mean	Interrupted-H	**124**	NA	**96**	Modal-H	**121**
SD		4.7	NA	28.8		4.7
Mean	Interrupted-L	**109**	NA	**100**	Modal-L	**102**
SD		6.0	NA	6.9		3.4
Mean	Interrupted-F	**119**	NA	**96**	Modal-F	**115-96**
SD		6.4	NA	9.8		8.6

Pitch results for interrupted vowels from both speakers confirmed the picture outlined in the previous sections. Pitch values of the first portion of interrupted-H tokens parallel those of modal-H tokens. Moreover, the pitch difference between interrupted-H tokens and interrupted-L ones was significantly different for both speakers (two tailed t-tests with unequal variance: LiaL, $p = .013$; TiuC, $p < .001$).

With respect to interrupted-L and -F tokens, considering both modal portions, these vowels also pattern with modal-L and modal-F, respectively.

[120] Standard deviation.

In order to evaluate the phonological status of the second vowel portion in interrupted vowels, tokens were measured for intensity and duration. Results are provided in the following table.

Table 86. Intensity results for interrupted vowels (LiaL and TiuC)

Intensity (dB)		LiaL				TiuC			
		1stV	Glot	2ndV	Total	1stV	Glot	2ndV	Total
Mean	Interrupted-H	70.8	62.3	**58.9**	63	71.3	63.1	**59.2**	66.4
SD		2.9	3.5	3.8	3	3.7	3.3	5.1	4.0
Mean	Interrupted-L	71.7	60.6	**65.7**	65	70.3	63.2	**64.5**	65.4
SD		3	4.3	2.2	3.1	3.6	4.5	3.4	3.8
Mean	Interrupted-F	69.3	61.6	**65.9**	64	69.3	64.1	**63.1**	65.5
SD		1.3	2.0	1.8	2	2.4	2.2	2.0	2.2

All types of interrupted vowels show a decrease in intensity values moving from the 1st modal portion of the vowel into the interrupted interval, an intrinsic characteristic of interrupted vowels, but the focus of this comparison relies on the second vowel portion. Intensity values for interrupted-H were the lowest in this parameter, but the divergences are not large. Although small differences in intensity may be perceptually relevant, results were not statistically significant ($p \approx 0.5$ or higher for both speakers).

Duration results are presented in the following table.

Table 87. Duration results for interrupted vowels (LiaL and TiuC)

Duration (ms)		LiaL				TiuC			
		1stV	Glot	2ndV	Total	1stV	Glot	2ndV	Total
Mean	Interrupted-H	47	66	**43**	154	62	68	**54**	184
SD		10.7	15	8.6	11.4	9.2	18.8	15.8	43.8
Mean	Interrupted-L	50.2	70	**64**	192	59	51	**70**	179
SD		10	10	17.8	12.2	11.6	11.2	24.6	47.4
Mean	Interrupted-F	53	56	**70**	180	57	64	**66**	188
SD		7.9	11	10.3	10.5	10.2	18.2	16.2	44.6

Duration of the first vowel portion in all three types of interrupted vowels is quite similar for both speakers, and with no significant differences (see t-tests in Table 88). In comparison, the glottalized/interrupted and the second vowel portions of these vowels show differences within and across speakers. Beginning with LiaL, the longest glottalized portion is that of interrupted-L, followed by tokens with H and F tones. The only significant difference during this portion was found between interrupted-L vs. F. More importantly, the second vowel portion of interrupted-H tokens was shorter and significantly different compared with interrupted-L and F tokens.

With respect to TiuC, the longest interrupted portion is reported for the vowels with high tone, then falling and then low tone, although differences are not large. Interrupted-H values were significantly different from interrupted-L (Table 88). Finally, the second vowel portion of interrupted-H tokens is the shortest, as with LiaL. Results were marginally significant when comparing interrupted-H vs. both interrupted-L and -F.

Table 88. Probability values from t-test for duration (LiaL and TiuC)

T-TEST	LiaL			TiuC		
	1stV	Glot	2ndV	1stV	Glot	2ndV
Interrupted-H vs. L	0.593	0.342	**0.013**	0.355	**0.008**	**0.051**
Interrupted-H vs. F	0.159	0.072	**0.000**	0.175	0.625	**0.045**
Interrupted-L vs. F	0.474	**0.015**	0.417	0.740	**0.025**	0.703

The last parameter to be considered is the voicing of the second vowel portion of interrupted vowels. I measure the duration of voicing (pitch pulses) within these second vowel-portions versus the duration of voicelessness for all the tokens. The prediction is that the second vowel portion in interrupted-H tokens will show less voicing, i.e. a larger portion of voicelessness. The following tables show the results and their statistical significance.

Table 89. Voicing results of the second vowel portion (interrupted vowels) (LiaL)

LiaL		2nd vowel duration	Voicing	%	Voicelessness	%
Interrupted-H	Mean	43	36.5	83%	6.5	17%
	SD	8.6	14.9		8.1	
Interrupted-L	Mean	64	55.6	87%	8.4	13%
	SD	17.8	11.4		6.9	
Interrupted-F	Mean	70	61.3	88%	8.7	12%
	SD	10.3	7.5		7.3	

Table 90. Probability values from t-test for voicing (second vowel portion; LiaL)

T-TEST	Voicing	Voicelessness
Interrupted-H vs. L	**0.032**	0.622
Interrupted-H vs. F	**0.011**	0.841
Interrupted-L vs. F	0.846	0.446

Table 91. Voicing results of the second vowel portion (interrupted vowels) (TiuC)

TiuC		2^{nd} vowel duration	Voicing	%	Voicelessness	%
Interrupted-H	Mean	54.4	42.4	78%	12.0	22%
	SD	15.8	19.9		9.3	
Interrupted-L	Mean	70	62.3	89%	7.7	13%
	SD	24.6	24.3		7.1	
Interrupted-F	Mean	66	61.5	93%	4.5	7%
	SD	16.2	15.2		7.3	

Table 92. Probability values from t-test for voicing (second vowel portion; TiuC)

T-TEST	Voicing	Voicelessness
Interrupted-H vs. L	0.137	**0.086**
Interrupted-H vs. F	**0.025**	0.238
Interrupted-L vs. F	0.666	0.569

Results show that the second vowel portion of interrupted-H tokens has the least amount of voicing among the interrupted vowels for both speakers. The voicing difference between interrupted-H vs. interrupted-L and –F tokens was significant in the case of LiaL. There were no differences on the voiceless period. As for TiuC, voicing differences were only significant between Interrupted-H vs. F, and marginally significant during the voiceless portion of Interrupted-H vs. L.

6.5.6.4 Discussion

The results of this experiment clearly support the predictions in terms of pitch, presented in (45), and repeated below.

(49) Tone (pitch) predictions: interrupted vowels

i) Interrupted (checked)-H: high pitch values during the first vowel portion.
ii) Interrupted (rearticulated)-L: low pitch values during the first and second vowel portions
iii) Interrupted (rearticulated)-F: high pitch values during the first vowel portion and low during the second.

Pitch results support the hypothesis that interrupted vowels bear high, low and falling tones. Interrupted-L tokens show an average pitch drop of 6 Hz for LiaL and 10 Hz for TiuC between the first and second vowel portions. This difference is hardly sufficient to consider it a contour tone (falling), and it is in fact a common change for a level tone (Chapter 4 shows that slight pitch lowering is common even in modal-L tokens in Quiaviní Zapotec). In comparison, interrupted-F tokens for LiaL average a 34 Hz fall, 199-165, whereas TiuC averages a 23 Hz fall, 119-96. Both patterns are clearly falling.

The most crucial comparison is that between the first vowel portion of interrupted-H tokens versus interrupted-L. The difference is significant for both speakers.

Let us consider in more detail the results for interrupted (checked)-H tokens, in particular, with respect to the second vowel portion. The results for LiaL show an average pitch of 222 Hz during the first portion and 170 H for the second. TiuC averages 124 vs. 96 Hz. However, as presented above, the portion after the glottal closure in the case of high-tone tokens is quite inconsistent in terms of pitch, and this is corroborated by the high standard deviations (LiaL: 25.9; TiuC: 28.8), much greater than any tonal difference in this study. These results demonstrate variation of pitch, and partially support the claim that pitch following the glottal is not relevant to tone. For further evidence bearing on the tone of the second vowel portion, I turn to the rest of the phonetic parameters.

The difference between a checked (interrupted-H) and a rearticulated (interrupted-L/F) vowel relies on the phonetic characteristics of the second vowel portion, as predicted in (46), repeated below in (50).

(50) Second vowel portion, interrupted vowels:

In comparison with interrupted-L/F, the second vowel portion of interrupted-H tokens (echo vowel) would show:

i) lower intensity values;
ii) shorter duration; and
iii) shorter voicing (fewer pitch pulses).

The timing patterns are a crucial aspect of the difference between the checked versus rearticulated analyses. In the first vowel portion, the duration is quite similar for the three vowels and with no significant differences (Table 88) whereas for the interrupted portion we can identify some differences. The longest interrupted portion is reported for the vowels with high tone, then falling and then low tone. If interrupted-H vowels are realized as checked, we in fact predict that they have a longer glottal closure. As illustrated in Table 88, differences are significant between Interrupted-H vs. -L tokens, non-significant between Interrupted-H vs. -F, and marginally significant when comparing interrupted-H vs. both interrupted-L and -F tokens. Finally, the second vowel portion of interrupted-H tokens is the shortest, as predicted. Although differences are not large, results were statistically significant (interrupted-H vs. -F, and interrupted-H vs. both interrupted-L and F tokens), and marginally significant (interrupted-H vs. L tokens).

The last parameter considered was voicing of the second vowel portion of interrupted vowels. Although results were in the predicted direction, differences were not large. For both speakers, the second vowel portion in interrupted-H tokens showed less voicing, and a larger portion of voicelessness when compared to interrupted-L and F, but results were marginal or non-significant.

To sum up the phonetic differences for the second vowel portion of interrupted vowels, results show that this final vowel portion has a shorter duration and shorter voicing (fewer pitch pulses) for interrupted-H tokens. Although the differences are not substantial, these predicted tendencies are strengthened if we consider the additional evidence presented in §6.5.2. This includes the lack of diphthongs for interrupted vowels with high tone, the clear phonetic realization of clitics as checked vowels (for which there is almost never an echo vowel), and the perceptual field test, where speakers identified interrupted-L and F vowels as interrupted-H, once these vowels were reduced to their first and glottalized portions only (suggesting the checked realization is an important cue distinguishing interrupted-H vowels).

Despite the partial results for the timing realization of interrupted vowels, tonal contrasts are maintained within these non-modal vowels and, consequently, support the hypothesis that interrupted vowels bear contrastive tone.

6.5.7 Interim summary: Interrupted vowels

I have argued here that the main difference among interrupted vowels is tone: in addition to minimal pairs, the acoustic analysis demonstrated that there are significant pitch differences for claimed high, low and falling items. In turn, tone determines the phonetic realization of these vowels: interrupted vowels with high tone are realized as checked vowels, a sequence of modal voice followed by glottalization, and optionally ending with an echo vowel (rare in clitics, common in roots). Interrupted vowels with low or falling tone surface as rearticulated vowels. In these vowels, both the first and second modal portions are relevant for the expression of tone, implementing glottalization in the middle.

Table 93. Interrupted vowels

	High	Low	Falling
Interrupted / aˀ /	[áʔᵃ̥]	[àˀà]	[áˀà]
	(checked)	(rearticulated)	(rearticulated)

6.6 General discussion

This section presents two further points of discussion with respect to the analysis of non-modal phonation in Quiaviní Zapotec. First, I show a side-by-side comparison of modal, creaky and interrupted vowels. Since the distinction between creaky and interrupted vowels has rarely been analyzed as contrastive cross-linguistically, it merits additional discussion and so, for descriptive interest, I present an overall comparison, along with minimal pairs.

Second, I summarize the timing patterns in non-modal phonation described in this chapter, as a crucial aspect in the phonetic implementation of the phonological contrasts in Quiaviní Zapotec.

6.6.1 Laryngeal vowels (creaky and interrupted): side-by-side comparison

A key aspect of the four-way phonation contrast in this language was establishing the unusual contrast between creaky and interrupted vowels. The previous two sections provided a detailed analysis of these voice qualities and demonstrate that laryngealized vowels bear contrastive tone. Creaky and interrupted vowels may be associated with high, low and falling tones (Table 94). I have not identified lexical items with laryngealized vowels that have rising tone. Minimal pairs in (51) illustrate the contrast between these two types of laryngealized vowels.

Table 94. Tone & phonation distribution: modal and laryngealized vowels

	High	Low	Falling	Rising
Modal	√	√	√	√
Creaky	√	√	√	X
Interrupted	√	√	√	X

(51) Creaky versus interrupted minimal pairs

a. / tsḛḭɲ / ˩ ‘fifteen’ vs. / tseˀiɲ / ˩ ‘thirteen’

b. / gḭa̰ / ˥˩ ‘flower’ vs. / giˀa / ˥˩ ‘market’

c. / ga̰ / ˥˩ ‘nine’ vs. / n-gaˀ / ˥˩ ‘green’

In related languages with a comparable phonetic contrast, the distinction is more typically allophonic, with the difference analyzed with the feature [constricted glottis] applied to both type of vowels (see next Chapter for a discussion of laryngeal features). However, based on Munro and Lopez (1999), I argue that in Quiaviní Zapotec creaky and interrupted vowels contrast with each other, suggesting two degrees of laryngealization at the phonological level. The main phonetic properties that characterize this contrast are intensity and airflow interruption. Creaky vowels have relatively continuous airflow and higher intensity than interrupted vowels, which show a drop in the amplitude envelope and strong or full glottalization. Below, I illustrate these parameters in the waveform and the spectrogram of these sounds.

In favour of two degrees of laryngealized vowels is the fact that a large degree of phonetic variation has been attested in the literature. Ladefoged and Maddieson (1996, p. 100) recognize glottal states such as creaky voice and glottal closure (checked), along with other parameters like stiff and slack voice, and suggest that all these phonation types "need to be distinguished within whatever feature set is proposed." (The issue of feature specification will be discussed in the next chapter.)

To the best of my knowledge**,** the first study that reported the phonemic distinction between creaky and checked (interrupted) vowels is Lyman and Lyman (1977) for Choapan Zapotec. Subsequently, a contrast among larygealized vowels has been described in Cajonos Zapotec (Nellis & Hollenbach, 1980, pp. 97-98), Quiaviní Zapotec (Munro & Lopez, 1999), Chichicapan Zapotec (Smith-Stark, 2003), and Güilá Zapotec (Arellanes, 2009); the last three variants are Valley Zapotec languages. The question remains, whether this is a unique characteristic of the Otomanguean family, particularly the Zapotec languages.[121]

In what follows I present a comparison of modal, creaky and interrupted vowels with high, low and falling tones. The goal of this comparison is to demonstrate the contrast between creaky and interrupted vowels by showing minimal pairs, along with

[121] In contrast, other scholars report allophonic variation between creaky and checked vowels. For instance, Jones and Knudson (1977) report that in Guelavía Zapotec (Valley) checked vowels contrast phonemically with plain vowels, but are in complementary distribution with creaky vowels. See also Ramos (2007).

their tone distribution and acoustic realization (both analyzed separately in the previous sections).

High tone

The (near) minimal pairs below illustrate the contrast among modal, creaky and interrupted vowels with high tone.

(52) a. / ʒi / ˥ → [ʒíː] ‘tomorrow’
b. / ʒḭmˑj / ˥ → [ʒ̰ímːʲ] ‘basket’
c. / ʒiˀ / ˥ → [ʒíʔ̥ⁱ] ‘cold’

(53) a. / ɾga / ˥ → [ɾgáː] ‘feels pity’
b. / ɾga̰n / ˥ → [ɾgá̰ːn] ‘pets’
c. / ɾgaˀ / ˥ → [ɾgáʔ̥ᵃ] ‘gets green’

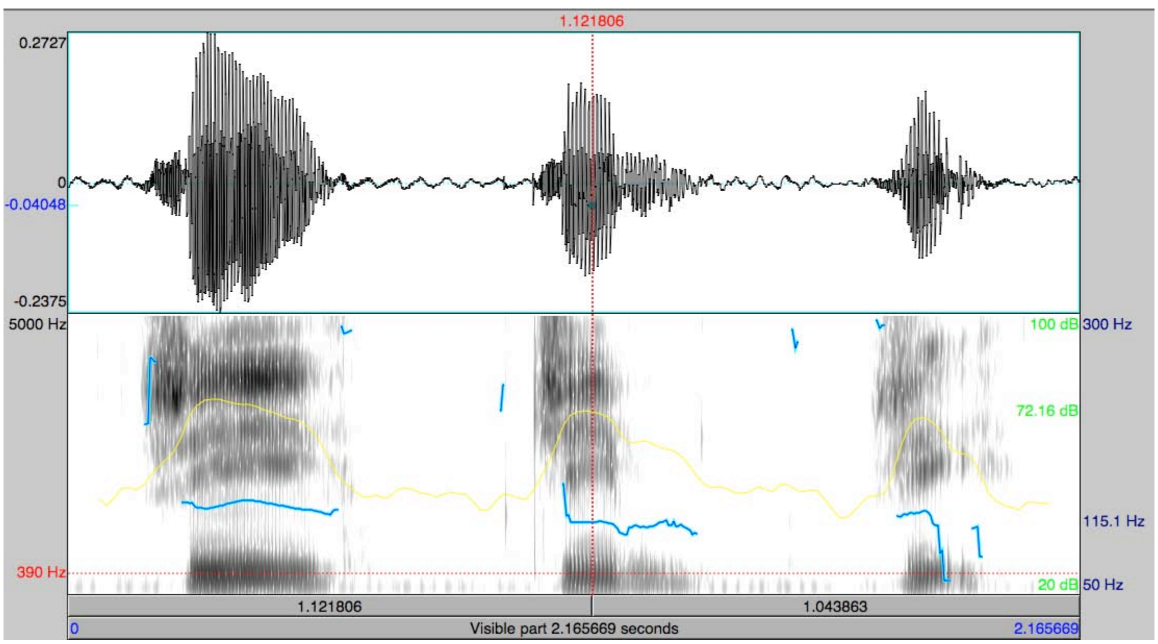


Figure 64. Waveform and spectrogram of / ʒi / ˥ → [ʒíː] ‘tomorrow’; / ʒ ḭmˑj / ˥ → [ʒ̰ímʲː] ‘basket’; and / ʒiˀ / ˥ → [ʒíʔ̥ⁱ] ‘cold’ by male speaker TiuC.

(54) High tone measures

a. / ʒi / ˥ → [ʒíː] ‘tomorrow’ (pitch: 128 Hz; duration: 280 ms)
b. / ʒḭl̰ˑj / ˥ → [ʒḭ́lʲː̥] ‘basket’ (pitch: 117 Hz; duration: 120 ms (+140 ms C))
c. / ʒiˀ / ˥ → [ʒíʔ̥ⁱ] ‘cold’ (pitch: 124 Hz; duration: 191 ms)

The pitch averages of the examples above illustrate the similarity and pattern of modal and laryngealized vowels with respect to high tone. Although the phonation types are different: modal, tense and checked—mainly reflected in differences in intensity, aperiodicity and pitch pulses—the three vowels have high pitch values.

Low tone

The (near) minimal pairs below illustrate the contrast among modal, creaky and interrupted vowels with low tone.

(55) a. / ɾbanj / ˩ → [ɾbàːɲ] ‘survives’
b. / ba̰ / ˩ → [bà̰ː] ‘tomb’
c. / baˀ / ˩ → [bàˀà] ‘eyeball’

(56) a. / gjia / ˩ → [gʲìˑà] ‘agave root’
b. / gjḭa̰ / ˩ → [gʲḭ̀à̰] ‘flower’
c. / gjiˀa / ˩ → [gʲìˀà] ‘market’

(57) a. / be / ˩ → [bèː] ‘mesquite bean’
b. / bḛ / ˩ → [bḛ̀ː] ‘Tanivet (*X:ta'isy Dàany Bèèe'*)’
c. / bleˀ / ˩ → [blèˀè] ‘take it out’

(58) a. ---
b. / tsḛḭɲ / ˩ → [tsḛ̀ḭ̀ɲ] ‘fifteen’
c. /tseˀiɲ/ ˩ → [tsèˀìɲ] ‘thirteen’

Figure 65 shows the waveforms and spectrograms of the examples in (55).

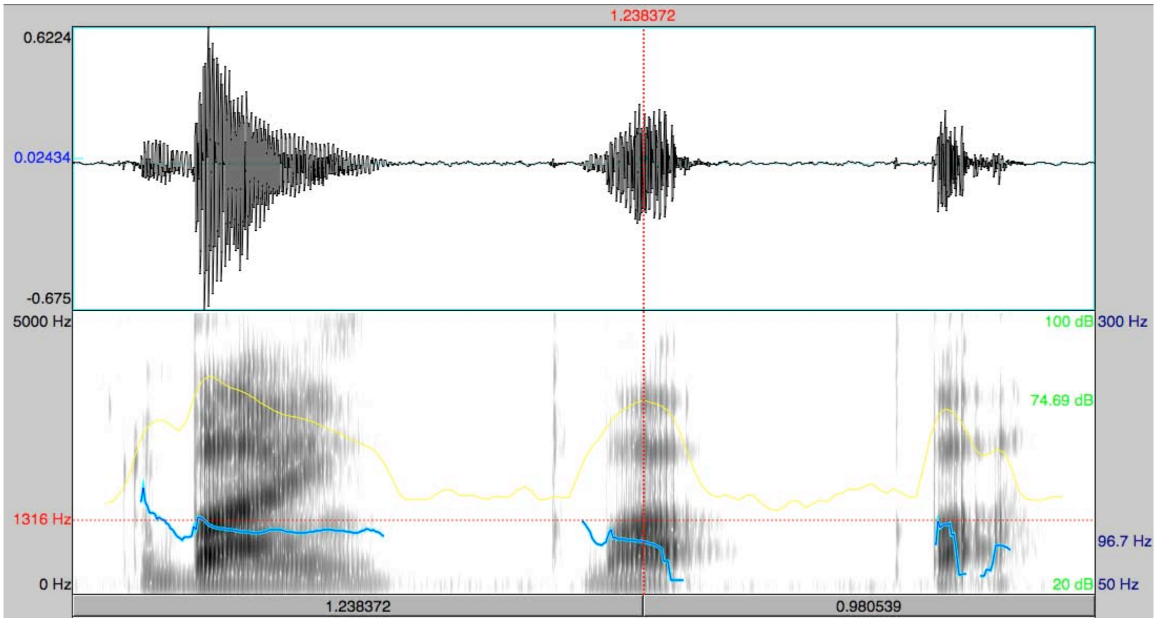


Figure 65. Waveform and spectrogram of / ɾbanj / ˩ → [ɾbàːɲ] ‘survives’; / ba̰ / ˩ → [bà̰ː] ‘tomb’; / baˀ / ˩ → [bàˀà] ‘eyeball’ by male speaker TiuC.

In Figure 65, the creaky example (in the middle of the spectrogram), shows an initial modal section where the pitch is relatively flat. This corresponds to the expression of the phonological tone. During the second half of the vowel the pitch drops and, concomitantly, the voice becomes creaky, reflected in the change in the appearance of the pulses in the spectrogram (an indication of jitter) and the decrease in amplitude. In comparison, the interrupted vowel is realized as a modal vowel with strong laryngealization in the middle, where the intensity is even lower than that of the creaky vowel. At the end of the first modal section the pitch drastically drops as the creakiness increases to eventually disappear in the middle of the vowel. Both the pitch and the voice get back to some regularity towards the last portion of the vowel. Clearly, the examples in illustrate three different phonation types, but in terms of tone and length, the three lexical items all express low tone and have very similar duration (59).

(59) Low tone measures

a. / ɾbanj / ˩ → [ɾbàːɲ] ‘survives’ (pitch: 106 Hz; duration: 235 ms)
b. / ba̰ / ˩ → [bà̰ː] ‘tomb’ (pitch: 97 Hz; duration: 220 ms)
c. / baˀ / ˩ → [bàˀà] ‘eyeball’ (pitch: 98 Hz (103-93); duration: 180 ms)

Falling tone

In turn, the following (near) minimal pairs contrast modal, creaky and interrupted vowels with falling tone.

(60) a. / ʒilj / ˥˩ → [ʒîːlʲ] ‘sheep’
b. / ʒḭl̰j / ˥˩ → [ʒḭ̂ːlʲ] ‘cotton’
c. / ʒiˀ / ˥˩ → [ʒíˀì] ‘cold’

(61) a. / beu / ˥˩ → [béù] ‘moon’
b. / bḛṵ / ˥˩ → [béṵ̀] ‘coyote’
c. / bteˀu / ˥˩ → [btéˀù] ‘type of bee’

(62) a. ---
b. / ga̰ / ˥˩ → [gâ̰ː] ‘nine’
c. /n-gaˀ/ ˥˩ → [ŋgáˀà] ‘green’

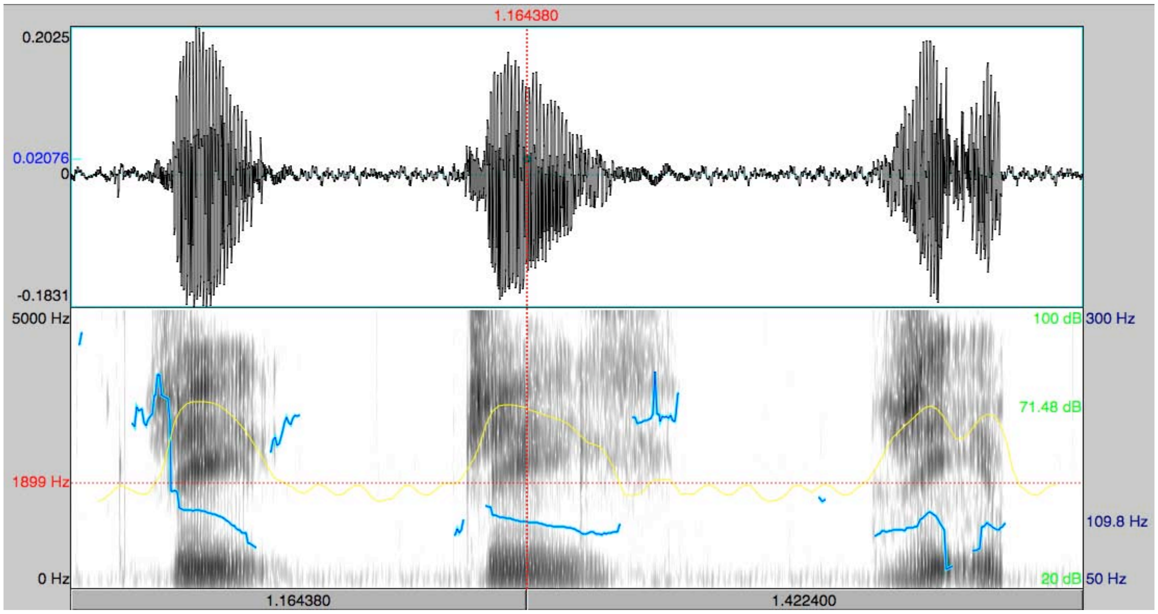


Figure 66. Waveform and spectrogram of / ʒilj / ˥˩ → [ʒîːlʲ] 'sheep'; / ʒḭl̰j / ˥˩ → [ʒḭ̂ːlʲ] 'cotton'; / ʒiˀ / ˥˩ → [ʒíˀì] 'cold' by male speaker TiuC.

(63) From Figure 66:

a. / ʒilj / ˥˩ → [ʒîːlʲ] 'sheep' (pitch: 120-90 Hz; duration: 199ms)

b. / ʒḭl̰j / ˥˩ → [ʒḭ̂ːlʲ] 'cotton' (pitch: 118-99 Hz; duration: 240 ms)

c. / ʒiˀ / ˥˩ → [ʒíˀì] 'cold' (pitch: 118-103 Hz; duration: 223 ms)

Once again, we observe that pitch values are within similar ranges for modal, creaky and interrupted vowels with falling tone. Intensity drops towards the end of the creaky vowels, but more noticeably at the middle of the rearticulated vowel. Nonetheless, it is desirable for future work to evaluate more systematically the phonetic parameters presented in this section (in the form of an experiment), both at the production and perceptual levels.

As a final point, I conclude this section with discussion of the co-occurrence of laryngealized vowels and tone. Although non-modal phonation is cross-linguistically associated with lowering of the fundamental frequency, there have been studies reporting the interaction between creaky voice and high tone. In fact, scholars have reported the tonogenesis of high tone as a reflex of glottal constriction (Hombert et al., 1979; Leer, 1979; Kingston, 2005). Creaky vowels in Quiaviní Zapotec may appear on the same mora as a high tone, but in order to phonetically coexist with this tone, the laryngealization employed is weak for such cases. Tone for interrupted vowels occurs during their modal portion, so there are less inherent articulatory restrictions to produce high tone. Laryngeal vowels then, both creaky and interrupted, co-occur with level tones—high and low—as well as falling tone.

Table 95. Tone & phonation: modal vs. laryngeal vowels

	High	Low	Falling	Rising
Modal	√	√	√	√
Laryngeal	√	√	√	X

In tonal languages the presence of contours seem to imply the presence of level tones. With this in mind, it is expected that non-modal vowels should be possible with level tones. As for the presence of falling tone and the absence of rising tone, the former is typologically much more common than the latter (Gordon, 2001; Zhang, 2001). The articulatory demands for a rising tone are higher than for either a level or a falling tone. Taking these facts into account the non-modal gap for rising tone in Quiaviní Zapotec follows a typological scale in terms of tone preference.

In terms of markedness, non-modal phonation is marked with respect to modal voice, and a rising tone appears to be a highly marked pitch contour cross-linguistically. Hence, the co-occurrence of laryngealized vowels with rising tone is avoided. More specifically, in the case of Quiaviní Zapotec, I have shown that non-modal phonation is confined to the second portion of breathy, creaky and checked vowels. Accordingly, the high portion of a rising tone would tend to be realized on the non-modal portion of the vowel. The absence of rising tones, therefore, relates to co-occurrence conditions on high tone and non-modal phonation (see next chapter).

Another important aspect of the phonetic realization of non-modal voice in Quiaviní Zapotec is that the degree of laryngeal constriction varies depending on the tone being expressed, as illustrated in Table 96. Creaky vowels with high tone have weak laryngealization, and are not realized with prototypical creaky voice, but instead with tense voice. By contrast, creaky-L and -F items show prototypical creaky voice. On the other hand, interrupted vowels also differ when expressing high tone. Their realization seemingly consists of a checked vowel [aʔ], whereas interrupted-L and -F are realized as rearticulated vowels [aˀa]. These “parallel” realizations of tone add to the already natural class that laryngealized vowels forms, by sharing a constricted glottis laryngeal state.

Table 96. Laryngeal constriction variation

	High	Low	Falling
Creaky / a̰ /	[á͡á̰̬] (tense)	[à͡a̰] (creaky)	[â͡a̰] (creaky)
Interrupted / aˀ /	[áʔᵊ̥] (checked)	[àˀà] (rearticulated)	[áˀà] (rearticulated)

In conclusion, Quiaviní Zapotec and its rich four-way set of non-modal phonation contrasts exemplifies two extremely uncommon typological characteristics: first, two degrees of phonological contrasts within laryngealized vowels (creaky versus interrupted); and second, the fact that these vowels may bear high tone.

6.6.2 Timing in non-modal vowels

An important aspect of non-modal phonation in Quiaviní Zapotec is the phonetic implementation of phonological contrasts. I have shown that non-modal voice does not last for the whole duration of the vowel, but is localized to a portion of it. In other words, a portion of the vowel is characterized by modal phonation. This modal portion takes place at the beginning of breathy, creaky and interrupted vowels, and it normally constitutes about the first half of the duration of the vowel. Breathy-L and creaky-L are the only instances where modal voice may not be present at all, as breathiness and creakiness are compatible with lowered pitch. This phonetic realization is schematized in Table 97.

Table 97. Tone & phonation distribution (phonetic implementation)

	High	Low	Falling	Rising
Modal	modal	modal	modal	modal
Breathy	X	(modal)-breathy	modal-breathy	X
Creaky	modal-tense	(modal)-creaky	modal-creaky	X
Interrupted	modal-glottal-(echo)	modal-glottal-modal	modal-glottal-modal	X

Previous studies have reported this modal voice component in the implementation of breathiness and creakiness, as in the case of Jalapa Mazatec, also an Otomanguean language (Silverman et al., 1995; Blankenship, 1997). Silverman (1997) suggests a link between the confinement of non-modal phonation to a portion of vowels and the contrastive use of tone in Jalapa Mazatec. He goes further and states that non-modal phonation affects fundamental frequency and unfavourably influences the ability of vowels to maintain tonal contrasts. As such, tone and phonation contrasts are realized via sequential timing: tonal contrasts are cued during modal phonation, followed by breathiness or laryngealization.

6.7 Conclusions

In this chapter, I have presented new phonological and phonetic evidence in the distribution and contrastive use of non-modal phonation in Quiaviní Zapotec. This includes modal, breathy, creaky and interrupted vowels, as originally described by Munro and Lopez (1999), considered under a new analysis that addresses the use of contrastive tone within non-modal phonation.

Chapter 4 demonstrated that tone is contrastive in Quiaviní Zapotec, and that all four tones can occur with modal voice. The present chapter has shown that breathy vowels can appear with low and falling tones, and both creaky and interrupted vowels appear with high, low and falling tones. The 12 vowel patterns in Quiaviní Zapotec are summarized in Table 98.

Table 98. Tone & phonation distribution in Quiaviní Zapotec

	High	Low	Falling	Rising
Modal	√	√	√	√
Breathy	X	√	√	X
Creaky	√	√	√	X
Interrupted	√	√	√	X

The phonotactics of tone and phonation, shown in Table 98, illustrate the contrastive but restricted distribution of non-modal phonation. While modal voice may be associated with all four tones, non-modal phonation's main gap is the lack of rising tone.

The next step is the considerable challenge of capturing Quiaviní Zapotec phonation types by means of laryngeal features. This endeavor is taken up in the next chapter.

Chapter 7:

Laryngeal complexity in Quiaviní Zapotec

7.1 Introduction

Two central issues in modern phonological theory are how to account for distributional restrictions within phonological systems and how such restrictions are motivated by phonetic patterns. This chapter addresses these issues, accounting for Quiaviní Zapotec non-modal phonation types and their interaction with tone.

Otomanguean languages are known for having complex tone systems and phonation contrasts. Silverman (1997, p. 236) refers to languages with vowels with both contrastive phonation and contrastive tone as *laryngeally complex.* This is certainly the case for Quiaviní Zapotec. As shown in previous chapters, this language possesses four contrastive tone melodies (high, low, rising and falling) and a four-way voice quality distinction with modal, breathy, creaky and interrupted vowels (cf. Munro & Lopez, 1999). In this chapter, I consider these contrasts, focusing on their featural specification and phonological representation.

The complexity relies on the number of distinctions involving the larynx, as both tone and phonation are based on the vibration of the vocal folds. This space is phonologically crowded and phonetic conflicts may arise, since some of these contrasts are incompatible (or, at least, difficult) if produced simultaneously (e.g. breathiness and high tone). In §7.2, I show that both tone and phonation challenge traditional ways of understanding phonological features and that we need a different account for Quiaviní Zapotec contrasts. In §7.3, I review the sound patterns and contrasts in which tone and phonation are used in Quiaviní Zapotec, and account for them under an emergent feature approach. Subsequently, taking into account the findings for metrical structure and tone from previous chapters, I present a comprehensive phonological representation of Quiaviní Zapotec vowels and prosody (§7.4). The chapter concludes with a formal analysis of Quiaviní Zapotec features and the tone-phonation interaction within Optimality Theory (Prince & Smolensky, 2004 [1993]).

7.2 Laryngeal accounts: Literature review & explanations

In light of Quiaviní Zapotec laryngeal contrasts, the goal of the following sections is to briefly review some models that aim to account for laryngeal contrasts, including tone and phonation types. We will see that both types of contrasts are challenging for the traditional view of phonological features, and partially inadequate for Quiaviní Zapotec.

7.2.1 The special status of tone

There have been many different attempts to formulate a satisfactory set of features for tonal contrasts, but tone phenomena are challenging to represent. In Leben's words (1973, p. 117):

> Is tone such a special phenomenon that it must be viewed as a feature on morphemes or larger units in some languages, as a feature on syllables in others, and as a feature on segments in still others? If so, then there is something left to explain: namely, why tone, unlike any other linguistic entity we know anything about, is capable of this many different types of representation.

Based on the arguable assumption that tones (like other segments) are composed of distinctive feature specifications, the desiderata for a feature system for tone might define contrastive levels, contours, relate tone features to laryngeal contrasts, and characterize observed tone alternations, among others. There has not been a consensus on such a model, but one fairly popular model uses two binary features, [upper] for tonal register, and a sub-component of it, [raised]. Four levels can thus be captured as follows:

(1) Tonal hierarchy (Pulleyblank, 1986, p. 125; after Yip, 1980)

[+upper]	[+raised]	H
	[-raised]	HM
[-upper]	[+raised]	M
	[-raised]	L

Systems with two levels have H lexically represented as [+upper], and L as [-upper]. It is not always clear, however, how to represent contours, as they behave differently in tonal languages. In addition, these features may be related to each other and to the laryngeal features that define voicing, aspiration and glottalization in a feature geometry that is still disputed. For various proposals and discussion see Halle and Stevens (1971; and below), Clements (1983), Bao (1990), Duanmu (1990, 1994), Hyman (1993), and Snider (1990, 1999).

Many issues have been raised in dealing with tonal feature models, among others, the number of possible level tones (most of these models account for 4 levels, enough for the majority of languages, but larger tonal systems have been reported in the literature), as well as the number of possible contour tones, not to mention their configuration. Another issue is where these features are associated. Do they link to the laryngeal node at the segmental level? This clearly predicts segmental behavior of tone, but tone is notorious for its independence from the segments on which it is realized (noticed since Firth 1948, and Pike 1948), and this fact led Goldsmith (1976) to propose that it be represented autosegmentally on a tier (or tonal node, Bao 1990) that is separate from the segments but linked to them by association lines.

The tone-segment segregation is supported by a wide variety of phenomena (mobility, stability, spreading, association, chain processes, etc.). Tone systems have properties that "surpass" segmental (and even metrical) systems; in other words, tone can do everything that segmental (and metrical) phonology can do, and more (Hyman, 2009). For this reason, tone phenomena do not fit well into conventional feature systems.

The purpose of this section has not been to present an exhaustive review of tonal models, but simply to show the challenge of accounting for tone featurally, particularly from a universalist perspective, where UG must provide a way to account for all patterns in tonal languages. Possibly most (or perhaps all) of the tone models in the literature would be able to account for the Quiaviní Zapotec tonal system, but assuming a universalist (nativist) approach, there would be unnecessary machinery in the phonological system of this language, with two level and two contour tones. In terms of acquisition there would be no evidence to show that children require that machinery to learn the tonal patterns in Quiaviní Zapotec; to put it differently, there is no evidence to show that children develop that model/machinery, except in languages where it is needed.

7.2.2 Laryngeal features

Laryngeal features have been a central concern of phonologists for more than 50 years (e.g. Jakobson, Fant & Halle, 1951; Chomsky & Halle, 1968, Kim 1970; Halle & Stevens, 1971, Iverson, 1983, Keating, 1984, Lombardi, 1991, Blevins, 1993, Kingston & Diehl, 1994, Iverson & Salmons, 1995, among others). The diversity of phonation types presented in the previous chapter, and particularly the distinction between creaky and interrupted vowels presents a phonological challenge. In generative phonology, all phonological contrasts are described by a set of universal features, provided by *Universal Grammar* if an innate approach is assumed (e.g. Chomsky & Halle, 1968), or part of a language-specific set of phonological features, assuming an emergent feature approach (Mielke, 2008 [2004]; Pulleyblank, 2006). The purpose of this discussion is to review different laryngeal feature models, in trying to account for the voice quality contrasts found in Quiaviní Zapotec.

A standard assumption in several feature geometry models is the existence of a laryngeal node (LN) from which the features [voice], [spread glottis] and [constricted glottis] are involved in the control of the larynx (Clements, 1985; Sagey, 1986; McCarthy, 1988; Odden, 1991; Shaw, 1991; Clements & Hume, 1995).

(2) LN

[voice] [spread glottis]

[constricted glottis]

Consider the following feature definitions (taken from Bernhardt & Stemberger 1998, Appendix B):

(3) Laryngeal features:

i) [+voice]: Sounds produced with vocal cord vibration (e.g., /d/, /i/).

ii) [+spread-glottis] ([s.g.]): The vocal cords are spread wide, leading to low-amplitude noise at the glottis.

iii) [+constricted-glottis] ([c.g.]): The vocal cords are pulled together tightly, so that regular periodic vibration is impossible.

Relating this set of phonological features to phonation types in vowels, we obtain the configurations in Table 99.

Table 99. Laryngeal specification for phonation types ([s.g.], [c.g.] & [voice])

	Voiceless V	Breathy V	Modal V	Laryngealized V	Glottal stop
[s.g.]	+	+	-	-	-
[c.g.]	-	-	-	+	+
[voice]	-	+	+	+	-

Let us now consider this set of laryngeal features in light of Quiaviní Zapotec. Based on Munro and Lopez (1999), the previous chapter showed the full range of phonation types in Quiaviní Zapotec, including breathy, modal, creaky and interrupted vowels. Phonetic and phonological evidence was presented to justify these four-way contrasts and their patterns. Accordingly, the specification of Quiaviní Zapotec vowels would be as follows:

(4) Distinctions between breathy, modal and creaky vowels in Quiaviní Zapotec

a) Breathy vowels	b) Modal vowels	c) Laryngeal vowels
V	V	V
|	|	|
LN	LN	LN
|	|	|
[+s.g.]	[-s.g.]	[-s.g.]
[-c.g.]	[-c.g.]	[+c.g.]

As illustrated, the features [s.g.], [c.g.] and [voice] would only account for the specification of three out of four voice quality contrasts in Quiaviní Zapotec. (The feature [voice] is not included as I assume all these vowels to be [+voice]). The problem derives from the distinction between creaky versus interrupted vowels: both would be specified as [+c.g.] (along with [-s.g.] and [+voice]). In other words, this feature set only allows for one type of laryngealized vowel.

The other laryngeal state in Table 99 is that of the glottal stop, specified as [+c.g.] and [-voice]. However, the glottal closure of interrupted vowels is analyzed as part of the vowel, not as an independent segment. Could this still be the specification of interrupted vowels? Differentiating creaky vowels from interrupted ones, as [+c.g., +voice] vs. [+c.g., -voice], respectively? It seems counter-intuitive to analyze interrupted vowels as phonologically voiceless, when this quality is not independently contrastive in Quiaviní Zapotec. One could assume that voiceless vowels must have a (predictable) voiced portion; however, the implication would be for these vowels to somehow pattern with [-voice] segments (e.g. fortis obstruents). In addition, such specification seems to be against the natural class formed by vowels in Quiaviní Zapotec; the feature [-voice] is a prototypical consonantal feature, but the glottal stop may or may not behave as a consonant within a given system.

An alternative scenario is to imagine solutions based on timing. Consider a specification like [-continuant, +strident] for an affricate, such as /ts/ (Clements, 1999). It poses a problem phonetically since stridency cannot be realized during the closure phase of a stop. The phonetic solution is based on timing: order the stridency after the stop phase. A similar scenario was presented with non-modal phonation in Quiaviní Zapotec (Chapter 6): breathy, creaky and interrupted vowels start with a modal portion, indicated by [+voice] and where tone is produced, and then, the vowel manifests non-modal phonation, incompatible for the most part with regular voicing and the expression of tone. The phonetic solution is timing in this case as well: order the modal voicing before the non-modal phonation. This analysis was presented in the previous chapter and it is applicable for both creaky and interrupted vowels; thus, a timing solution to differentiate these vowels from each other is not sufficient because it would not distinguish creaky and checked vowels.

Table 100. Timing patterns for laryngealized vowels (Quiaviní Zapotec)

<table>
<tr><td></td><td colspan="3">◄ vowel ►</td></tr>
<tr><td>Creaky vowels:</td><td colspan="2">modal voice = tone</td><td>non-modal voice</td></tr>
<tr><td>Checked vowels:</td><td colspan="2">modal voice = tone</td><td>non-modal voice</td></tr>
<tr><td>Rearticulated:</td><td>modal voice = tone</td><td>non-modal voice</td><td>modal voice = tone</td></tr>
</table>

(Checked and rearticulated are variants of interrupted vowels)

As shown in the graphic, if timing is to be encoded in Quiaviní Zapotec non-modal contrasts, then both creaky and checked vowels could be specified as contour segments: [-c.g.][+c.g.] (and even breathy vowels: [-s.g.][+s.g.]). Nonetheless, this phonation phasing is entirely predictable. If single specification at the phonological level will lead to a constant phonetic implementation, it seems unlikely that most vowel types in Quiaviní Zapotec are complex segments.

Even if all interrupted vowels were rearticulated, vowel specification would be unnecessarily complicated. Rearticulated vowels surface as a three-phase vowel, composed of a modal-glottalized-modal sequence. These vowels then would be triple contour segments as [-c.g.][+c.g.] and again [-c.g.]. In addition, the surface variation of non-modal vowels in terms of timing makes it hard to rely on (for instance, a creaky vowel with low tone may show creakiness during the whole vowel). Encoding timing into phonological features has been generally problematic, and for the most part rejected (e.g. Silverman, 1997a, 1997b). Here, this solution does not seem applicable to Quiaviní Zapotec, or other Otomanguean languages.

There is a universalist model that recognized the distinction between creaky and interrupted (glottalized) vowels, that of Halle and Stevens (1971), which is also the best-known attempt to combine tonal and laryngeal features.

Halle and Stevens (1971) argue that speakers may independently control two laryngeal parameters: glottal width by movement of the arytenoid cartilages and vocal fold tension by controlling the cricothyroid and thyroarytenoid muscles. Glottal width is encoded by the features [spread glottis] and [constricted glottis], and the main innovation of the model relies on encoding vocal fold tension with the features [stiff vocal folds] and [slack vocal folds]. These features are binary and their combinations account for voicing, tone, as well as voice quality contrasts, illustrated below.

Table 101. Laryngeal Feature Mapping (Halle & Stevens, 1971, p. 203)

Consonant:	/b/	/b/	/p/	/ p /	/bʰ/	/p ʰ/	/ɓ/	/ʔb/	/ p'/
Vowel:	/a/	/à/	/á/	/ḁ/	/a̤/			/a̰/	/aʔ/
[s.g.]	-	-	-	+	+	-	-	-	-
[c.g.]	-	-	-	-	-	+	+	+	+
[stiff v.f.]	-	-	+	-	-	-	-	-	+
[slack v.f.]	-	+	-	-	+	-	-	+	-

Despite this innovative approach, the model is not without problems. The most obvious is that it only allows for three levels of tone. In addition, the articulatory research on which it was based has been challenged (cf. Edmonson & Esling, 2006).[122] Finally, the model is ill-equipped to deal with languages with both contrastive tone and phonation (e.g. Otomanguean), as it predicts no co-occurrence between non-modal phonation and tone, and therefore, fails to account for a language like Quiaviní Zapotec.

[122] Even if we were just to use the feature [stiff v.f.] to distinguish creaky vs. interrupted vowels in QZ, there is no articulatory research (i.e. laryngoscopy) on this language to confirm the particular vocal fold tension in the production of these vowels.

In the following sections, I revisit the laryngeal complexity of Quiaviní Zapotec and account for it within an emergent feature approach.

7.3 Quiaviní Zapotec emergent laryngeal specification

7.3.1 Quiaviní Zapotec tonal specification

In Chapter 2, an emergentist feature approach (Mielke, 2008 [2004]; Pulleyblank, 2006) was adopted in this dissertation. Here I return to this proposal with respect to Quiaviní Zapotec laryngeal complexity.

In order to account for Quiaviní Zapotec tonal patterns, I assume that tone is not part of the geometry of laryngeal features (cf. Bao, 1999). Instead tones are autosegments that are independent from the segments on which they are realized. The co-registration of tones (or *autosegments*) on one tier with those on another is represented by association lines. Particularly, the association of tones and segments at the surface level is obtained through the moraic structure (Chapter 5). In Quiaviní Zapotec, we only need to refer to the levels high and low, represented as the autosegments H and L in the phonology, shorthand values of a single binary tone feature [+/-raised] (cf. Pulleyblank, 1986; Yip, 1980). Based on these elements, contour tones are analyzed as complex: HL (falling) and LH (rising). Nothing else is needed in the grammar to refer to tonal units/features.

(5) Quiaviní Zapotec tonal inventory: / H, L, HL, LH /

7.3.2 Quiaviní Zapotec laryngeal features

The account for the difference between creaky and interrupted vowels requires more discussion. In what follows, I present the phonological and phonetic facts about these two types of laryngealized vowels and propose that the featural distinction emerges from their sound patterns and contrast.

There is an extensive typological literature on how creakiness and glottal stop pattern, but this is mostly allophonically,[123] or as a result of phonological processes. This revolves around the fact that both sounds are produced with the same mechanism: constriction of the glottis, the difference being in the degree on which airflow is interrupted at the larynx. More specifically, the sound pattern of creaky and interrupted vowels in Quiaviní Zapotec is found in their interaction with tone. Both types of vowels are able to bear tone, and both bear the same ones: high, low and falling. In contrast with modal voice, and along with breathy vowels, laryngealized vowels do not co-occur with rising tone. Within non-modal phonation, creaky and interrupted differ from breathy voice in that both types of laryngealized vowels may appear with high tone.

The co-occurrence of high tone with both creaky and interrupted vowels is also important in light of the pattern of these vowels. Non-modal phonation is cross-linguistically associated with lowering of the fundamental frequency (Gordon & Ladefoged, 2001). In the case of laryngeals, the constriction of the vocal folds causes aperiodicity in the signal, and the optimal conditions to manipulate pitch are not achieved. As a result, the implementation of high tone and laryngealized voice is "special" for both creaky and interrupted vowels (see §6.4 & §6.5, Chapter 6). In contrast to prototypical creaky voice (found in both low and falling tone), creaky-H tokens are realized with tense voice, /a̰/ ˥ → [á̬], which corresponds to weak laryngealization, and, thus, it is possible to manipulate pitch.

On the other hand, interrupted-H tokens are produced as checked vowels, /aˀ/ ˥ → [áʔ], as opposed to the rearticulated realization of interrupted-L and -F ([aˀa]) (the phonetically *weak* second vowel portion seems to be able to bear low tone only). In brief, the implementation of these phonological features is compromised in the phonetics due to articulatory conflict.[124]

---

[123] In other Zapotec languages, creaky and interrupted vowels are in complementary distribution (e.g. San Pedro Mixtepec Zapotec, Ramos, 2007).
[124] Along the production demands, it could be hard to perceive contrasts because of the short duration and weak cues of the vowel portion in question.

The phonotactics of creaky and interrupted vowels reveal differences between them. The former may be short (followed by a fortis consonant) or long (followed by a lenis consonant or in an open syllable), whereas the latter are always long (considering both modal and glottalized portions). Interrupted vowels appear mostly in open syllables, but also followed by lenis consonants. In other words, interrupted vowels are banned in syllables with a fortis coda.

This segmental distribution is related to the laryngealization of the vowels and their prosodic status. As shown before (Chapters 2 and 3), fortis consonants are strongly articulated and quite long in coda position, consequently analyzed as moraic; this would conflict with the similarly strong and complex articulation of interrupted vowels and suggests that interrupted vowels are necessarily bimoraic in prominent positions, and in fact, their duration (Chapter 6) corresponds to that of long modal vowels (analyzed as bimoraic in Chapter 3).[125]

The special prosodic status of the glottal closure is common cross-linguistically. For instance, checked vowels are commonly analyzed as bimoraic, e.g. in Ki'chee' (Isaacs & Wolter, 2003), and the realization of a full glottal stop may be restricted to prominent positions; in Capanahua (Elias Ulloa, 2006), a glottal stop in coda position only appears in word initial syllables or within the head of the foot, otherwise it coalesces with the vowel, surfacing as a creaky vowel.[126] In other words, the complex articulation of vowel + glottal closure normally implies syllable weight, prosodic saliency, and presents more phonotactic restrictions than the co-articulation of a vowel and laryngealization (creakiness).

Phonetically, there are characteristics to show both the pattern and the contrast between creaky and interrupted vowels in Quiaviní Zapotec. Laryngealization implies more constriction in the glottis compared to other types of phonation. As previously mentioned, in the continuum of phonation types (see Figure 67) creaky and interrupted vowels occupy the right side of the continuum, towards a more closed laryngeal configuration. This correlates with creaky and interrupted vowels having lower intensity,

[125] This is corroborated in that syllables with interrupted vowels may stand alone as prosodic words or in prominent positions within phrasal contexts. This characteristic implies that they satisfy the minimal requirement of prosodic words to form a bimoraic foot (Chapter 3).
[126] In Otomanguean languages there are also other cases of sensitivity of glottalization to prosodic structure (e.g. Itunyoso Trique, DiCanio, 2006).

a decrease in the amount of airflow, and an increase in signal aperiodicity in comparison with modal vowels. (These phonetic properties were illustrated and confirmed acoustically in Chapters 4 & 6.)

	Most open ←			→	Most closed
Phonation type	Voiceless	Breathy	Modal	Creaky	Glottal closure

Figure 67. Continuum of phonation types (Ladefoged, 1971)

The same phonetic properties that distinguish modal voice from laryngealized voice differentiate creaky and interrupted vowels. The former have higher intensity values and relatively continuous airflow. The latter always show a drop in the amplitude envelope and strong or full glottalization; both parameters are always acoustically evident in the waveform and the spectrogram of these sounds.

Closely related to the amount of airflow, periodicity also distinguishes creaky vs. interrupted vowels. During the non-modal portion of these vowels, the signal is always more irregular (i.e. stronger glottalization) for interrupted vowels than for creaky.[127]

Along with the description of Chapter 6, the above phonological and phonetic facts have shown that creaky and interrupted vowels in Quiaviní Zapotec are two phonemically distinct types of laryngealized vowels, the realization of which is not predictable in terms of tone or syllable structure (as in other Zapotec languages). Quiaviní Zapotec exemplifies an emergent distinction within laryngealized vowels; the phonemic distinction between creaky and interrupted vowels is not due to anything other than laryngeal features (underlying specification). The question now is what the best characterization of this contrast is.

Assuming that features emerge from sound patterns and phonetic properties, a feature like [+constricted glottis] clearly distinguishes creaky and interrupted vowels from modal and breathy vowels; hence, it is desirable to use this feature to account for laryngealized vowels as a natural class. In distinguishing creaky vs. interrupted vowels,

[127] Periodicity can be calculated as jitter (variation in the periodicity of the signal); however, this acoustic correlate is based on the fundamental frequency, which is impossible to track for most interrupted vowels, since a glottal closure implies cessation of airflow, and, thus, the vibration of the vocal folds. We would face the same problem calculating the degree of constriction based on spectral tilt.

both intensity and the interruption of airflow are reliable parameters to implement the contrast (not in absolute terms, but relatively to the degree of constriction of these vowels in a given production).

As such, creaky vowels may be specified as [+high amplitude] and interrupted vowels as [-high amplitude]. Nonetheless, there are different ways to use or obtain low amplitude, including prosody, and although this parameter is constant in distinguishing these vowels, it seems more plausible to consider it as a phonetic correlate of the contrast. (Another potential problem is that breathy vowels also have quite low amplitude.)

In terms of the amount of airflow, creakiness reflects continuous laryngealization, while any segments accompanied by a glottal stop implies (near) cessation of airflow. Creaky vowels represent therefore a continuant phenomenon, while interrupted vowels are non-continuant. Along these lines interrupted vowels may be specified as [-continuant]. Following Bernhardt and Stemberger (1998, p. 932), the feature [+continuant] is defined as characterizing "sounds in which air continues to move through the oral cavity […] Oral stops and affricates, nasal stops and glottal stop entirely block the airflow through the oral cavity and are [-continuant]." As such, if the glottal stop is analyzed as a vocalic feature in interrupted vowels (/a^{ʔ}/), then it is reasonable to specify these vowels as [-continuant]. Although interrupted vowels are not always realized with a full glottal closure, the degree of airflow that is treated as [-continuant] may vary from language to language, just as e.g. the exact boundary between /i/ and /e/ can vary between languages. For vowels, it may just mean very low amplitude, rather than full cessation of airflow.[128] An emergent feature approach can reasonably lead us to different boundaries for different languages. Interrupted vowels may be realized with a strong period of creakiness (that is commonly perceived, nonetheless, as a glottal stop). The amount of airflow in interrupted vowels is insufficient to count as [+continuant].[129]

This innovative use of the feature [continuant] for the specification of laryngealized vowels needs some clarification. It may be problematic in relationship with other [-continuant] segments, e.g., stops, since features serve the purpose of defining

[128] Scholars usually label a glottal stop [-continuant], even though we know it can also be realized as creaky voice in many languages, without full closure (Ladefoged & Maddieson, 1996).
[129] Despite of the variation in the glottal closure, the airflow interruption in interrupted vowels, i.e. the laryngeal constriction, is always greater than that of creaky vowels.

natural classes. We need to emphasize, however, that vowels do not pattern in any way with [-continuant] consonants; features like [consonantal] & [sonorant] play hierarchically higher roles than [continuant] in Quiaviní Zapotec phonology in terms of natural classes; interrupted vowels are specified as [-consonantal, -continuant]. Moreover, we need to make a clear distinction in that the continuancy in these vowels is not used exactly the same way that it is for consonants (just as the feature [+voice] is not used exactly the same way for vowels and voiced consonants).

The characterization of both creaky and interrupted vowels as [+constricted glottis] is supported in the literature by the fact that both types of vowels use the same laryngeal mechanism (Edmonson & Esling, 2006). The additional specification with the feature [+/-continuant] is supported by the cross-linguistic contrasts along a laryngeal constriction scale, with languages using different points contrastively. Ladefoged and Maddieson (2006) report at least three clearly defined phonetic points of laryngealization, focusing on the manner in which the vocal folds vibrate: tense (or stiff) voice, creaky voice and glottal closure. Tense voice is allophonic with creaky voice in Quiaviní Zapotec, but contrastive in Cajonos Zapotec (Tejada, 2009) and Chong (DiCanio, 2009); creaky voice is phonemic in many languages, as well as the glottal stop (see §6.2, Chapter 6), but only a few Zapotec languages use them both contrastively. Adding the use of supra-glottal mechanisms to the vibration of the vocal folds, we could add harsh and strident phonation types as other states of laryngeal constriction. Bai exemplifies the contrastive use of harsh voice (Edmondson & Esling, 2006), whereas !Xóõ (Traill, 1985) includes creaky and strident phonation types, as another language with two phonemic degrees of laryngeal constriction. In brief, within a single dimension, that of laryngealization, languages may use a number of different contrasts, encoded phonologically at a language-specific level. Along these lines, apart from the use of [constricted glottis], a logical possibility to differentiate creaky vs. interrupted vowels is to propose a scalar approach for the feature [constricted glottis] (e.g. [+c.g.1], [+c.g.2], etc.). A risk with this approach is to fail to account for the characterization of creaky and interrupted vowels as a natural class, along with how the rest of the features are conceived.[130]

A final consideration to account for the distinction between creaky and interrupted vowels would be a feature that specifically refers to the closure versus the partial closure of the vocal folds. For example, a new feature like [+/-*interrupted*], defined as '(vocalic) sounds produced with a glottal closure'. However, although its use may prove useful in the future, the feature [interrupted] seems *ad hoc* and would fulfill exactly the same role that the feature [continuant] fills in the distinction of laryngeal vowels, a feature that is independently motivated in the system. In addition, the feature [interrupted] does not capture the phonetic variation of interrupted vowels between a full glottal stop and a short and strong period of glottalization. Instead, a language-specific boundary for the definition of the feature [continuant] captures this characteristic. In summary, within an emergent feature approach, I proposed the use of the feature [continuant] to distinguish creaky vs. interrupted vowels. This proposal captures the continuance of creakiness versus the non-continuant characteristic of interrupted vowels, which is at the core of this distinction, favors the economy of features, and the language-specific boundary to establish a categorical contrast within a continuum of airflow interruption.

To conclude, this section has presented the sound pattern of laryngealized vowels in Quiaviní Zapotec, creaky and interrupted, with the purpose of accounting for their contrast in terms of laryngeal features. The proposal has been to encode their contrast focusing on the degree of laryngeal constriction of these vowels. The feature [+/-constricted glottis] for creaky and interrupted vowels defines a natural class (also attested in other Zapotec and Otomanguean languages, as well as cross-linguistically), distinguishing them from modal and breathy vowels. Finally, the degree of constriction between laryngeal vowels is encoded with the feature [+/-continuant]. Creaky vowels are specified as [+c.g., +continuant], and interrupted vowels as [+c.g., -continuant]. The relevant feature specification for Quiaviní Zapotec vowels is given below.

[130] I thank F. Arellanes (personal communication, August 2007) for our pioneer discussion about these contrasts in terms of degrees of constriction.

Table 102. Voice quality feature specification in Quiaviní Zapotec [131]

	/ a̤ /	/ a /	/ a̰ /	/ aˀ /
[s.g.]	+	-	-	-
[c.g.]	-	-	+	+
[continuant]	+	+	+	-

7.4 Quiaviní Zapotec comprehensive phonological representation

Chapter 2 showed that short vowels appear before fortis consonants and long vowels before lenis consonants (or in open syllables). In Chapter 3, this pattern was explained prosodically. I argued that the minimal prosodic word consists of a bimoraic foot. In monosyllables, this is satisfied in one of two ways. First, if the syllable is open, or closed by a lenis consonant, the vowel is lengthened, and becomes bimoraic. Second, if the coda consonant is fortis, it contributes a mora. This pattern is also observed for breathy and creaky vowels:

(6) Breathy

	VC_{fortis}		VC_{lenis} (or open σ)	
a.	/ ta̤p / ˩ → [tà̤$_{\mu}$p$_{\mu}$]	‘four’	/ jṳ / ˩ → [jṳ̀$_{\mu\mu}$]	‘soil’
b.	/ gje̤t / ˩ → [gjè̤$_{\mu}$t$_{\mu}$]	‘squash’	/ gei̤ʒ / ˩ → [gè$_{\mu}$i̤$_{\mu}$ʒ]	‘town’
c.	/ nˑa̤ʃ / ˩ → [nà̤$_{\mu}$ʃ$_{\mu}$]	‘chocolate’	/ na̤ / ˩ → [nà̤$_{\mu\mu}$]	‘now’

(7) Creaky vowels

	VC_{fortis}		VC_{lenis} (or open σ)	
a.	/ ɾgḭlˑj / ˥ → [ɾgḭ́$_{\mu}$lʲ$_{\mu}$]	‘looks for’	/ ɾgḭlj / ˩ → [ɾgḭ́$_{\mu\mu}$lʲ]	‘waters’
b.	/ zḭlˑj / ˥ → [zḭ́$_{\mu}$l$_{\mu}$ʲ]	‘a lot of’	/ sḭlj / ˩ → [sḭ́$_{\mu\mu}$lʲ]	‘breakfast’
c.	/ bḛkw / ˩ → [bḛ́$_{\mu}$kʷ$_{\mu}$]	‘dog’	/ mḭʒ / ˥˩ → [mḭ̂$_{\mu\mu}$ʒ]	‘Mixe’
d.	/n-ga̰ts/ ˥˩ → [ŋga̰$_{\mu}$ts$_{\mu}$]	‘yellow’	/ bdo̰ / ˩ → [bdó̰$_{\mu\mu}$]	‘baby’

Including the proposed laryngeal features, the following illustrates a comprehensive phonological representation of Quiaviní Zapotec creaky vowels (virtually the same representations account for breathy vowels except for changing the feature [-c.g.]).

[131] Since all vowels are [+consonantal] and [+voice], these features are not included in this table.

(8) a) CreakyV + fortisC b) CreakyV + lenisC

```
      H                        L
      | \                      | \
      μ  μ                     μ μ
      |  |                     | /
   ɾ g ḭ  lʲ   'looks for'   ɾ g ḭ̀  lʲ   'waters'
      |                        |
      LN                       LN
      |                        |
   [+c.g.]                  [+c.g.]
   [+cont]                  [+cont]
```

Monosyllables with interrupted vowels also satisfy the Quiaviní Zapotec minimality requirement of a bimoraic foot. However, these vowels present a phonotactic restriction as they cannot be followed by fortis coda consonants. In other words all these vowels are long, that is, bimoraic.

(9) Interrupted vowels

$VʔC_{fortis}$	VC_{lenis} (or open σ)
None	a. /ɾgaˀ/ ˥ → [ɾgáʔᵃ̥] 'becomes green gain'
	b. /ɾgaˀ/ ˩ → [ɾgàˀà] 'gets caught'
	c. /ʒiˀnj/ ˥˩ → [ʒíˀìɲ] 'son'

(10) a) Interrupted V: checked b) Interrupted V: rearticulated

```
      H                                 L
      | \                               | \
      μ  μ                              μ  μ
      |/                                |/
   ɾ g áʔ   'becomes green again'    ɾ g àˀà    'gets caught'
      |                                 |
      LN                                LN
      |                                 |
   [+c.g.]                           [+c.g.]
   [-cont]                           [-cont]
```

As illustrated for single interrupted vowels, checked and rearticulated, both moras attached to the single vowel root (recall that the glottal closure is a vocalic feature). The justification for this representation relies on the analysis of interrupted vowels as single segments. As argued in Chapter 6, the glottal closure is analyzed as part of the vowel.

Diphthongs enrich the diversity of the phonological specification and representation of Quiaviní Zapotec, particularly in terms of voice quality. In what follows, I present a brief review of the most relevant cases.

A principle that has driven the analysis of this dissertation is that segments are preferably specified with single features; the existence of contour or complex segments is not rejected, but it should be the last resort of accounting for a phonetic realization. Diphthongs do not represent a complex segment, but a sequence of two vowels, each one fully specified. Accordingly, each member of a diphthong has a single specification for laryngeal features, and may encode two different specifications for phonation types, resulting in a phonological voice quality contour within a single syllable. This is in fact the case in Quiaviní Zapotec, as analyzed for several lexical items in Munro and Lopez (1999).

Below, I illustrate Quiaviní Zapotec examples of different combinations in terms of modal and non-modal sequences.

(11) Modal + modal

a. / banˈgual / ˥ → [ban.ˈgúˑál] ‘old (of a person)’
b. / nʲienʲ / ˥ → [ɲíéˑɲ] ‘is audible’
c. / n-kwɨiby / ˥ → [n-kwɨíby] ‘new’ (< Sp. *nuevo*)
d. / luas / ˥ → [lúás] ‘light’ (< Sp. *luz*)

(12) Modal + non-modal (breathy or creaky)

a. / ge̤i̤ʒ / ˩ → [gè̤i̤ʒ̊] ‘town’
b. / dua̤lˑ / ˥˩ → [dú͡à̤l̤ː] ‘sin’
c. / beṳ / ˥˩ → [béṳ̀ ~ βéṳ̀] ‘turtle’
d. / beṵ / ˥˩ → [béṵ̀ ~ βéṵ̀] ‘coyote’

(13) Non-modal + non-modal

a. / gj̤i̤a̤ / ˩ → [gʲ̤i̤ˑà̤] ‘rock’
b. / gʲia̰ / ˩ → [gʲḭˑa̰] ‘flower’
c. / gḛṵ / ˩ → [gḛˑṵ] ‘river’
d. / ɾ-a̰ḭ / ˩ → [ɾa̰ˑḭ] ‘gets cooked’
e. / ɾ-dṵa̰ʒ / ˩ → [ɾdṵˑa̰ʒ] ‘finishes’

Notice that the one missing sequence in diphthongs — nonmodal-modal — is also the one that goes against the phonetic ("sub-phonological") timing or phasing pattern in simple, monophthongal vowels: modal-non-modal.

Below, I illustrate the moraic representations of diphthongs. Beginning with modal vowels, diphthongs may surface as monomoraic, if followed by a fortis consonant, or as bimoraic, if followed by a lenis one.

(14) a) Diphthong + fortisC b) Diphthong + lenisC

```
      H                               H
      | \                             | \
      μ  μ                            μ μ
      /\  |                           |  |
  l u a  s    'light'      b a n g u  a  l   'old person'
     | |                              |  |
   LN LN                           LN LN
      \/                              \ /
  [-s.g.]                          [-s.g.]
  [-c.g.]                          [-c.g.]
```

Diphthongs with modal vowel plus non-modal vowel illustrate a phonological and phonetic voice quality contour within a single syllable.

(15) a) Modal + breathy b) Modal + creaky

```
      H  L                 H  L
      |  |                 |  |
      μ  μ                 μ  μ
      |  |                 |  |
   b  é  ṳ̀   'turtle'   b  é  ṵ̀   'coyote'
      |  |                 |  |
     LN  LN               LN  LN
      |  |                 |  |
 [-s.g.] [+s.g.]      [-c.g.] [+c.g.]
```

7.5 Formal account: Quiaviní Zapotec non-modal vowels

The goal of this section is to account for Quiaviní Zapotec laryngeal complexity in terms of a constraint-based grammar, namely a formal account within Optimality Theory (Prince & Smolensky, 2004 [1993]). Two issues are considered: (i) feature specification; and (ii) phonotactic gaps in the tone-phonation distribution. The former is represented in Table 103, and the latter in Table 104.

Table 103. Voice quality feature specification in Quiaviní Zapotec [132]

	/ a̤ /	/ a /	/ a̰ /	/ aˀ /
[s.g.]	+	-	-	-
[c.g.]	-	-	+	+
[continuant]	+	+	+	-

Table 104. Tone & phonation distribution in Quiaviní Zapotec

	High	Low	Falling	Rising
Modal	√	√	√	√
Breathy	X	√	√	X
Creaky	√	√	√	X
Interrupted	√	√	√	X

The general observation is that non-modal phonation is cross-linguistically associated with lowered fundamental frequency (F0) relative to modal phonation (e.g. Gordon &

[132] Since all vowels are [+voice], the feature is not included.

Ladefoged, 2001). Adapted from Picanço (2005, p. 346), the constraint on H tone in laryngealized and breathy vowels can be formulated in the form of grounded constraints, following Archangeli and Pulleyblank (1994).

(16) *[c.g.]/H (*CG/H)
If [+c.g.] then not H; or
If [+c.g.] then L

(17) *[s.g.]/H (*SG/H)
If [+s.g.] then not H; or
If [+s.g.] then L

In Quiaviní Zapotec, laryngealized vowels (creaky and interrupted) occur with H, hence, *CG/H must be ranked below a faithfulness instance of maximality to tone: MAX(H) >> *CG/H. (In order to prevent the loss of laryngeal features, I assume the constraints MAX[c.g.] and MAX[s.g.] are undominated.)

(10) MAX(H)
A (high) tone in the input must have a correspondent in the output.

(18) MAX(H) >> *CG/H

<table>
<tr><td>H
|
μ
|
/ɾgi̠l·j/ ˥ ‘looks for’
|
[+c.g.]</td><td>MAX(H)</td><td>*CG/H</td></tr>
<tr><td>a. ☞
H
| \
ɾgí̠$_{\mu}$l$^{j}_{\mu}$
[+c.g.]</td><td></td><td>*</td></tr>
<tr><td>b. L
| \
ɾgí̠$_{\mu}$l$^{j}_{\mu}$
[+c.g.]</td><td>*!</td><td></td></tr>
<tr><td>c. ɾgí̠$_{\mu}$l$^{j}_{\mu}$
[+c.g.]</td><td>*!</td><td></td></tr>
</table>

In comparison, breathy vowels in Quiaviní Zapotec are only prevented from cooccurring with H tone, but they do occur with falling tone (HL). We need, therefore, to separate the constraint in (17) into the negative and positive path conditions in (19) and (20).

(19) *[s.g.]/H
   If [+s.g.] then not H

(20) [s.g.]/L
   If [+s.g.] then L

Following Archangeli and Pulleyblank (1994, p. 169-170), a negative path condition (19) prohibits the cooccurrence of two F-elements on a path; whereas a positive path condition (20) makes the requirement that a path involving some F-element is well formed only when another F-element is also present on the path. Accordingly, all the possible combinations of breathy vowels with high and falling tone, illustrated in (21), violate the negative path condition in (19), but only those with a high level tone, (21i) and (21ii), violate the positive path condition in (20). (Instances of short and long breathy vowels with low tone satisfy both constraints.)

(21) *Breathy-H and breathy-F in Quiaviní Zapotec

```
i) *H       ii) *H      iii) H  L    iv) H  L
    |           / \          | /         |  |
    μ          μ   μ         μ           μ  μ
    |           \ /          |           \ /
    V            V           V            V
  [+s.g.]     [+s.g.]     [+s.g.]      [+s.g.]
```

Example iv) is the most relevant here. Assuming the definition of "path" in Archangeli and Pulleyblank (1994), the conditions must be interpreted as ‘For all specs [+s.g.], there is a path to L’, in which iv) is permitted (Alternatively, example iv) violates the condition under the interpretation: ‘For all paths involving [+s.g.], there is a L’).

The crucial ranking to account for the ban against breathy vowels with high tone in Quiaviní Zapotec, but their occurrence with falling tone is below.

(22) Ranking: SG/L >> MAX(H) >> *SG/H, *CG/H

This analysis predicts that it is possible to have breathiness with falling tone, if and only if the breathy vowel is associated with both H and L. Let us compare in (23), all the different types of coda in Quiaviní Zapotec with breathy vowels, as a profile of markedness violations. As established in Chapters 3 and 5, fortis consonants are moraic in codas, but only fortis sonorants bear tone.

(23) SG/L >> *SG/H

	SG/L	*SG/H

a. H L
    | /
   μ μ
   | |
   V O_{fortis}
[+s.g.]
		*

b. H L
   | |
   μ μ
   | /
   V O_{lenis}
[+s.g.]
		*

c. H L
   | |
   μ μ
   | |
   V R_{fortis}
[+s.g.]
	*	*

d. H L
   | |
   μ μ
   | /
   V R_{lenis}
[+s.g.]
		*

As illustrated above, the current ranking predicts that breathy vowels occur with falling tone in all types of syllables except when followed by fortis sonorants in coda. Apparent counter-examples to this prediction are given below.

(24) a. / ba̤lˑj / ˥˩ ‘fire’
b. / dua̤lˑ / ˥˩ ‘sin’

Nonetheless, in these examples the [+s.g.] feature spreads to the fortis sonorant, and thus, through this consonant, the feature is associated with L, satisfying SG/L. In order to properly evaluate these candidates, the constraints that deal with mora-tone association from Chapter 5 solve the issue.

(25) SPECIFY T: A mora must be associated with a tone

(26) *CONTOUR: A mora may be associated with at most one tone

(27) *LONGT: A Tone may be associated with at most one mora

In Chapter 5, I showed that SPECIFY T outranks *CONTOUR and *LONGT (since I am only presenting breathy vowels, the constraint *CG/H is left out for clarity).

(28) Breathy-F with fortis sonorant (SG/L >> MAX(T) >> *SG/H)

<table>
<tr><td>H L
| /
μ
|
/ ba̤lˑj /
[+s.g.]</td><td>SG/L</td><td>MAX(H)</td><td>SPECIFY T</td><td>*SG/H</td><td>*LONGT</td><td>*CONTOUR</td></tr>
<tr><td>a. H L
| /
μ μ
| |
bá͡à̤ l̤ːʲ
[+s.g.]</td><td></td><td></td><td>*!</td><td>*</td><td></td><td>*</td></tr>
<tr><td>b.
H L
| /|
μ μ
| |
bá͡à̤ l̤ːʲ
[+s.g.]</td><td></td><td></td><td></td><td>*</td><td>*!</td><td>*!</td></tr>
<tr><td>c. ☞
H L
| |
μ μ
| |
bá ̀l̤ːʲ
\ /
[+s.g.]</td><td></td><td></td><td></td><td>*</td><td></td><td></td></tr>
</table>

Candidate a. violates SPECIFY T, leaving the mora of the sonorant unspecified. Candidate c. wins over b., since the latter violates *LONGT, where L is associated with both moras.

So far, the analysis accounts for the co-occurrence of laryngealized vowels with high and falling tone, as well as the absence of breathy vowels with level high tone, and their co-occurrence with falling tone. Non-modal vowels in Quiaviní Zapotec occur with low tone, as expected cross-linguistically. The missing gap of rising tone with non-modal vowels in Quiaviní Zapotec is also expected, but still to be encoded formally.

As sketched in Chapter 6, the absence of rising tone in non-modal vowels is based on tone and phonation markedness. See below.

(29) Markedness tone scale (Zhang 2001; Yip 2002) [133]

*H >> *L

(30) Tone markedness contraints:

i) *H >> *L
ii) *LH >> *HL
iii) *LH >> *HL >> *H >> *L (*TONE)

As presented above, high tone is more marked than low tone, whereas rising tone is more marked than falling tone. Together, level tones are preferred to contour tones. The above tone markedness scales interact with the following phonation type constraints.

(31) Phonation markedness scales

i) Modal > Non-modal
ii) Modal > [+s.g.], [+c.g.]

(32) *Non-modal phonation >> *modal phonation

Based on the above, the absence of rising tone and non-modal phonation is simply encoded by the postulation of *LH/Non-modal, this constraint is undominated in

[133] This is counterbalanced by the tonal prominence scale (de Lacy, 2002, p. 1-2): H > M > L (cf. Pulleyblank, 2004). Tonal scales may also combine with the structural positions foot head (Hd) and foot non-head (non-Hd) to form constraints (see de Lacy, 2002; after Prince & Smolensky, 2004 [1993]).

Quiaviní Zapotec. Further investigation on this constraint interaction is required in light of cross-linguistic variation.

(33) *LH-Non-modal
‘The co-occurrence of rising tone and non-modal vowels is prohibited’

7.6 Conclusions

In this chapter, I have accounted for the laryngeal complexity of Quiaviní Zapotec in terms of its phonological specification and representation, as well as the constraint interaction that explains the tone-phonation type interaction in this language. The chapter builds on all previous chapters and, thus, presents a cumulative and comprehensive analysis.

I showed that tone and phonation types are two phenomena that do not fit well within universalist feature approaches. Fundamental frequency and the manner in which the vocal folds vibrate present a wide range of phonetic possibilities; the phonological categorization of these parameters as tone and phonation types is language-specific. The sound patterns of Quiaviní Zapotec and the phonetic properties of its laryngeal contrasts support the view of features and linguistic categories as emergent (e.g. Mielke, 2008 [2004]). From this perspective, tones in Quiaviní Zapotec are autosegments associated with moras, whereas phonation types derive from laryngeal features, distinguishing, in particular, creaky vowels as [+continuant] and interrupted vowels as [-continuant].

Chapter 8:

Conclusions

8.1 Contribution

Quiaviní Zapotec is a language with one of the most complex prosodic arrays of patterns along multiple dimensions. These dimensions include, but are not limited to, contrastive tone and stress, in close interdependence with phonemic distinctions among four phonation types (voice qualities), a pervasive contrast between fortis and lenis consonants, and a complex syllable structure.

This dissertation analyzed prominence, tone and voice-quality patterns of Quiaviní Zapotec including their interaction. I analyzed the phonological structures of these patterns, accounting for prosodic and featural association, and the conditioning patterns between tone and phonation. In more detail, this work makes a significant empirical contribution by providing a descriptive generalization of vowel and consonant length (Chapter 2), the reanalysis of tone as contrastive in Quiaviní Zapotec (Chapter 4), and a new approach to the study of the four-way phonation contrast in this language: modal /a/, breathy /a̤/, creaky /a̰/ and interrupted /aˀ/ vowels (cf. Munro & Lopez, 1999).

This dissertation presented the first thorough phonetic documentation of the prosody of Quiaviní Zapotec, including metrical structure, tone, and how voice qualities relate to these patterns. The findings of this study are intended to improve the documentation of Zapotec languages, and to benefit the community in its effort to maintain the language, primarily with a revision of the Munro and Lopez (1999) orthography in light of the phonetic and phonological analysis presented here.

Quiaviní Zapotec phonological complexity presents different challenges to traditional feature theories (e.g. nativist), and provides evidence in favor of an emergent feature approach. In this dissertation, this was treated in detail for two topics: the fortis/lenis distinction (Chapter 2), and the contrast between creaky and interrupted vowels (Chapter 7). The fortis/lenis distinction is analyzed as a composite of properties, including both language-specific phonetic characteristics and sound patterns, encoded with the feature [+/-fortis]. The phonetic distinction between creaky and interrupted vowels is rarely used contrastively in the world's languages (Ladefoged & Maddieson, 1996); however, I provide new phonetic and phonological evidence that supports this contrast in Quiaviní Zapotec. Creaky vowels represent a continuant phenomenon (continuous laryngealization), while interrupted vowels are non-continuant (cessation of airflow). Along these lines interrupted vowels are specified as [-continuant]. This characterization is based on how the exact boundary between [+continuant] and [-continuant] varies; an emergent approach will precisely lead us to such different boundaries: although interrupted vowels are not always realized with a full glottal closure, the amount of airflow in interrupted vowels is insufficient to count as [+continuant].

In addition to the featural specification, the theoretical contributions rely on two topics: (i) the role of the mora, as the link for different patterns in the phonology of this language, and (ii) the mapping between phonology and phonetics in the expression of laryngeal contrasts. Following Arellanes (2009) and Arellanes and Chávez-Peón (2009), I argued that the moraic status of consonants is based on the fortis/lenis distinction in Quiaviní Zapotec; both fortis obstruents and sonorants contribute to syllable weight in coda position (Chapter 3). This characterization, however, does not hold in the expression of tone. Due to feature incompatibility (i.e. *[-SON][TONE]), fortis obstruents cannot co-occur with tone; only fortis sonorants, in conjunction with vowels, bear tone in this language (Chapter 5). The acoustic analysis of the moraic and tonal configurations shows how phonological patterns are informed by phonetics.

Moreover, a full understanding of tone requires an understanding of how it converts into a precise phonetic implementation. This was particularly evident for the timing of non-modal phonation (Chapters 6 and 7). The description of non-modal vowels was analyzed following the laryngeal timing patterns of Silverman's (1997a, 1997b) phasing and recoverability hypothesis. I showed that tone and phonation contrasts are realized via sequential timing: tonal contrasts are cued during modal phonation, followed by breathiness or laryngealization.

The analysis presented in this study showed that the overall phonological complexity of Quiaviní Zapotec is possible on the basis of interaction at different levels, as well as phonetic compatibility. The first strategy that the language uses is to restrict most contrasts to salient positions, namely the stressed syllable (root), and thus, the stress pattern is demarcative. It is in terms of moraicity and foot type where the metrical structure presents more intricate associations. Tone in Quiaviní Zapotec has a relatively low functional load compared to other Otomanguean languages; however, an inventory of two level and two contour tones is not typologically small. The different voice qualities are, nonetheless, the most salient and complex distinction in Quiaviní Zapotec phonology. Its four-way contrast is cross-linguistically rare, and it is in the interaction of these phonation types with tone where the phonetic compatibility plays a crucial role.

Within this phonological complexity, there are predictable gaps, such as the absence of rising tone with non-modal vowels. I have shown (Chapter 6) that non-modal phonation is confined to the second portion of breathy, creaky and checked vowels. Accordingly, the high portion of a rising tone would tend to be realized on the non-modal portion of the vowel. The absence of rising tones, therefore, relates to co-occurrence conditions on high tone and non-modal phonation. This is formalized in terms of a markedness interaction: *Non-modal/LH (Chapter 7).

Also related to phonetic compatibility, the co-occurrence of high tone and non-modal phonation is highly marked cross-linguistically. As such, the language implements high tone with laryngealized vowels in particular ways (tense voice for creaky vowels, checked realization for interrupted vowels). In contrast, breathy vowels are banned from bearing high tone, whereas the co-occurrence of breathiness with falling tone (HL) is only possible due to the presence of L in the contour, formalized in the form of the grounded constraint ‘If [+spread glottis], then L (SG/L)’.

As illustrated in the previous paragraphs, the phonetics-phonology interface permeates the topics of this study. It was shown in various places that phonetic constraints not only regulate how a phonological representation can be realized but also determine at least some of its properties, which seem to imply visibility between these modules of grammar.

Overall, this dissertation shows how phonological complexity is conditioned by the phonetics, particularly, how different prosodic patterns may coexist in a single system to the extent of phonetic grounding. Whenever there is phonetic conflict in the implementation of phonological contrasts, languages compromise the expression of these distinctions or avoid them entirely. In Quiaviní Zapotec we observe compatibility (e.g. creaky voice & low tone), concurrent compromise (e.g. creaky-H as tense voice), phase compromise (creaky-F as modal-creaky voice sequence), and complete incompatibility, which turns into a phonemic or distributional gaps (e.g. *breathy-H).

8.2 Comprehensive comparison with Munro and Lopez (1999)

Throughout this dissertation, I constantly referred to the work of Munro and Lopez (1999), a milestone in the study of Quiaviní Zapotec in particular and Valley Zapotec in general. There are many things in this dissertation that I have adopted from Munro and Lopez (1999), including the consonant and vowel-quality inventory, the fortis/lenis distinction among both obstruents and sonorants, the tone melodies (high, low, rising, falling), the four-way phonation contrast, stress and loanword description, and basically all the morphosyntactic analysis. In contrast to the wide scope of this ground-breaking work on Quiaviní Zapotec, I have focused on the fine details of tone and of phonation types both phonetically and phonologically. Munro and Lopez (1999) recognized that they had not fully explored the complexity of tone and phonation types (p. 5).[134]

In what follows I present a full comparison between Munro and Lopez (1999) and Munro et al. (2008) with the reanalysis of tone and phonation presented in this dissertation.

Table 105 shows the vowel complex patterns described for Quiaviní Zapotec in Munro and Lopez (1999). In the Pattern column, the vowel patterns not included in Munro et al. (2008, unida I, §4.5, pp. 50-51) are underlined. Combination-form dictionary entry refers to shortened forms of some of these vowel patterns, once affixes are added to the root. The rightmost column includes the reanalysis of this dissertation including the phonation type followed by tone. Recall that in the Munro and Lopez (1999) orthography, *a* = modal, *ah* = breathy, *à* = creaky and *a'* = checked vowel.

[134] This particular academic dialogue on the tone-phonation types interaction has also been observed in the analysis of other Zapotec languages, including Santa Ana del Valle Zapotec with Rojas (2010) after Esposito (2003), San Pablo Güilá Zapotec with Arellanes (2009) after López Cruz (1997), and this is also the case in Quiaviní Zapotec itself with Munro et al (2008) after Munro and Lopez (1999) (see below). In general, the analysis of tone-phonation interaction in Zapotec and Otomanguean languages is one of the most relevant on-going debates in the linguistic analysis of these language families.

Table 105. Munro and Lopez (1999, p. 4) vowel patterns (comparative table)

	Pattern	Combination	Examples	Tone	This thesis
1	*aa*	*aa* (same)	*rdaa* 'gets bitter'	high	Modal-H
2	*iia*	*ia*	*badiia* 'roadrunner'	high	Modal-H
3	*a'*	*a'* (same)	*tyo'p* 'two'	high	Modal-H
4	*ah*	*ah* (same)	*zah* 'grease'	low	Breathy-L
5	*ahah*	*ah*	*bihih* 'air'	low	Breathy-L
6	*àa*	*àa* (same)	*bòo* 'charcoal'	low	Modal-L
7	*a'a*	*a'a* (same)	*gyi'izh* 'city person'	rising	Modal-R
8	*a'aa*	*a'a*	*chi'iinnzh* 'bedbug'	rising	Modal-R
9	*àaa*	*a'a*	*nnàaan* 'mother'	rising	Modal-R
10	*àaa'*	*a'a*	*rsìii'lly* 'morning'	rising	Modal-R
11	*a'ah*	*a'* (final), *a'ah* (same; non-final)	*zhi'ih* 'nose'	falling	Interrupted-F
	a'ah(+C)		*cu'uhb* 'tejate'	falling	Breathy-F
12	*a'ahah*	*a'ah*	*gahll* gui'ihihzh 'sickness'	falling	Breathy-F
13	*a'aah*	*a'ah*	*be'euh* 'turtle'	falling	Breathy-F
14	*a'aha*	*a'ah*	*re'ehiny* 'blood'	falling	Breathy-F
15	*aa'ah*	*aa'* (final), *a'ah* (non-final)	*baa'ah* 'earlier today'	falling	Interrupted-H
	aa'ah(+C)		*guee'ihzh* 'town'		Breathy-F
16	*a'aa'*	*aa'*	*bi'ii'by* 'pipe (plant)'	falling	Modal-F
17	*aa'*	*aa'* (same)	*bax:aa't* 'toad'	falling	Modal-H
18	*a'àa*	*àa*	*zhi'ìilly* 'sheep'	falling	Modal-F
19	*àà a'*	*àa'*	*bèèe'll* 'snake'	falling	Creaky-L
20	*a'àa'*	*àa'*	*zhi'ìi'zh* 'pineapple'	falling	Creaky-F
21	*àa'ah*	*àa'*	*bàa'ah* 'eyeball'	falling	Interrupted-L
22	*ààa'ah*	*àa'*	*rcwààa'ah* 'throws'	falling	Creaky-L
23	*àa'*	*àa'* (same)	*bèe'll* 'sister'	falling	Creaky-H
	(some)		*bdòo'* 'baby''		Creaky-L
24	*àa'a*+n	*àa'a* (same)	*zhìi'iny* 'son'	falling	Interrupted-F
	àa'a(+C)		*rtàa'az* 'beats'		Creaky-LF?
25	*aàa'ah*	*aàa'*	*rloòo'oh* 'floods'	falling	Creaky-F?
26	*aàa'*	*aàa'* (same)	*zhiìi'lly* 'cotton'	falling	Creaky-F
27	*aahah*	*aah*	*iihahz* 'year'	falling	Breathy-F
28	*iiah*	*aah*	*cu'liiahd* 'altar boy'	falling	Breathy-F
29	*aah*	*aah* (same)	*baahlly* 'flame'	falling	Breathy-F
30	*àah*	*àah* (same)	*rzùahz* 'gets drunk'	falling	Breathy-L
31	*ahaha*	*aha*	*curehehizh* 'cabbage'	falling	Breathy-L
32	*aaha'*	*aha'*	*barcwiaha'cw* 'bwitch'	falling	Breathy-F
33	*aha'*	*aha'* (same)	*nsehe's* 'fast'	falling	Breathy-L

The 33 vowel patterns of Munro and Lopez (1999) were reduced to 20 in Munro et al. (2008, §4.5, pp. 50-51), which explained and guided many of the simplifications that I proposed in this dissertation. Before discussing in detail these changes, I present the proposal of this dissertation and then go through the comparison. My analysis of Quiaviní Zapotec presents 12 vowel patterns (Table 106).

Table 106. Tone & phonation distribution

	High	Low	Falling	Rising
Modal	√	√	√	√
Breathy	X	√	√	X
Creaky	√	√	√	X
Interrupted	√	√	√	X

And with phonemic transcription:

Table 107. Tone & phonation distribution

	High	Low	Falling	Rising
Modal	/ a / ˥	/ a / ˩	/ a / ˥˩	/ a / ˩˥
Breathy	---	/ a̤ / ˩	/ a̤ / ˥˩	---
Creaky	/ a̰ / ˥	/ a̰ / ˩	/ a̰ / ˥˩	---
Interrupted	/ aˀ / ˥	/ aˀ / ˩	/ aˀ / ˥˩	---

Modal vowels may be associated with all four tones in Quiaviní Zapotec (Chapters 4 & 5). Breathy vowels occur with low and falling tones, whereas creaky and interrupted vowels occur with high, low and falling tones. Several comments are needed in order to understand the differences between Munro and Lopez (1999) and my analysis, starting with the fact that the Munro and Lopez analysis has both orthographic and phonological goals, whereas the analysis in Table 106 is purely phonological. Table 108 reduces the 33 vowel patterns of Munro and Lopez (1999) to the 12 interacting tone-phonation patterns proposed in this dissertation.

Table 108. Munro and Lopez (1999, p. 4) vowel patterns for what is proposed in this dissertation (tone & phonation distribution).[135]

	High	Low	Falling	Rising
Modal	*aa* *iia* *a'* *aa'*	*àa*	*a'àa* *a'aa'*	*a'a* *a'aa* *àaa* *àaa'*
Breathy	X	*ah* *ahah* *aha'*[136] *àah*[137] *ahaha*[138]	*a'ah*+C [139] *a'ahah* *aa'ah*+C *a'aah* *a'aha* *aahah* *iiah* *aah* *aaha'*	X
Creaky	*àa'* (some)	*àa'*(some) *àáa'* *àa'a*+C [140] *àa'ah*[141]	*a'àa'* *aàa'* (most) *aàa'ah*	X
Interrupted	*aa'ah* (no coda) *a'* (clitics)	*àa'ah* (no coda)	*a'ah* (no coda) *àa'a*+*n*	X

Throughout the dissertation I have compared and explained my analysis with respect to that of Munro and Lopez (1999). Chapter 2 focuses on modal vowels with high tone, explaining the vowel patterns *aa, iia, a'* and *aa'*, all in the first cell of the comparison above. As established in Chapter 2, vowel length is not lexically contrastive, but is predictable from prosody. As such it is not included as a tone-phonation pattern in my analysis (Table 106). In the orthography this difference is encoded, among other

[135] Once again, in Table 108, the 13 vowel patterns excluded in the proposed simplification of Munro et al (2008) are underlined.

[136] These items are followed by fortis coda obstruents, so the duration of the consonant causes the perception of a glottal stop (this is a similar case to that of short checked vowels in the dictionary, analyzed as short modal vowels in Chapter 2). The crucial point here is that the vowel does not become modal; it is breathy all the way to the end.

[137] In diphthongs the modal-breathy sequence is possible.

[138] Same as above.

[139] Consider this kind of variation in a dictionary entry, with different possible vowel patterns within this cell (breathy-F): *wbwi'ihzh, wbi'ihzh, wwi'ihihzh, wbwihzh* 'sun'.

[140] The entries with this pattern that have a coda consonant other than /n/, for example *rtàa'az* 'beats up' or a variation of *bèe'cw* / *bèe'ecw*, are reclassified here as creaky-L tokens. The laryngealization of examples with /n/ in coda, as *gùu'an* 'bull' and *zhìi'iny* child', are considered here interrupted vowels.

[141] This vowel pattern basically refers to *rcwàáa'ah* 'throws' and derivations of it; another item is *rzììi'ih* 'buys; gets' (their combination form is *àa'*).

ways, with the vowel patterns *a'* (for a short vowel) versus *aa* (for a long vowel). The vowel pattern *iia* refers only to diphthongs. Diphthongs certainly entail a longer phonetic duration compared to single vowels, but both the duration of the patterns *aa* (pattern 2) and *iia* (pattern 3) are within the range of phonologically derived long vowels.

Chapter 4 analyzed the rest of the vowel patterns that I claim have modal voice. Detailed experiments confirmed this voice quality, using the parameters of periodicity (jitter) and spectral tilt that have been shown in the literature to differentiate modal from non-modal voice quality. The vowel pattern *àa*, already noted as suspicious in terms of its phonation type by Munro and Lopez (1999), is analyzed here as modal-L. The rising tone vowel patterns (*a'a, a'aa, àaa,* and *àaa'*) may be simplified to *a'a* in their combination form, as Table 105 shows; this already suggests a similar pattern for these vowels, but vowel length and the coda consonant type may have played a role for the classification presented in the dictionary. All the items with rising tone considered in the experiment in Chapter 4 show modal voice. Finally, modal voice with falling tone is somehow restricted. The number of items with the vowel patterns *a'àa* and *a'aa'* is small, and it seems that this tone has been taken over by non-modal phonation. The analysis of Chapter 4 confirmed the contrastive characteristic of tone in Quiaviní Zapotec, which in turn encouraged a reconsideration of the vowel patterns with non-modal voice.

The rest of the vowel patterns from Munro and Lopez (1999), included as breathy, creaky and interrupted vowels in Table 108, were examined in Chapter 6. The biggest cluster of vowel patterns is found with breathy vowels; however, it is essential to mention that most of them were also simplified in Munro et al. (2008); the underlined patterns are not included in this subsequent work. I assumed they were reduced to other breathy vowel patterns (see for instance combination forms in Table 105). In my analysis, all these patterns are classified as breathy vowels with either low or falling tones. Nevertheless, the analysis of some breathy vowel patterns may require additional future attention.

All the vowel patterns included within creaky vowels in Table 108 were originally described with falling tone in Munro and Lopez (1999); however, Chapter 6 showed significant differences among these items in terms of pitch. Creaky vowels with falling tone always start with a modal voice portion, where a small and brief rise occurs at the beginning, followed by a clear falling pitch contour of 20 to 30 Hz. The second portion of the vowel shows creakiness. In contrast, creaky vowels with high and low tone do not show this steep falling pitch, although their pitch is not as flat as that of level tones with modal voice, pitch means are comparable. Towards the second portion of creaky-H and -L vowels, the pitch may fall more noticeably, where non-modal phonation takes place and tone is no longer expressed (except with creaky-H, where tense voice and high tone may co-occur). Tone is certainly harder to identify in non-modal vowels, but based on the quantitative results of Chapter 6 and assuming the four-way tonal contrasts in Quiaviní Zapotec, the analysis of creaky vowels in Table 106 is credible.[142] In terms of duration, the Munro and Lopez (1999) spelling in forms like *bèe'kw* 'dog' does not reflect the short nature of these vowels (reanalized as / bḛkw / ˩ → [bḛˀkːʷ] 'dog'). Creaky vowel duration differences follow the same characteristics as the rest of the phonation types: short vowels are followed by fortis coda consonants, whereas long vowels appear before lenis coda consonants.

Finally, interrupted vowels clearly exemplify a crucial difference between Munro and Lopez (1999) and my analysis with respect to syllable nuclei. These scholars maintain that a syllable "may contain up to three individual vowels, each with its own phonation" (p. 3). In contrast, I claim that monophthongs (single vowel quality segments) have single laryngeal specifications, and surface voice-quality sequences are the result of the phonetic implementation of phonological features. Diphthongs, however, may be specified for different phonation types as they are formed by two root nodes (e.g. / dua̤lˑ / ˥˩ → [dṳ́͡à̤l̤ː] 'sin', see Chapter 7). Consequently, the corresponding vowel patterns for interrupted vowels (Table 108) are reinterpreted as single root-node vowels, interrupted (finally or in the middle) by the strongest form of laryngealization in this language. The modal portions of these vowels show clear pitch differences (Chapter 6), as correlates of the tone they are associated to. This analysis is consistent with many descriptions of

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[142] Another major difference in the analyses consisted in considering the presence of the glottal stop (final checked vowel) a phonetic variation of creaky vowels (Chapter 6); the glottal stop is present only before oral stops and in open syllables word finally. Since its realization is contextual it is not considered part of the underlying form.

Zapotec languages with checked and rearticulated vowels (e.g. Lyman & Lyman, 1977; Nellis & Hollenbach, 1980; Smith-Stark, 2003)

Another important comment with respect to these differences relies on the considerable amount of intra-speaker and inter-speaker variation in terms of phonation types, also variable depending on the type of speech (careful versus fast). This is also referred to in Munro et al. (2008, I-3, §3.5, p. 34): "Some words are pronounced differently by different speakers of Valley Zapotec. The most common differences are in vowels." Some differences between Munro and Lopez (1999) and the analysis presented in this dissertation may be due to these speaker differences.

To further illustrate this comparison, Table 109 shows only a subset of Munro and Lopez (1999) vowel patterns reduced to the 12 tone-phonation patterns proposed here. I consider neither the vowel patterns for clitics, nor those excluded in Munro et al. (2008).[143] I also removed the vowel patterns that are restricted to diphthongs,[144] and those vowel patterns found with very few items in the dictionary.[145] This comparison provides a much more simplified look at Munro and Lopez (1999) vowel patterns within the analysis presented in this dissertation.

Table 109. Subset of Munro and Lopez (1999, p. 4) vowel patterns, simplified for what is proposed in this dissertation (tone & phonation distribution).

	High	Low	Falling	Rising
Modal	*aa* *a'*	*àa*	*a'àa* *a'aa'*	*a'a*
Breathy	X	*ah* *ahah*	*a'ah+C* *a'ahah* *aa'ah+C*	X
Creaky	*àa'*	*ààa'* *àa'a+C*	*a'àa'* *aàa'*	X
Interrupted	*aa'ah* (no coda)	*àa'ah* (no coda)	*a'ah* (no coda) *àa'a+n*	X

143 Except *a'àa* and *a'aa'* that are reanalyzed as modal falling here; and *a'àa'* as clear cases of creaky falling.

144 This includes *iia* for modal vowels with high tone, and *iiah* for breathy vowels, already simplified in Munro et al (2008).

145 For example *aa'*, always with a fortis obstruent in coda position, as in *bax:aa't* 'toad'. The vowels of this and other words with this vowel pattern were measured and confirmed to be a short (Chapter 2). Another example with few items is the vowel pattern *ààa'ah*, which only appears in *rcwààa'ah* 'throws', simplified to a creaky vowel.

In summary, the main points or differences between Munro and Lopez (1999) and the analysis presented in this dissertation are: (i) tone and (ii) phonetic implementation. Munro and Lopez (1999) recognize tone melodies in Quiaviní Zapotec, but only as derived from phonation types; consequently, only phonation type is represented in the orthography. On the contrary, this study has shown that tone is contrastive in Quiaviní Zapotec (Chapter 4), i.e. tone is part of the underlying forms. In turn, when the specification of the voice quality is not compatible with the underlying tone, e.g. creaky vowel with falling tone, the phonetics of the language produces a surface modal vowel portion to express tone, followed by the non-modal phonation (Chapters 6 & 7). Importantly then, this analysis considers two levels of representation, e.g. / ḛ / ˥˩ → [ê͡ḛ]. Instead, the analysis Munro and Lopez (1999) suggests a parallel phonetic-phonological representation in terms of phonation type contrasts. The result is that our two analyses agree in many of the patterns at the phonetic level, in contrast with the underlying representation, where this dissertation proposes a simpler phonological approach.

8.3 Further research

This dissertation has focused on the metrical structure of Quiaviní Zapotec at the Prosodic Word level, as well as tone and phonation at the root level. The data and analyses presented here are by no means a complete treatment of the prosodic patterns of Quiaviní Zapotec. Further research is needed in several respects.

Follow-up analyses may include perceptual studies of the proposed patterns for tone and phonation. The claim that all tones occur in modal voice, the tone co-occurrence with creaky vowels, the tense voice allophone, as well as the checked versus rearticulated phonetic realizations of interrupted vowels, are all issues worth pursuing in more detail. Few languages provide the possibility of conducting experimental research on the tone-phonation interaction at the level of complexity found in QZ. In this study it proved difficult to quantify the phonetic factors involved, and thus research on the specific cues that listeners pay attention to may clarify the proper learning and weighting of the phonetic properties.

In more detail, there are many possible cues speakers are paying attention to, and it is not always possible to link them directly with the phonological information. Particularly, how separable pitch cues and voice quality cues are in Quiaviní Zapotec perception. And analyzing tone and phonation on their own, whether there are cues other than f0 for the tonal contrasts that listeners can draw on; and similarly, what cues listeners are using for "voice quality" contrasts (e.g. jitter, spectral tilt). Brunelle (2009) and Kirby (2010), for example, investigate Vietnamese tone perception across dialect boundaries, concluding that listeners weight tone and phonation differently based on dialect background. (Especially relevant here, is the fact that different phonological contrasts may use the same correlates/cues.) Similar studies may be pursued for Quiaviní Zapotec, in particular, and Zapotec languages in general.

Another interesting avenue of research is the analysis of tone and phonation outside the root. As sketched in Chapter 3, most initial unstressed syllables in disyllabic roots and prefixes appear to have phonetic mid pitch (only a small number of these types of syllables are marked with a specific vowel pattern, other than a single modal vowel, in Munro & Lopez, 1999). In terms of the acquisition of Quiaviní Zapotec, J. Stemberger (personal communication, March 15, 2010) has observed that the pitch of these syllables is highly variable. An initial hypothesis is that the majority of unstressed initial syllables are toneless. On the tone-stress interaction, Yip (2007, p. 242) points out that “one of the most wide-spread phenomena is the loss of all tonal contrasts in unstressed position, in much the same way that unstressed vowels neutralize to schwa in English.” This might diachronically lead to the complete loss of tonal contrast in the input in initial unstressed syllables, in line with the proposed prosodic differences between stressed (prosodic heads) and unstressed syllables (non-heads) outlined in Chapter 3.

The morpho-phonemics of tone and phonation are particularly complex in terms of verb inflection, including suppletion, cases of simplification of tone and phonation in root-suffix forms, among other processes. Many of these phenomena are considered in Munro and Lopez (1999), where verb entries are given with irregular inflected forms. Further analysis and detailed description appear in Munro et al (2008). A formal analysis of many of these morpho-phonological patterns deserves attention in future research. This further examination may support or challenge the findings of this dissertation (see Arellanes, in prep. for some morphophonemic analysis in San Pablo Güilá Zapotec).

The analysis of metrical structure in Quiaviní Zapotec in this dissertation focused on the Prosodic Word. A clear next step is to investigate prosodic phenomena at the next prosodic level, namely the Intonational Phrase. Potential issues of interest include basic sentence intonational contours, focus, and boundary tones. As a starting point, Esposito (2003) reported important differences for tone and phonation when analyzing different types of utterances in Santa del Valle Zapotec. For example, it was found that in isolation or sentence-initial position, where the f0 is high, the phonetic contrast between phonation types was minimized.[146] In sentence-final position, when the tokens had a lower f0, the contrast between modal, breathy and creaky voice was preserved. As briefly discussed in Chapters 4 and 6, the differences in phonation seem less dependent on position-in-utterance in Quiaviní Zapotec. Investigation on this aspect of the phonology may lead to prosodic comparisons among Valley Zapotec variants.

Related to phrasal domains, in Chapters 4 and 5, I mentioned that words in isolation have the tendency to drop the pitch towards the end. This is particularly common in the case of low tone and in words with lenis codas. It is not clear at this point if QZ has a low tone boundary phrase finally, or if this pitch lowering is simply phonetic inertia.

One promising area of future research for the patterns analyzed in this study is language acquisition. Pioneer studies on acquisition include Stemberger and Lee (2007), Stemberger et al (2007), and Chávez-Peón et al (*in press*). The phonological complexity of Quiaviní Zapotec presents considerable challenges for children acquiring the language, particularly as regards tone-phonation interaction. It is well known that tone is acquired early cross-linguistically, but there is practically no literature on the acquisition of phonation types. The analysis of linguistic development in these areas has a potential impact on models of language learnability.

[146] In contrast, Picanço (2003, p. 37) reports for Mundurukú (Tupí), that vowels may be heavily creaky when words are pronounced in isolation.

In conclusion, there are many lines for the future investigation in Quiaviní Zapotec, and more generally, there is a critical need to continue studying threatened indigenous languages spoken in small communities (see Blevins, 2007; and Harrison, 2007). Based on the seminal work of Munro and Lopez (1999) and Munro et al (2008) in Quiaviní Zapotec, as well as other studies in Zapotec languages — particularly Arellanes (2009) — this dissertation has added to our understanding of Quiaviní Zapotec and how it fits into the Otomanguean language family and the universals of human language.

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Appendices

Appendix A: Phonetic experiment (Chapter 3): Syllable weight and the fortis/lenis distinction (results by consonant type)

This appendix includes additional figures and statistical analysis for the phonetic experiment presented in Chapter 3: Syllable weight and the fortis/lenis distinction. All types of consonants — stops, fricatives, and nasals — were grouped together in the figures presented in Chapter 3. Here, I presented the results by consonant type, for each speaker.

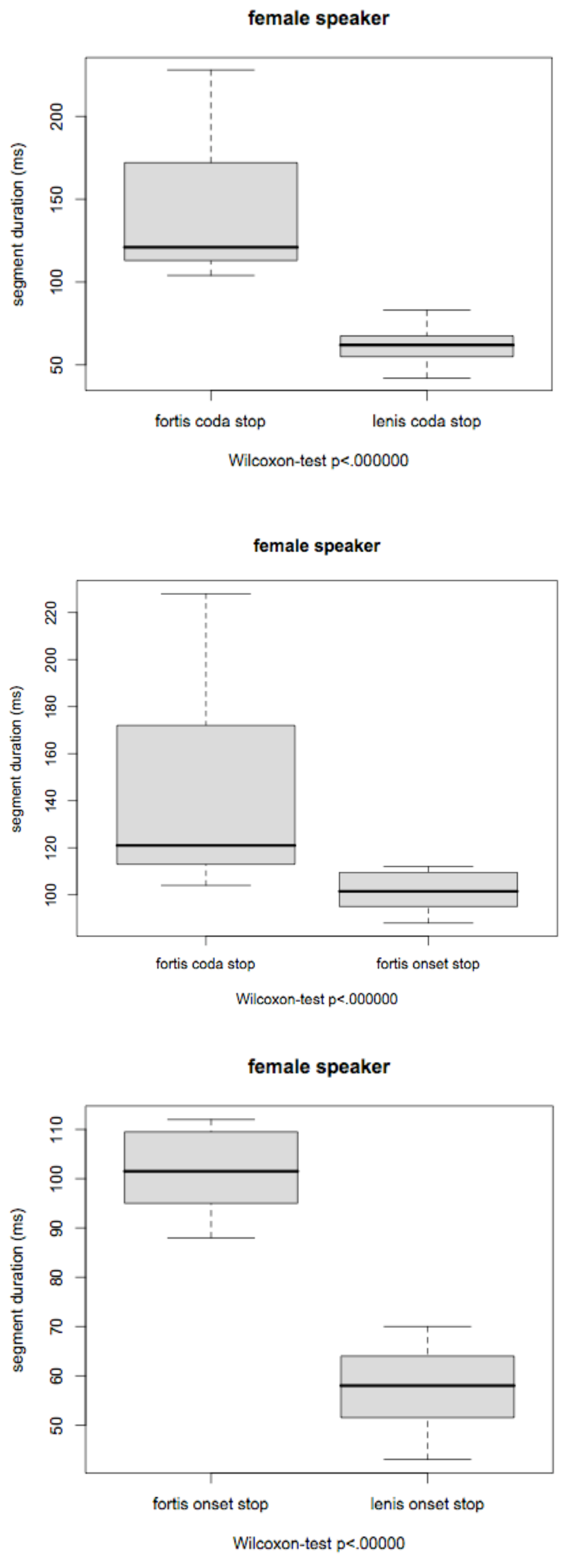


Figure 68. Box plots and Wilcoxon tests of female results for stops.

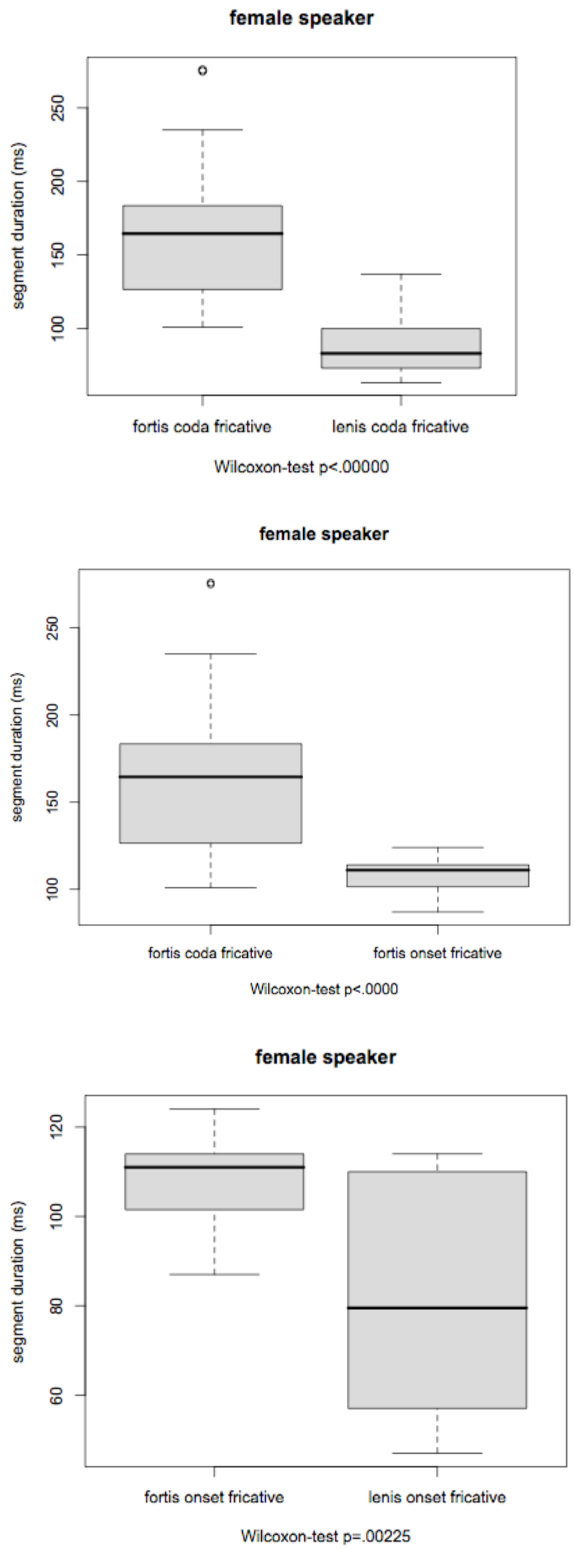


Figure 69. Box plots and Wilcoxon tests of female results for fricatives.

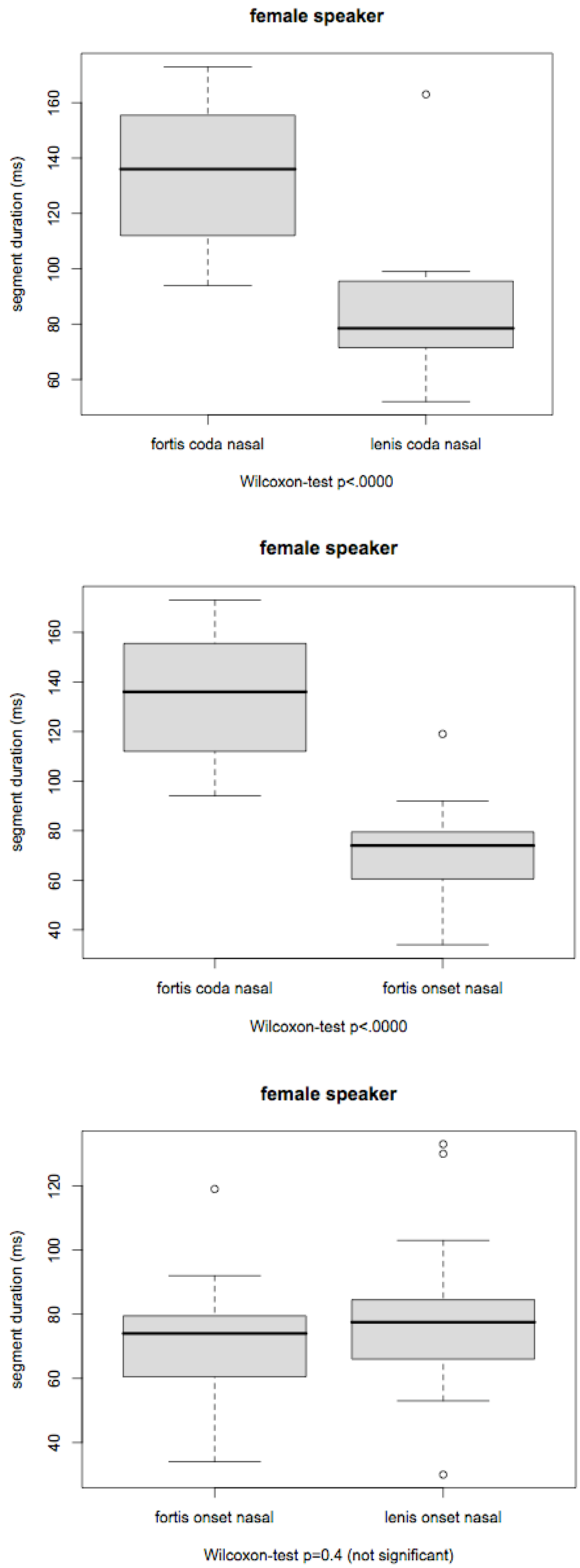


Figure 70. Box plots and Wilcoxon tests of female results for nasals.

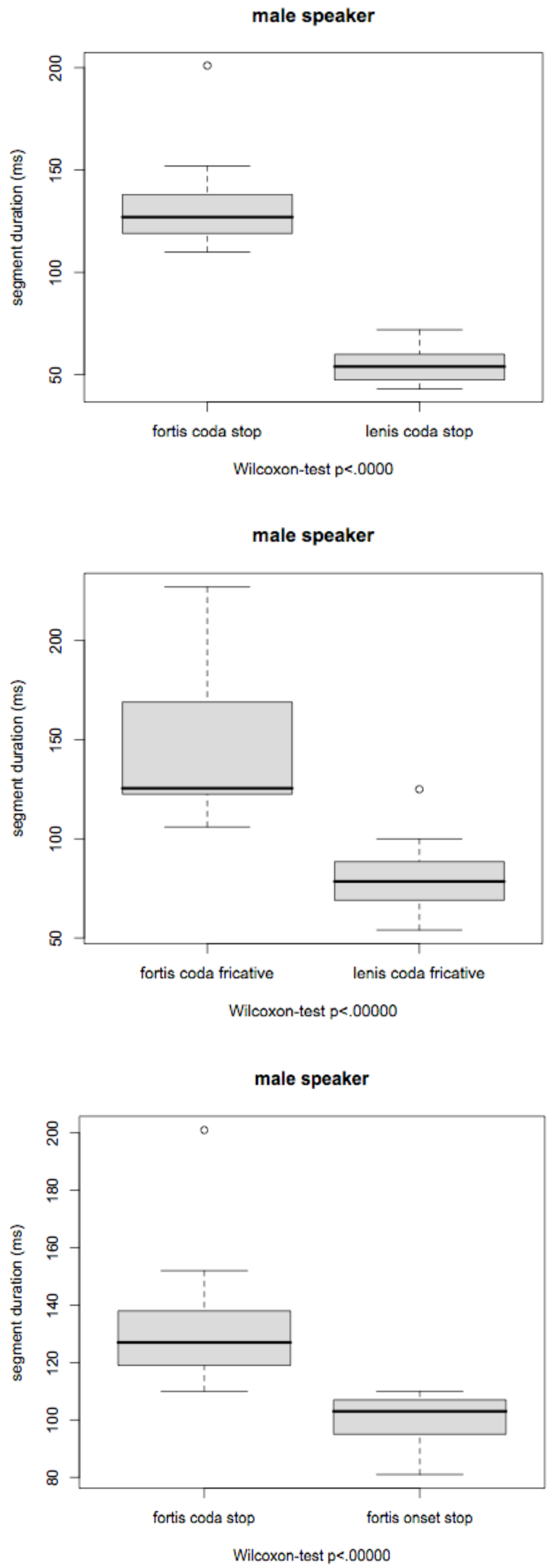
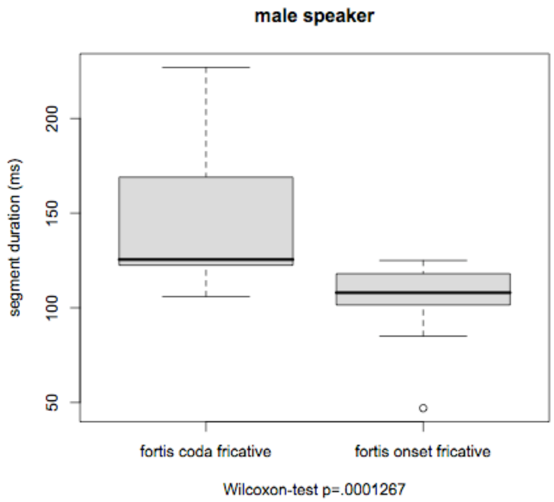
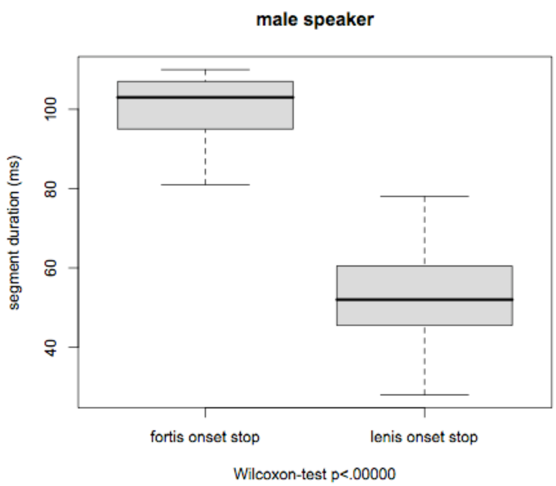


Figure 71. Box plots and Wilcoxon tests of male results for stops.





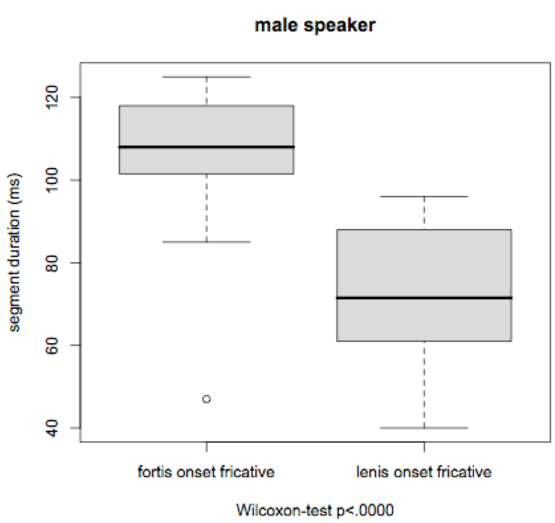


Figure 72. Box plots and Wilcoxon tests of male results for fricatives.

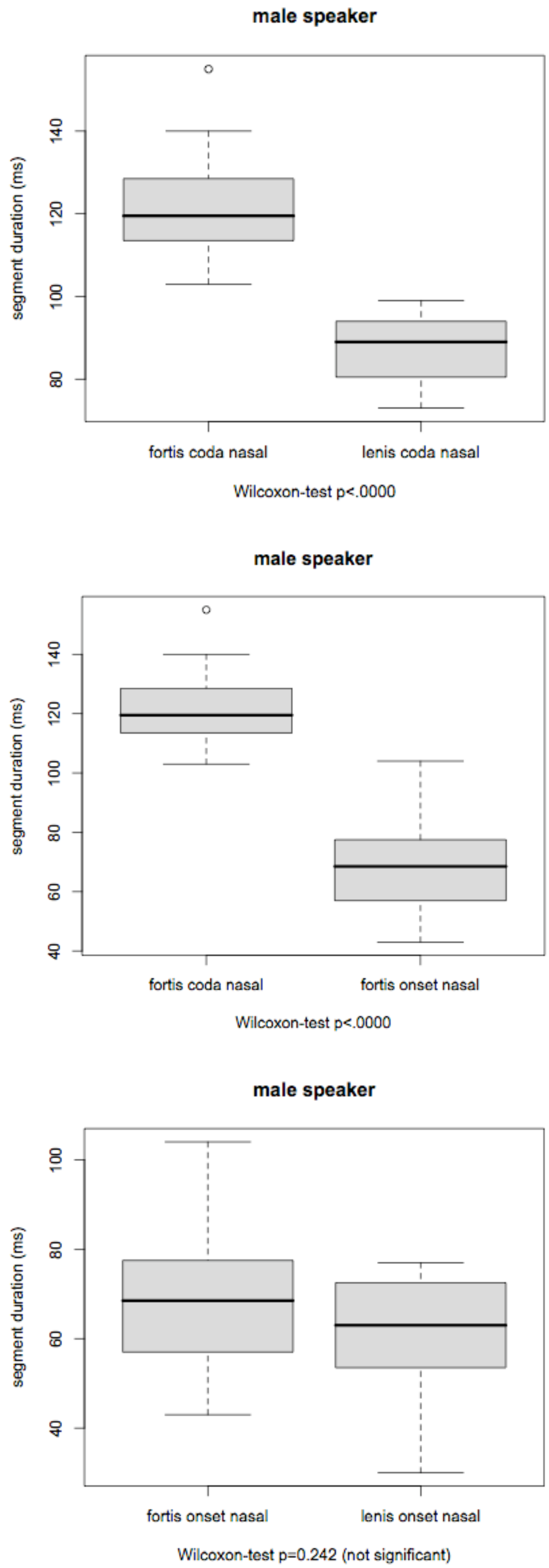


Figure 73. Box plots and Wilcoxon tests of male results for nasals.

Appendix B. UBC Certificate of Ethics approval

The University of British Columbia
Office of Research Services and Administration
Behavioural Research Ethics Board

Certificate of Approval

PRINCIPAL INVESTIGATOR	DEPARTMENT	NUMBER
Stemberger, J.P.	Linguistics	**B03-0855**

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT

UBC Campus ,

CO-INVESTIGATORS:

Chavez-Peon, Mario, Linguistics; Gibraiel, Diana, Linguistics; Lee, Felicia, Linguistics

SPONSORING AGENCIES

Hampton Research Endowment Fund

TITLE :

First Language Acquisition in San Lucas Quiavini Zapotec

APPROVAL RENEWED DATE	TERM (YEARS)	AMENDMENT:	AMENDMENT APPROVED:
APR - 5 2005	1	March 31, 2005, Co-investigator	APR - 5 2005

CERTIFICATION:

The protocol describing the above-named project has been reviewed by the Committee and the experimental procedures were found to be acceptable on ethical grounds for research involving human subjects.

[redacted]

Approval of the Behavioura [redacted] earch Ethics Board by one of the following:
Dr [redacted] es Frankish, Chair,
Dr. Cay Holbrook, Associate Chair,
Dr. Susan Rowley, Associate Chair
Dr. Anita Hubley, Associate Chair

This Certificate of Approval is valid for the above term provided there is no change in the experimental procedures

The University of British Columbia
Office of Research Services and Administration
Behavioural Research Ethics Board

Certificate of Approval

PRINCIPAL INVESTIGATOR	DEPARTMENT	NUMBER
Stemberger, J.P.	Linguistics	**B03-0855**

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT

UBC Campus ,

CO-INVESTIGATORS:

Chavez-Peon, Mario, Linguistics; Gibraiel, Diana, Linguistics; Lee, Felicia, Linguistics

SPONSORING AGENCIES

Hampton Research Endowment Fund

TITLE :

First Language Acquisition in San Lucas Quiavini Zapotec

APPROVAL RENEWED DATE	TERM (YEARS)	
APR 2 7 2006	1	

CERTIFICATION:

The request for continuing review of the above-named project has been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

[redacted]

Approved on behalf of the Behavioural Research Ethics Board
by one of the following:
Dr. Peter Suedfeld, Chair,
Dr. Susan Rowley, Associate Chair
Dr. Jim Rupert, Associate Chair
Dr. Arminee Kazanjian, Associate Chair

This Certificate of Approval is valid for the above term provided there is no change in the experimental procedures

The University of British Columbia
Office of Research Services
Behavioural Research Ethics Board
Suite 102, 6190 Agronomy Road, Vancouver, B.C. V6T 1Z3

CERTIFICATE OF APPROVAL - AMENDMENT & RENEWAL

PRINCIPAL INVESTIGATOR:	DEPARTMENT:	UBC BREB NUMBER:
Joseph P. Stemberger	UBC/Arts/Linguistics	H03-80855

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:

Institution	Site
UBC	Point Grey Site

Other locations where the research will be conducted:
Subjects' homes, in the village of San Lucas Quiaviní, Oaxaca, Mexico.

CO-INVESTIGATOR(S):

Felicia A. Lee
Mario Chavez-Peon

SPONSORING AGENCIES:

Social Sciences and Humanities Research Council of Canada (SSHRC) - "Orsil title - First Language Acquisition in Zapotec & Slovene"
UBC Hampton Research Endowment Fund - "First Language Acquisition in San Lucas Quiavini Zapotec"

PROJECT TITLE:
Orsil title - First language acquisition in San Lucas Quiaviní Zapotec

CERTIFICATE EXPIRY DATE: April 23, 2008

AMENDMENT(S):	RENEWAL AND AMENDMENT APPROVAL DATE: April 23, 2007

Document Name	Version	Date
Consent Forms:		
Zapotec consent form	2.0	April 20, 2007

The application for continuing ethical review and the amendment(s) for the above-named project have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approval is issued on behalf of the Behavioural Research Ethics Board and signed electronically by one of the following:

Dr. Peter Suedfeld, Chair
Dr. Jim Rupert, Associate Chair
Dr. Arminee Kazanjian, Associate Chair
Dr. M. Judith Lynam, Associate Chair
Dr. Laurie Ford, Associate Chair

The University of British Columbia
Office of Research Services
Behavioural Research Ethics Board
Suite 102, 6190 Agronomy Road, Vancouver, B.C. V6T 1Z3

CERTIFICATE OF APPROVAL- MINIMAL RISK RENEWAL

PRINCIPAL INVESTIGATOR:	DEPARTMENT:	UBC BREB NUMBER:
Joseph P. Stemberger	UBC/Arts/Linguistics	H03-80855

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:

Institution	Site
UBC	Vancouver (excludes UBC Hospital)

Other locations where the research will be conducted:
Subjects' homes, in the village of San Lucas Quiaviní, Oaxaca, Mexico.

CO-INVESTIGATOR(S):

Felicia A. Lee
Mario Chavez-Peon

SPONSORING AGENCIES:

Social Sciences and Humanities Research Council of Canada (SSHRC) - "Orsil title - First Language Acquisition in Zapotec & Slovene"
UBC Hampton Research Endowment Fund - "First Language Acquisition in San Lucas Quiavini Zapotec"

PROJECT TITLE:
Orsil title - First language acquisition in San Lucas Quiaviní Zapotec

EXPIRY DATE OF THIS APPROVAL: April 14, 2009

APPROVAL DATE: April 14, 2008

The Annual Renewal for Study have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approval is issued on behalf of the Behavioural Research Ethics Board

Dr. M. Judith Lynam, Chair
Dr. Ken Craig, Chair
Dr. Jim Rupert, Associate Chair
Dr. Laurie Ford, Associate Chair
Dr. Daniel Salhani, Associate Chair
Dr. Anita Ho, Associate Chair

The University of British Columbia
Office of Research Services
Behavioural Research Ethics Board
Suite 102, 6190 Agronomy Road, Vancouver, B.C. V6T 1Z3

CERTIFICATE OF APPROVAL- MINIMAL RISK RENEWAL

PRINCIPAL INVESTIGATOR:	DEPARTMENT:	UBC BREB NUMBER:
Joseph P. Stemberger	UBC/Arts/Linguistics	H03-80855

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:

Institution	Site
UBC	Vancouver (excludes UBC Hospital)

Other locations where the research will be conducted:
Subjects' homes, in the village of San Lucas Quiaviní, Oaxaca, Mexico.

CO-INVESTIGATOR(S):

Felicia A. Lee
Mario Chavez-Peon

SPONSORING AGENCIES:

Social Sciences and Humanities Research Council of Canada (SSHRC) - "Orsil title - First Language Acquisition in Zapotec & Slovene"
UBC Hampton Research Endowment Fund - "First Language Acquisition in San Lucas Quiavini Zapotec"

PROJECT TITLE:
Orsil title - First language acquisition in San Lucas Quiaviní Zapotec

EXPIRY DATE OF THIS APPROVAL: April 14, 2010

APPROVAL DATE: April 14, 2009

The Annual Renewal for Study have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approval is issued on behalf of the Behavioural Research Ethics Board

Dr. M. Judith Lynam, Chair
Dr. Ken Craig, Chair
Dr. Jim Rupert, Associate Chair
Dr. Laurie Ford, Associate Chair
Dr. Anita Ho, Associate Chair

The University of British Columbia
Office of Research Services
Behavioural Research Ethics Board
Suite 102, 6190 Agronomy Road, Vancouver, B.C. V6T 1Z3

CERTIFICATE OF APPROVAL- MINIMAL RISK RENEWAL

PRINCIPAL INVESTIGATOR:	DEPARTMENT:	UBC BREB NUMBER:
Joseph P. Stemberger	UBC/Arts/Linguistics	H03-80855

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:

Institution	Site
UBC	Vancouver (excludes UBC Hospital)

Other locations where the research will be conducted:
Subjects' homes, in the village of San Lucas Quiaviní, Oaxaca, Mexico.

CO-INVESTIGATOR(S):

Felicia A. Lee
Mario Chavez-Peon

SPONSORING AGENCIES:

Social Sciences and Humanities Research Council of Canada (SSHRC) - "Orsil title - First Language Acquisition in Zapotec & Slovene"
UBC Hampton Research Endowment Fund - "First Language Acquisition in San Lucas Quiavini Zapotec"

PROJECT TITLE:
Orsil title - First language acquisition in San Lucas Quiaviní Zapotec

EXPIRY DATE OF THIS APPROVAL: April 15, 2011

APPROVAL DATE: April 15, 2010

The Annual Renewal for Study have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approval is issued on behalf of the Behavioural Research Ethics Board

Dr. M. Judith Lynam, Chair
Dr. Ken Craig, Chair
Dr. Jim Rupert, Associate Chair
Dr. Laurie Ford, Associate Chair
Dr. Anita Ho, Associate Chair